ASSESSING THE VIABILITY OF FOLDABLE - EXPANDABLE CONTAINER HOMES FOR POST-DISASTER HOUSING IN NEW ZEALAND

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Abstract

Natural disasters frequently demolish New Zealand, with its diverse landscapes. It is particularly susceptible to various natural disasters due to its unique geological position on the edge of the Pacific Ring of Fire (McKinnon, Scott, and Margaret Cook, 2020). This makes it prone to earthquakes, volcanic activity, tsunamis, and extreme weather events. A notable example of such a disaster is Cyclone Gabrielle, which struck the Hawke's Bay region in New Zealand. It creates wide damage in housing properties, leaving damaged bridges and culverts, buried roads, significant dropouts, and isolated communities in its wake. One of the major difficulties for government authorities and policymakers is to build houses for the victims of such natural disasters within as short a period as possible. The rapid provision of safe, durable, and affordable shelters is essential to restore a sense of normalcy for affected populations. Traditional reconstruction methods are often slow, expensive, and complex, particularly in regions with limited resources or logistical challenges. This has led to the exploration of alternative housing solutions, such as the use of modified shipping containers.

In New Zealand, as it is a reality, expeditious and resilient housing options are crucial for recovery after a natural disaster. Therefore, strategic solutions should be introduced to assist the responsible entities and agencies in providing shelters to the disaster victims within a short duration.

Container homes offer a unique combination of structural integrity, portability, and affordability, making them an attractive option for post-disaster housing. Their inherent durability allows them to withstand harsh environmental conditions, and their modular nature facilitates quick assembly and scalability. Additionally, container homes can be prefabricated and easily transported to disaster sites, reducing the time required for construction and enabling immediate relief efforts. This thesis explores the feasibility of using double-wing expandable foldable container homes as an innovative post-disaster housing solution in New Zealand, focusing on the aftermath of Cyclone Gabrielle in Hawke's Bay.

Findings indicate that container homes offer significant advantages, including reduced construction timelines, cost savings, and the adaptability needed for fast recovery in

disaster-affected regions. However, challenges remain in achieving compliance with New Zealand's stringent building codes and in adapting the homes to withstand several factors such as seismic/ wind resistance, waterproofing, etc. which are prevalent in many disaster-prone areas. Regulatory requirements, such as PS1 and PS4 design approvals and local council consents, emerge as pivotal considerations that can delay deployment if not streamlined.

Dedications

I dedicate this thesis to my father and mother, who gave me life and shaped my journey. I also extend my heartfelt gratitude to my Husband, Mr. Geffin Joseph, for his unwavering support during challenging times and to my siblings for their constant encouragement. Also, I dedicate this thesis to my beloved son, Dhian Geffin whose boundless energy and curiosity inspire me every day.

While completing this thesis, I was five months pregnant. Navigating the challenges of pregnancy and motherhood while working on this thesis has been a true test of resilience and strength. I dedicate this thesis to my unborn baby, who has been a constant companion and a silent motivator, reminding me of the importance of perseverance and love during this journey.

Additionally, I dedicate this work to all researchers, past and present, in the field of the built environment, whose efforts have advanced and refined our practices.

Declaration

This thesis represents my own work and does not include, without proper acknowledgment, any material previously submitted for a degree or diploma at any university. To the best of my knowledge, it contains no material previously published or written by another person, except where explicit reference is made in the text. All significant contributions by others, including co-authored publications, are duly acknowledged.

Gayathry Babu 2025

Acknowledgments

I would like to express my heartfelt gratitude to everyone who supported and guided me throughout the journey of completing this thesis.

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I am profoundly grateful to Hebei JiaCheng, the manufacturer of the double-wing foldable container home model, for providing comprehensive technical details, product specifications, and certification documents. Their cooperation formed the foundation of this study and enabled me to explore the potential of container housing in addressing New Zealand's housing needs.

I also wish to express my gratitude to the local companies and professionals who generously contributed their time, resources, and expertise. Special thanks to the structural engineers and architects in Hamilton and Auckland, whose critical insights on adapting modular container homes to local regulations and building standards enriched my research significantly.

My sincere appreciation goes to the team at the Ōtorohanga District Council for their assistance and openness in discussing local regulatory considerations. Their input was invaluable in contextualizing my findings within New Zealand's housing policies.

Lastly, I am deeply thankful to God for providing me with the strength, resilience, and determination to complete this thesis. His guidance and blessings have been the cornerstone of this achievement.

To everyone who has supported me directly or indirectly, I extend my deepest gratitude.

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M2	Square meter
FT	Foot
EM-DAT	Emergency Events Database
BBB	Build back better
ISO	International Organization for Standardization
RoHS	Restriction of Hazardous Substances
US	United States
FEMA	Federal Emergency Management Agency
CAD	Computer-Aided Design
UV	Ultraviolet
SPC	Stone plastic composite
PVC	Poly Vinyl Chloride
NZS	New Zealand Standard
NZ	New Zealand
NGOs	Non-government organizations
SIP	Structural Insulated Panel
PS	Producer Statement
NZBC	New Zealand Building Code
WHO	World Health Organization
CRED	Centre for Research on the Epidemiology of Disasters
UN	United Nations
NOAA	National Oceanic and Atmospheric Administration
EQC	Earthquake Commission
CERA	Canterbury Earthquake Recovery Authority
SH	State Highway
SFDRR	Sendai Framework for Disaster Risk Reduction
NZCRS	New Zealand Claims Resolution Service
RIF	Regional Infrastructure Fund
DRR	Disaster Risk Reduction
RC	Reinforced Concrete
KM	Kilo meter
CFS	Cold-Formed Steel
MM	Millimeter
LTD	Limited
KM/HR	Kilometer per hour
W/(m^2·K)	Watts per square meter per kelvin
DB	Decibel
TPO	Thermoplastic polyolefin
EPDM	Ethylene propylene diene terpolymer
HVAC	Heating, Ventilation, and Air Conditioning
BCAs	Building Consent Authorities
BRANZ	Building Research Association of New Zealand
SED	Specific engineer design
MBIE	Ministry of Business, Innovation and Employment

E2/AS1	The Acceptable Solution to E2 External Moisture
QA	Quality Assurance
ANARP	As nearly as is reasonably practicable
LBP	Licensed building practitioner
ISA	Initial Seismic Assessment
DSA	Detailed Seismic Assessment
DFR	Design Features Reports
IEP	Initial Evaluation Procedure
NZTA	New Zealand Transport Agency
ICR	International Certification Registrar
EN Standard	European Standard
CPR	Construction Products Regulation
EPS	Expandable polystyrene
USD	United States dollar
NZD	New Zealand dollar
N. D	Not detected
IL	Importance Level
M/S	Meter per second
FRR	Fire Resistance Rating
PIR	Polyisocyanurate
XPS	Extruded polystyrene
ASTM	American Society for Testing and Materials
PGA	Peak Ground Acceleration
KN	Kilo Newton

CHAPTER 1

INTRODUCTION

1.1. Introduction to the research study

Post-disaster housing is the provision of both temporary and permanent shelters for individuals and families who have lost their homes due to natural disasters. Currently, New Zealand has a slow and complicated post-disaster housing process. The nation's distinctive geological position makes it vulnerable to a wide range of natural disasters, such as earthquakes and floods, which frequently lead to significant damage to homes and infrastructure. Managing post-disaster housing is a multifaceted process that entails the consideration of factors such as the size of the disaster, the location of the affected areas, the response of the government, and insurance coverage that meets the consumer's needs (Saumyang Patel, et al, 2013). The regulation regarding the quality of the buildings in New Zealand, which is aimed at the provision of robust buildings that would be disaster-resistant, also serves as a factor that hampers the recovery processes (Amaratunga, Dilanthi, and Richard Haigh, 2011). Besides these challenges supply chain disruptions, labor shortages, and financial constraints also cause delays to the already lengthy recovery timelines.

Given the urgency of post-disaster housing in New Zealand, there is a growing need for innovative solutions that can streamline recovery processes and offer faster, scalable, and sustainable shelter options. This research explores one such solution: the viability of using double-wing expandable foldable container homes as a housing recovery model, particularly in the aftermath of Cyclone Gabrielle in Hawke's Bay. These modular homes, designed to be compact during transport and easily expandable on-site, promise efficiency, speed, and flexibility—key attributes required in post-disaster recovery scenarios.

1.2. Background of research

Fritz described disaster as a discrete occurrence concentrated in time and space, physically harmful to a society or one of its subdivisions, in such a way that all or some essential functions of the society or subdivision concerned are gravely disrupted (Fritz, 2022). There are several research organizations and bodies globally that have interests in the management cycle of disaster, mainly the five stages of disaster management which include the prevention stage, preparedness stage, mitigation stage, response stage, and relief stage (Shahzad et al, 1970). According to them, 6disasters are divided into three categories: (1) natural, (2) artificial, and (3) hybrid. It doesn't matter what kind of disaster occurs; the main point is post-disaster management. Most firms and the government, especially architects and designers, non-government organizations (NGOs), and other agencies, have taken measures to address such a tragedy regarding the components of post-disaster recovery efforts.

Whenever there is a large number of damage or destruction, many people become victims, homeless, helpless, and in demand of a safe place to get secure. Post-disaster reconstruction includes housing and infrastructure restoration. Both are basic concerns, although there are several studies and research that have been primarily directed toward housing reconstruction in the aftermath of a disaster that leaves behind many victims. The two concepts of shelter and housing have been used in classifying two different classes of homes (Sylves, 2022). From here the victims get temporary accommodation that the shelter offers before they can make their own arrangements. "Housing" on the other hand, means a shelter that provides full accommodation in all forms of physical and social means and the administrative structure. In other words, shelters are provided during the process of alleviation and sustainable housing must be brought in to enable disaster-stricken populations to return to their normal productivity (Gunawardena, 2014).

The challenges faced in post-disaster housing recovery, such as delays in construction and rebuilding, mirror those found in normal construction processes. To address these challenges, there is a growing emphasis on exploring alternative construction methods. Modular, off-site construction, such as double-wing expandable foldable container homes, presents a promising solution for improving the efficiency and speed of housing recovery. Such homes are industrially manufactured and prefabricated, allowing for faster deployment and assembly, which is particularly valuable in time-sensitive disaster recovery contexts (Koria, 2009).

This study aims to assess the viability of double-wing expandable foldable container homes as a post-disaster housing solution in New Zealand, with a specific focus on the recovery efforts following Cyclone Gabrielle in Hawke's Bay. By evaluating the technical, logistical, and economic aspects of this housing model, the research seeks to determine its potential as a scalable and effective alternative to traditional post-disaster housing solutions.

1.3. Research methodologies

This thesis explores the viability of double-wing foldable and expandable container homes as post-disaster housing solutions in Hawke's Bay, following Cyclone Gabrielle. The double-wing foldable and expandable container home model for this research has opted from the company 'Hebei Jiacheng Integrated Housing Co. Ltd', established on December 22, 2021, with its registered address located in the West District of the Economic Development Zone in Fucheng County, Hengshui City, Hebei Province, China. The manufacturer has explored this model in disaster recovery and as a housing option for Europe, Africa, Southeast Asia, North America, South America, and the Middle East. In this research, some methodologies have been adopted which include:

a. Case Studies: This thesis examines post-disaster scenarios where container homes were utilized, providing an in-depth analysis of how these structures benefitted victims during housing reconstruction efforts. The study includes case studies from areas affected by earthquakes, hurricanes, and wildfires, where container homes played a significant role in recovery.
b. Utilizing various reports: Most of the information about the incident Cyclone Gabrielle in Hawke's Bay region has been taken from the reports of Hawke's Bay's Civil Defense and Emergency Management Group Responses, News reports from NZ Transport Agency, reports from The New Zealand Herald, reports from the Stuff News, reports from the Extreme Weather Research Platform established by the Ministry of Business Innovation and Employment (MBIE) and journals from google scholar.
c. Model Selection Process: To understand the most effective recovery methods in New Zealand after a disaster, the first step involved analyzing the country's current post-disaster housing recovery patterns. New Zealand's unique geographic location, prone to natural disasters such as earthquakes and cyclones, has led to significant challenges in rapid housing reconstruction. Notable events, such as the Canterbury earthquakes and Cyclone Gabrielle,

highlighted the limitations of traditional recovery models, which often involve lengthy construction processes, regulatory hurdles, and a shortage of labor and materials. The review of current recovery practices revealed a reliance on conventional building methods, which, while resilient, are slow and expensive to deploy in disaster-stricken areas. These methods often fail to provide timely relief to displaced populations, leading to prolonged displacement and housing insecurity. Additionally, the complexity of insurance claims and adherence to stringent building codes further delay the reconstruction process.

In response to these challenges, my analysis focused on alternative housing models that offer faster, more cost-effective, and sustainable solutions. This led to the consideration of prefabricated modular homes. I did some research on many options like Steel SIP Homes, Extruded Aluminum framed homes, etc. but I found utilizing repurposed container homes is one of the best options because of their characteristics which have already been explained. I selected a model based on **double-wing foldable and expandable container homes** manufactured by **Hebei Jaicheng**, a Chinese company with a proven track record in modular housing solutions (https://www.jiachenghouse.com/). The model's ability to expand quickly and provide ample living space makes it ideal for post-disaster scenarios where speed and flexibility are crucial. The team from Hebei Jaicheng provided comprehensive details about the container home, including architectural drawings, the materials used, product certifications, and the company's brochure. These materials highlighted the house's durability, ease of transportation, and compliance with international building standards, making it an attractive option for New Zealand's disaster recovery efforts. However, there exist many challenges such as the wind resistance of the model to implementing such a prefabricated solution from another country to New Zealand.

d. Expert Opinions: Rather than conducting formal interviews, much of the insight was gathered through ongoing conversations via email. My focus was on understanding how the proposed model could be transported and adapted to the New Zealand housing market. Implementing this type of housing option presents several challenges, including obtaining PS1 (producer statement –

design), PS4 (producer statement – design/construction review), and consent from local councils where we plan to introduce these models.

This valuable information was collected through consultations with local building experts and organizations, as well as through communications with key local councils including Napier City Council, Hastings District Council, Hawke's Bay Council, Otorohanga District Council, and Hamilton City Council. These sources provided critical guidance on navigating regulatory requirements and adapting the model to meet New Zealand's building standards and council approval processes.

1.4. Aim and scope of the research

This research aims to assess the viability of using double-wing foldable and expandable container homes as a post-disaster housing solution in New Zealand, specifically in the recovery efforts following Cyclone Gabrielle in Hawke's Bay. The study focuses on evaluating the technical, logistical, and regulatory challenges of deploying these homes, including their compliance with New Zealand's building codes, environmental conditions, and the local disaster recovery context. The scope of the research includes analysing the design, structural integrity, and adaptability of container homes, exploring their potential benefits such as rapid deployment, cost-efficiency, and flexibility, and identifying necessary modifications to meet the country's stringent building standards and environmental challenges.

1.5. Outline of the thesis

The thesis is outlined into the following 11 chapters:

Chapter 1 Introduces the research background, methodology, aims, and scope, alongside the thesis structure.

Chapter 2 examines the impact of natural disasters on New Zealand's housing recovery, advocating for resilient, sustainable solutions like double-wing expandable container homes and emphasizing the importance of modular designs, improved building standards, and community-driven strategies.

Chapter 3 highlights shipping container homes as a resilient, cost-effective post-disaster solution, emphasizing their adaptability, rapid deployment, and the integration of Māori cultural values to create sustainable, community-focused housing.

Chapter 4 evaluates the cost-effectiveness, modularity, performance, and regulatory challenges of Hebei JiaCheng's foldable container homes for post-disaster housing in New Zealand, offering recommendations to streamline compliance and promote adoption.

Chapter 5 analyzes the design, specifications, and regulatory compliance of Hebei Jiacheng's double-wing container homes, focusing on their durability, cost-efficiency, adaptability, and performance metrics like insulation, fire safety, and seismic resistance to meet diverse climate needs.

Chapter 6 evaluates the system and site-specific compliance of double-wing container homes with the New Zealand Building Code, focusing on performance metrics like seismic and wind resistance, fireproofing, insulation, and flood mitigation, while recommending adaptations for Hawke's Bay's unique environmental and regulatory conditions.

Chapter 7 examines the compliance challenges of deploying double-wing container homes in New Zealand, highlighting design and regulatory gaps related to seismic, wind, fire safety, and flooding risks, and emphasizing the need for adaptations to meet stringent local requirements.

CHAPTER 2

LITERATURE REVIEW

2.1. Chapter introduction

Natural disasters have become an increasingly pressing concern for New Zealand, with the country experiencing a surge in the frequency and intensity of events such as earthquakes, cyclones, floods, and volcanic eruptions. These disasters not only cause widespread physical damage to homes and infrastructure but also have far-reaching social, economic, and psychological effects on communities. Housing recovery, a critical component of post-disaster response, poses unique challenges due to the need for speed, resilience, and adaptability in rebuilding efforts. This chapter delves into the impact of natural disasters on housing recovery in New Zealand, highlighting how the housing sector has struggled to adapt to escalating risks while addressing the needs of displaced populations.

The chapter begins by examining key disaster events, including the Canterbury earthquakes of 2010-11 and Cyclone Gabrielle of 2023, which have underscored the vulnerabilities of traditional housing methods in disaster-prone areas. It provides an overview of the recovery processes, emphasizing the complexities of funding, insurance disputes, regulatory compliance, and labor shortages that slow down rebuilding efforts. Through an analysis of these events, the chapter sheds light on the systemic barriers to efficient recovery and the urgent need for innovative approaches to housing reconstruction.

Additionally, the chapter explores the growing importance of resilient and sustainable housing solutions, such as modular and prefabricated designs, which offer advantages like quick deployment, durability, and adaptability to diverse disaster scenarios. Drawing on case studies from Christchurch and Hawke’s Bay, it illustrates how these solutions can be tailored to New Zealand's unique environmental and regulatory context. The discussion includes an evaluation of government-led recovery strategies, community-led initiatives, and lessons learned from international disaster recovery efforts.

By integrating insights from global best practices and local experiences, this chapter aims to highlight the potential of forward-thinking approaches to housing recovery. It underscores the role of innovative design, proactive planning, and enhanced community engagement in creating housing solutions that not only meet immediate needs but also build long-term resilience against future disasters. This foundation sets the stage for a detailed exploration of specific housing innovations, such as double-wing expandable container homes, as viable options for enhancing post-disaster recovery efforts in New Zealand.

2.2. Research method

The research methods employed in the document adopt a multidisciplinary approach, combining qualitative and quantitative techniques to provide a comprehensive analysis of post-disaster housing recovery challenges and solutions. The primary methods include a literature review, case studies, data analysis, and stakeholder interviews.

A detailed literature review forms the foundation of the research, synthesizing insights from scholarly articles, government reports, and global disaster recovery frameworks. This method identifies knowledge gaps, evaluates the efficacy of existing housing solutions, and informs the exploration of innovative approaches such as modular and prefabricated housing.

The study also employs case studies, focusing on significant disaster events in New Zealand, such as the Canterbury earthquakes and Cyclone Gabrielle, to contextualize the unique challenges and responses associated with housing recovery. These case studies highlight real-world complexities, such as regulatory compliance, funding issues, and community involvement, offering lessons applicable to future recovery efforts.

To support the qualitative findings, data analysis uses secondary data from global disaster databases, such as EM-DAT. This analysis examines trends in the frequency, impact, and financial costs of natural disasters, providing a quantitative backdrop to the discussion on New Zealand's vulnerability and preparedness.

Lastly, a comparative analysis evaluates post-disaster housing strategies from international contexts, such as Japan, Sri Lanka, and the Philippines, to draw parallels and identify best practices that could be adapted to New Zealand's circumstances. By combining these methods, the research ensures a balanced and robust understanding of the complexities and opportunities in post-disaster housing recovery.

2.3. EM-DAT: A global database for disaster risk management

The data which includes dates and localities of over 17,000 natural and technological disasters in the world have been recorded from 1900 to date in an international database known as EM- DAT. The Emergency Events Database EM-DAT was created in 1988 by the World Health Organization, WHO and the Centre for Research on the Epidemiology of Disasters, CRED. It allows crucial data to be extracted: the geographic, temporal, and human impacts and how severe these impacts might be to assess vulnerability and inform disaster risk management. The database is extracted from various origins, including UN agencies, non-governmental firms, reinsurance corporations, research institutes, and press agencies. According to EM-DAT, a disaster is an occurrence or threat that causes damage, ecological change, or disruption of social services (basically anything that disrupts the normal course of life), beyond the capabilities and possibilities within the country to offset all or part of that situation. Further, the campaign serves to standardize decisions on disaster preparedness and risk reduction strategies and confer a rational foundation for priority setting and vulnerability assessment. EM-DAT provides a worldwide catalog at the country level of human and financial losses due to natural disasters in cases with (or exceeding) one of the following criteria:

- 10 fatalities
- 100 affected people
- A state of emergency proclamation
- appeal joined by another country

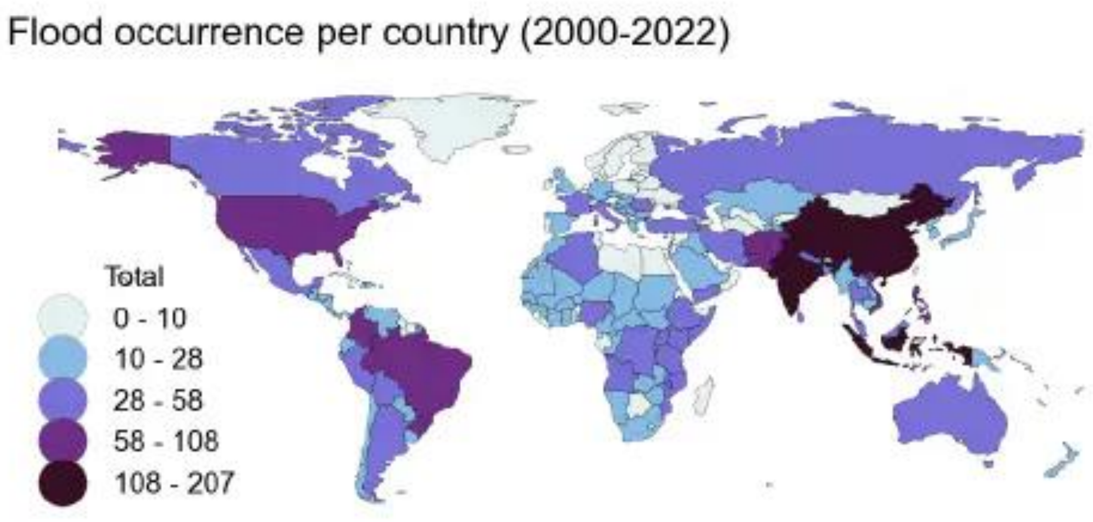

Fig.1 World map illustrating the occurrence of floods per country from 2000 to 2022 as per EM-DAT (https://www.emdat.be/)

According to EM-DAT, the map portrays flood risk across different regions, featuring areas most ostentatious to flooding during the specified period. The map is coloured based on how many times the country faces floods; a darker colour means a greater number of floods.

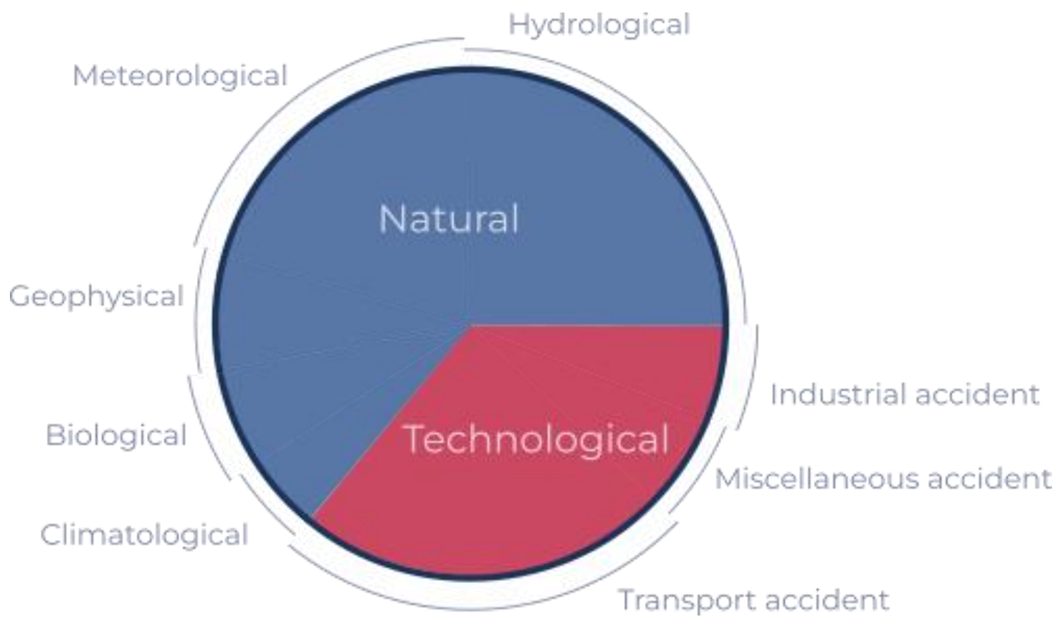

Fig.2 Pie chart emphasizing the natural and technological disasters (https://www.emdat.be)

The EM- DAT database categorizes disasters as natural or technological hazards. There are also four additional classifications in the Natural group which are Hydrological, Meteorological, Geophysical, Biological, and Climatological. The technologically specific category is broader; it covers three types, transport, industrial, and miscellaneous accidents. Around 2/3 of disasters within EM-DAT relate to natural hazards, as shown in the chart (https://www.emdat.be).

2.4. Rising frequency and impact of global disasters: New Zealand's trends

Disasters, both manmade and natural, are severe events with low expectations of occurrence and high outcomes that affect individuals, families, and many communities (Saumyang Patel, et al, 2013). However, climate change, global warming, increasing sea levels, and rise in temperature levels have upgraded with higher frequency of occurrences (NOAA, 2009; Arndt et al., 2010). It is noticeable from the increase in consecutive natural disasters from earthquakes, cyclones, floods, and volcanic eruptions over the decades in New Zealand. Natural disasters have become more destructive and have been highly costly over the years in New Zealand. The same type of disasters became more destructive and expensive as years passed. It has been predicted that these severe outcomes are going to shoot up in upcoming years due to the increase in the number of natural disasters and the rise in global warming (NOAA, 2009; Arndt et al., 2010).

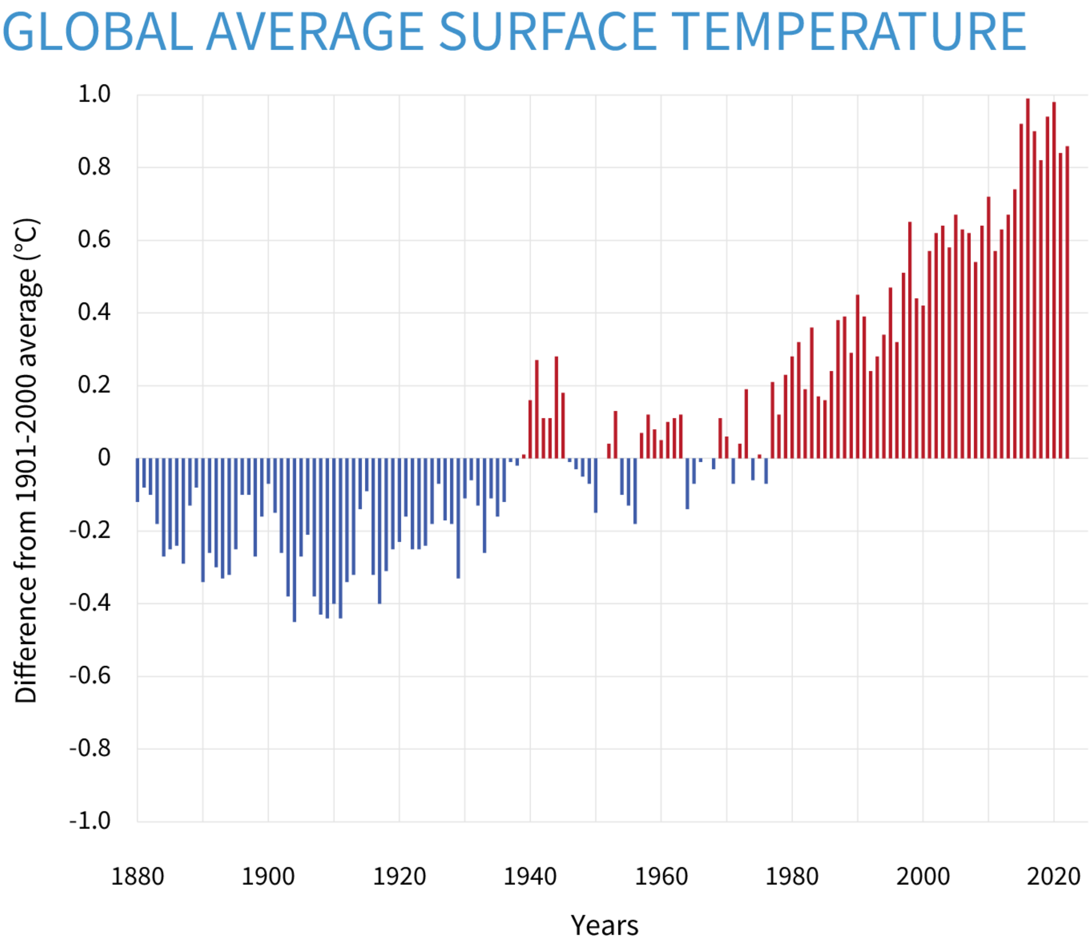

Fig.3 Annual surface temperature from 1880–2023 relative to the 20th-century average (1901-2000). Colored bars represent years that were cooler (blue) or warmer (red) than average. NOAA Climate.gov graph, based on data from the National Centers for Environmental Information. (https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature)

2.5. Natural disasters and housing recovery in New Zealand

Major events such as the Canterbury earthquakes in 2010-11 and the Kaikōura earthquake in 2016 led to extensive building damage, infrastructure failure, and displacement of thousands of people. These disasters place immense pressure on the government, local authorities, and communities to quickly rebuild and recover housing, but in a way that achieves both safety and resilience (Jha, Abhas K., 2010). Dealing with the aftermath of these natural disasters has been a difficult and complex process for the New Zealand housing system. Following disasters, the attention turns to saving lives and getting people out of precarious housing situations. Still, the longer-term recovery will require all these phases with damage assessments, funding, insurance payouts and adherence to new building codes which put a stronger focus on resilience as future disasters are likely though their timing and impact are uncertain.

In response to these challenges, New Zealand has implemented a variety of mitigation strategies targeting housing recovery after natural disasters (Comerio, Mary C. 2014.). Among these, are highly regulated building codes, more effective land use planning that keeps development out of high-risk areas, programs to help communities become more resilient, and new construction methods using different materials. Government organizations such as the Earthquake Commission (EQC) that provide financial support and oversee recovery are essential to effective response. There has also been a growing recognition of the need to involve residents in the process of rebuilding — what is known as community-led recovery. This approach attempts to ensure that reconstruction is more inclusive, locally adapted, and resilient.

Although significant advances have been made in boosting the nation's resilience to natural disasters, major stakes persist. The housing community landscape will have to look at other ways to make homes more resilient, (i.e. climate change-related disasters like major flood events or storms). Furthermore, the development of more sustainable and resilient houses resistant to future natural disasters and with the least environmental footprint is crucial. Key lessons from previous recovery efforts in New Zealand: How they can inform better preparedness and response for the number of local authorities we have, improving community resilience and building back safer, stronger homes (Mannakkara, Sandeeka, Suzanne Wilkinson, and Regan Potangaroa, 2018).

2.5.1. Overview of housing recovery in Christchurch

The post-2010 recovery from the earthquake that struck Christchurch is a typical example of the hardships that New Zealand is confronted with in post-disaster housing. The said earthquake left the city of Christchurch in utter destruction, displacing thousands of residents and severely damaging the city's infrastructure (Potter, Sally H., et al, 2015). Although emergency shelters were set up, the process of turning them into permanent housing took longer. Most of the residents in the city kept on facing the housing problem till today, the finalization of some houses was still in limbo because of issues like conflicting insurance claims, labor shortages, and bureaucratic red tape, all pumping brakes on the process (Saumyang Patel, et al, 2013). Setting a long-term accommodation was a big problem for the residents, and as much as ten years later, some homes were still being reconstructed.

Nevertheless, the recovery process has also shown the world the strong resistance and good imagination of the inhabitants of Christchurch (Hayward, Bronwyn Mary, 2013). The involvement of the community in the recovery was among the most vital parts, as it was the local populace who were the most active in the revival of their neighborhoods. Local nongovernmental organizations (NGOs) have also been pivotal in helping to provide services and resources to displaced residents. The people's commitment and the presence of the cultural beliefs empowered the people by showing how their resilience and flexibility helped the community to have a head start on the recovery path.

However, the situation is still critical, especially with government reaction and insurance aspects in the scene (He, Lulu, et al. 2021). A good number of residents were made to undergo prolonged waiting periods due to the delayed release of insurance claims, and the policy of the insurance companies was not the way it should be for certain. The political leaders were also blamed for being too slow and bureaucratic, with many citizens saying their problems were just ignored. These are the issues that require faster and more efficient post-disaster housing processes in New Zealand, as well as better communication and coordination among government bodies, insurance agencies, and local communities. People waited for creative housing and construction designs and methods that were adopted to build more resilient housing and affordable, durable, easily buildable, and can withstand future disasters.

2.5.2. Cyclone Gabrielle and its recovery

The strong winds from Cyclone Gabrielle have brought widespread destruction in infrastructure, houses, roads, communications, and livelihood in the northern and eastern parts of the North Island of New Zealand. This is New Zealand's most costly natural disaster besides earthquakes, as economic losses are expected to be higher than the losses of the 2016 Kaikōura earthquake.

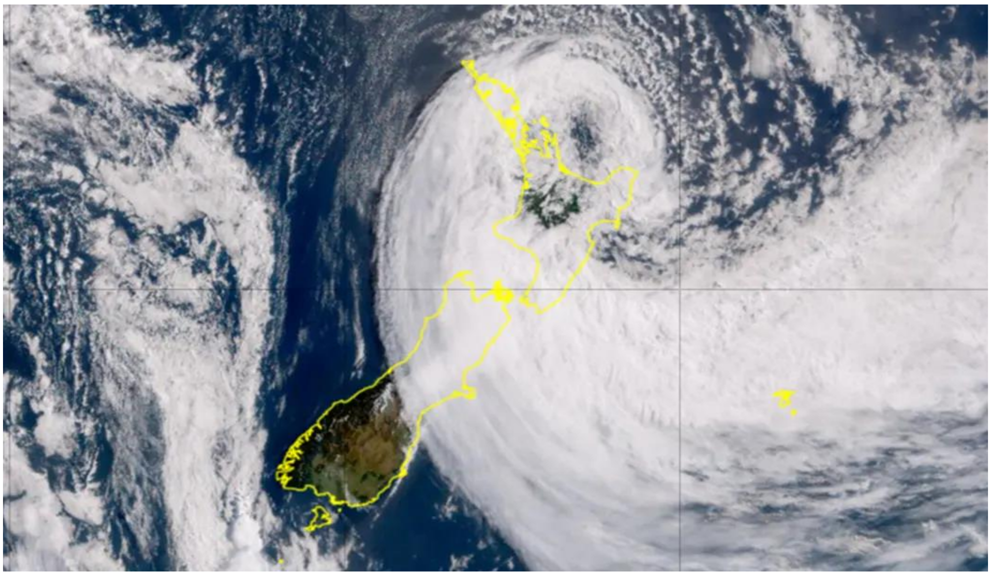

Fig.4 Satellite imagery of Cyclone Gabrielle

(https://www.rnz.co.nz/news/national/527568/cyclone-gabrielle-the-new-benchmark-for-future-storms-in-new-zealand-researcher)

Walking through the Hawke's Bay region in late October, Gabrielle caused damage to infrastructure and local orchards and farms at the peak of the harvesting season. This report was produced in the Division of Economic Affairs of the Ministry of Foreign Affairs and Trade, New Zealand with New Zealand Trade and Enterprise Which Inflorded the Primary Sector Minister. With the escalation of the weather event, there was little awareness and intelligence of the danger and damage, very much for the East Coast towards the HBGECC or GECC, the Hawke's Bay Civil Defense Emergency Management Group, Emergency Coordination Centre (https://www.hbemergency.govt.nz/cyclone-gabrielle-review/). After the event, 83 clamped houses in Hawke's Bay were marked with red stickers which are meant to show that entry into the premises is prohibited while for the other 840 clamped houses yellow stickers were placed indicating that there are restrictions in place for people entering the houses (8 Williams, Caroline (24 February 2023). "The numbers which show how bad Cyclone Gabrielle was". Stuff News). An estimated 10,500 people were displaced and 11 people died during the incident. Moreover, over 70,000 residents remained deprived of basic services like health services, power, road connectivity in every direction, wastewater, drinking water, and Internet and cell phone networks (Chris Neuenfeldt, et al, 2024).

Fig.5 How the kitchen looks after Gabrielle's impact (https://www.habitat.org.nz/impact-stories/one-year-on-cyclone-gabrielles-effect-on-housing)

Recovery from Cyclone Gabrielle raises the same imperatives for creative housing solutions as previous disasters such as the Christchurch earthquakes. Christchurch's recovery has been no easy, long, or complex process. The government established CERA, the Canterbury Earthquake Recovery Authority, to manage the rebuild. Major elements included substantial insurance payouts, a significant inflow of money, and strategic urban planning, including green spaces and new zones. However, the rebuild was slow due to regulatory challenges, insurance disputes, and the pure and utter scale that rebuilding an entire city entailed. By 2023, much of Christchurch has been rebuilt, but recovery has taken more than a decade or is still occurring. Much of the inner suburban areas were being significantly redesigned into long-term resilience planning (Regan Potangaroa, 2010).

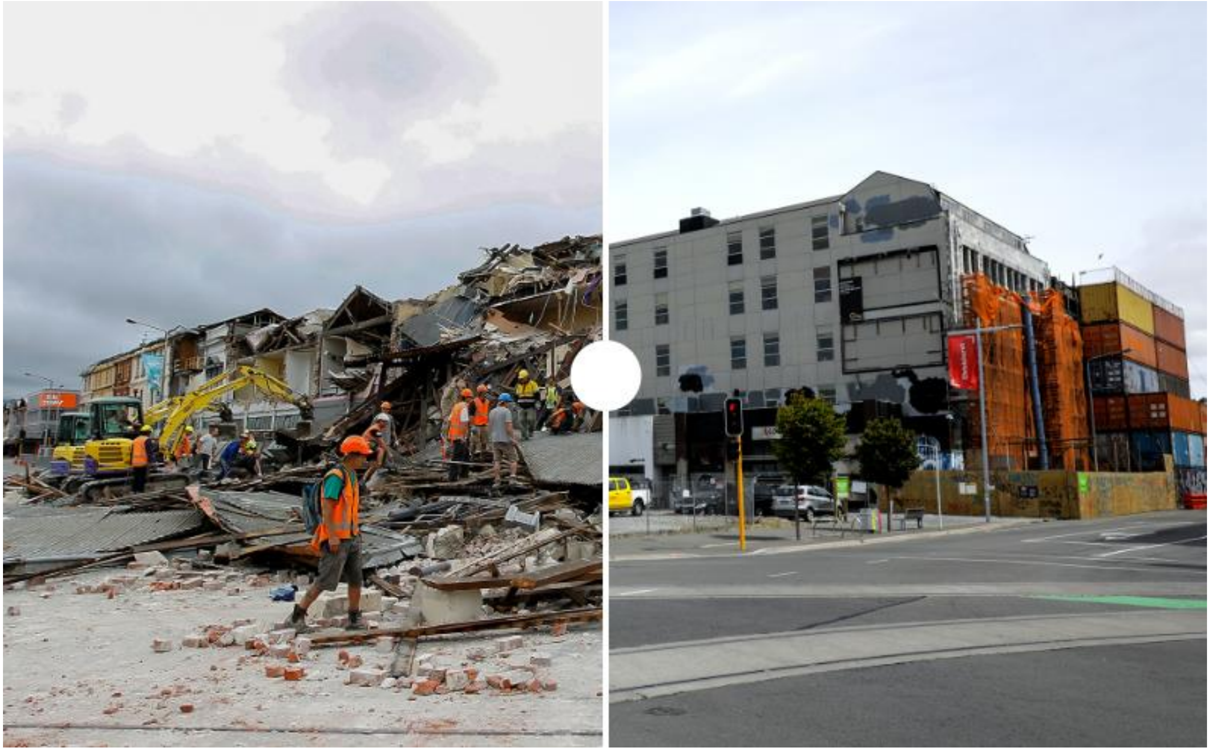

Fig.6 Manchester & Lichfield Streets, 2011 - 2021

(https://www.rnz.co.nz/news/national/436822/then-and-now-how-the-2011-christchurch-earthquakes-changed-the-city)

The recovery in Hawke's Bay focuses on rebuilding infrastructures, bridges and roadhouses and supporting the agricultural economy. While there has been great government funding and community effort, several challenges remain, particularly regarding flood mitigation and future-proofing homes against climate-related disasters. The research investigated various resilient building methodologies appropriate for New Zealand, focusing on technologies that reduce damages from a range of natural disasters such as earthquakes, cyclones, and floods. This paper will discuss a double-wing foldable and expandable container house model as one of the possible post-disaster housing solutions in Hawke's Bay after Cyclone Gabrielle. It looks at the model's resilience against natural disasters, outlines its specifications, compares it to existing housing solutions, and addresses the challenges it may face in the New Zealand market and with local authorities.

2.5.3. Impact of Cyclone Gabrielle on Housing

2.5.3.1. Napier's story

Fig.7 Napier City flooded by Cyclone Gabrielle (https://www.nzherald.co.nz/photos/cyclone-gabrielle-in-pictures-hawkes-bay/A6MUKPFSAFGPVFE4GJNXKR7NSM/)

On February 14, 2023, Cyclone Gabrielle pounded Hawke's Bay; one of its worst-hit cities was Napier. It would thus be that day that went into the annals of this region to highlight a sad day of destruction because it caused city-wide flooding and infrastructure damage, isolating whole communities. The storm, when it hit Napier, caused wide disruptions, leaving over 70,000 residents cut off from all essential services. Lack of electricity, and communication systems, and the destruction of roads, especially along SH2 and SH5, rendered several areas inaccessible. The total collapse of health services, supply of drinking water, and mobile connectivity aggravated the situation further.

The cyclone heavily hit the city of Napier and its environs where houses and community infrastructures have been badly destroyed. The roads have gone, hence isolating the communities and making the action of the emergency services quite challenging. Amongst the crucial factors after the cyclone was the separation of urban Napier from the remainder of the region, hence increasing the feelings of powerlessness within the population.

Since then, the city has moved from an immediate emergency response to a recovery phase. This is led by the Napier City Council in collaboration with mana whenua and tangata whenua, government agencies, and local groups. They work in unison to reconstruct city facilities so the city can regain its original shape before the cyclone; this, however, might take time and be difficult.

The recovery efforts focus on:

- Restoring basic services such as power, water, and communications.
- Reconstruction of critical roads and transport links to reconnect isolated communities, including devastated SH2 and SH5 corridors.
- Innovative solutions to expedite the rebuilding of homes and infrastructures are needed, including making them resilient to future natural disasters.
- The use of innovative rebuilding techniques and partnerships with indigenous groups are seen as vital for long-term success.

Recovery by Napier was thus very much a consultative process between the local communities and the central government

2.5.3.2. Hatings's Story

Fig.8 The effects of Cyclone Gabrielle on Hastings City
(https://waateanews.com/2023/02/16/mp-eyes-devastation-around-hastings-kainga/)

The Hastings District stands out as a prominent territorial authority in the Hawke's Bay region on New Zealand's North Island. The district faced significant devastation after Cyclone Gabrielle struck. In February 2023, the fierce winds, torrential rain, and flash floods brought by the cyclone wreaked havoc on much of the city's infrastructure. Some of the roads were completely submerged, homes had been destroyed, and there was displacement, as several residents fell victim to this destruction. The sad thing was that there were some injuries, and even fatalities, further adding to the feeling of loss and disruption community members felt.

Mayor Sandra Hazlehurst said the scale of the task in rebuilding the district was immense, a lot had been done to date, and the extent of the destruction would make full recovery a long and complex road. The mayor said, "We are making good progress with Cyclone Gabrielle, but there is a lot more to go.". While a lot has been done, it is estimated that it will take 7 to 10 years to fully rebuild." This estimate signifies how grave the damage was, especially in major infrastructures involving roads, housing, and other basic services that require longer, continuous efforts to revive.

Recovery efforts in Hastings are focused on:

- Rehabilitating infrastructure such as roads and bridges that have been flushed away by the flood
- Reconstruction of houses to house the displaced to cover the demand for temporary housing.
- Restore community assets and support local businesses that were affected by the storm. The focus would be on long-term economic recovery in the district.

The council continues working with government agencies and the wider community on the development of a recovery plan, which addresses short-term needs and longer-term resilience strategies. In this regard, measures regarding flood mitigation, and improving building standards to better handle the challenges in climatic events, are included.

2.6. Challenges in housing recovery after natural disasters in New Zealand

In New Zealand, Housing Recovery after natural disasters faces significant disputes. Insurance payouts take months longer to materialize, slows down rebuilding efforts, while strictness in the building regulations which are designed to ensure future resilience increases costs as well as time. Lack of labor in adequate time and the shortage of material inflame these delays, especially in highly developed areas with high demand. Displacement creates problems in finding sufficient housing for temporary use, leading to overcrowding and extended displacement.

The social and psychological factors affect the residents with the threat of trauma, anxiety, and depression from relocation to disaster-stricken areas. Recovery efforts are also hampered by economic barriers, particularly for those without adequate insurance. In addition to this, there is a delay in restoring essential infrastructure, such as electricity and water (or rebuilding which takes months or years), and takes much longer to get back on its feet.

These housing recovery problems symbolize the complexity of disaster response in New Zealand, reinforcing the necessity for streamlined and regulative processes, improved coordination across all relevant stakeholders, and resilient planning to facilitate Swiffer, longer-lasting recoveries.

2.6.1. Mental health and housing challenges in New Zealand's disaster recovery

According to Donatti, C, et al 2024, in New Zealand, during 7 climate-related disaster types between (and including) 2000–2020 such as drought, Riverine flood, tropical cyclone, flash flood, Landslide, mudslide, wildfire, heat wave, Cumulative percentage of people impacted is 0.20%, the total number of people impacted is 8449, number of events happened is 11 and number of people impacted per event is 768. The degree of mental health problems is affected by factors such as personal loss, destruction of a community, and disaster proximity, with vulnerable populations like children and those in developing countries being particularly affected. Most people undergo acute stress, only a few of them have long-term problems that can last for years (Bryant, 2006). There has been growing research into the mental health consequences of major disasters. Studies in New Zealand have been advocated to check the prolonged mental health effects on residents following a series of earthquakes, including a fatal one in 2011 at Christchurch, a group of middle-aged residents detailed significantly lower threshold in mental health, vitality, social functioning, and emotional roles compared to national norms. The depression rate and bipolar disorder were clearly higher than in non-earthquake-affected residents (Spittlehouse, Janet K., et al. 2014). Ellis, Pete M., and Sunny CD Collings, 1997 gave comprehensive details of issues concerning mental health, prevention programs, and initiatives for health promotion in New Zealand. Various strategies have been promoted for different age groups from infants to old age people by introducing community-based interventions and social support systems.

The mental health effects of disasters in New Zealand, aggravated by housing loss, reflect a broader challenge for emergency response teams. These severe events have hitched up the responsibilities of the emergency team and have imposed more difficulties in choosing the appropriate plans and logistic policies. (Saumyang Patel, et al, 2013). One such challenge is to provide temporary or emergency houses for the disaster victims (Félix, D, 2014). People manage to suffer the loss of shelter and the places where they work, live, and transact business. Infrastructure facilities in disasters make them vulnerable and hence become fully reliant on government and other agencies. On the other hand, agencies must arrange the required response operation and corresponding strategies, interventions, and services to minimize the stress on the victims. Based on the damage done to homes and the availability of funds, the emergency agencies must choose to relocate and accommodate victims. This relocation or the residential mobility, may be a temporary one or even a permanent one. In severe cases, with disasters such as earthquakes and fires, entire residents or the victims in an affected area need to move to find security and safety and rebuild their necessities due to houses being damaged or to seek better air conditioning (Belcher & Bates, 1983; Peacock et al., 2018).

2.6.2. Addressing broader social and economic challenges in post-disaster planning

Apart from planning for shelter, the issues facing emergency planners include financial aid, food, clothing, opportunities to work and earn, modes of transportation, medical and health care facilities, schools and colleges, and community centers. Also, social impacts on the communities, both host and displaced communities, are observed because of the variation in population composition, culture, and financial aspects. Thus, change in location or residential mobility affects the three areas: mental, social, and economic structure. Many residents are suffering from trauma after the forceful relocation due to the impact of severe damage. Vice versa, many studies explained the psychological distress like the risk of anxiety and depression for those victims who remained or returned to disaster-affected areas (Denise Blake[1], et al, 2022). Disaster relocation plans must consider how to address the cultural attachment people have to their original land (Denise Blake[1], et al, 2022) and rebuild based on their requirements.

The Canterbury earthquake sequence has developed into one of the largest registered population movements both temporary and permanent in the history of New Zealand. The total population of Christchurch decreased by around 8,900 (2.5%) people between 2010 June and 2011 June (SIMON BERNARD DICKINSON, 2013). New Zealand’s national health agency, Te Whatu Ora, mentioned to RNZ that the number of residents who sought mental health support from the local general practitioner had leaped 30% in Hawke's Bay since Cyclone Gabrielle (Chris Neuenfeldt, et al, 2024). Considering all these, it is essential to provide housing to victims in their own region to aid its mental, social, and economic regrowth and rebuilding processes.

2.6.3. Insurance challenges in housing recovery after disasters

During recent disaster events across the world, planners have also faced problems in getting insurance for housing or recovery. After the impact of a hazard, funding issues will be a serious concern, and it is not a new story to many countries. In 1974, after the impact of Cyclone Tracy in the city of Darwin, the northern territory of Australia, the reconstruction efforts and ideas were taken by the experts. (K.J. Walters, 1978) Financial crises to build back the city had a huge impact on the recovery because the discussion for recovery had to be taken together by the government, people, local agencies, insurance companies, and supporting authorities. The author could have compared the reconstruction efforts after Darwin with other incidents across the world, and then a prospective solution could have been suggested. One of the greatest challenges was the unwillingness of international private insurers to settle claims in a timely fashion and the government's inability to put more pressure on them. Thus, insurance and housing crises have developed (Zuzana Bzonková, 2014). During the earthquake incident in Canterbury, the Christchurch Fiasco focused specifically on insurance issues. Sarah Miles' book is very thorough but does not contain information about insurance and policyholder protection in New Zealand, but discusses them in a broader context as well, often in connection with the United States or Australia (Zuzana Bzonková, 2014). Between June 2011 and July 2015, the New Zealand Government declared two financial offers to the victims of house damage who held full insurance for their properties in red zones. One was the government fully purchasing the house and land at 2007-2008 relatable value and taking over all the insurance claims relating to the package and the other was, the government would purchase the land only and the owners would deal with their own insurance companies regarding the damage of the property. After nine months, the victims chose one of the offers and vacated their properties and the government took over the property and did either demolition or removal of all the houses and fixtures on the land (Lulu He, et al, 2021).

Like the above case, several insurance policies have been introduced by the New Zealand government in different disaster scenarios in New Zealand. In early 2023 the Auckland floods and Cyclone Gabrielle caused significant damage around the North Island and generated a 402% spike in insurance claims. The New Zealand Claims Resolution Service (NZCRS) offers assistance to policyholders following natural disasters aimed at minimizing disputes, addressing problems, and making sure that claims are settled as quickly as possible. The concerned individuals could coordinate with everyone involved in their claim process ("North Island Floods and Cyclone Gabrielle." *Insurance & Financial Services Ombudsman*. Web. https://www.ifso.nz/pages/north-island-floods-and-cyclone-gabrielle.). Cyclone Gabrielle insurance recovery advice has been provided by the Insurance Council of New Zealand and proclaimed consumer guide for the victims (Consumer Guide:

Cyclone Gabrielle Insurance Recovery Advice." *Insurance Council of New Zealand*, Feb. 2023. Web. https://www.icnz.org.nz/wp-content/uploads/2023/02/Consumer-guide-Cyclone-Gabrielle-insurance-recovery-advice-Feb-2023.pdf.).

2.6.4. Enhancing legislative frameworks for accelerated disaster recovery in New Zealand

After insurance and funding concerns, the next question is how fast the recovery is going to happen. In New Zealand, experts have suggested ideas for the improvement of legislative provisions to facilitate large-scale recovery management (James Olabode Bamidele Rotimi, 2012). The research has identified that there is a need for better integration of environmental concerns into recovery processes, the importance of stakeholder collaboration, and the adoption of flexible regulatory frameworks and effective legislation should facilitate rather than hinder reconstruction efforts, thus supporting sustainable development and resilience in affected communities (James Olabode Bamidele Rotimi, 2010). The author could have done a detailed analysis of the intersection of environmental management and post-disaster recovery, there is insufficient focus on legislative flexibility during emergency reconstruction and limited empirical data on how environmental legislation hinders or aids recovery efforts.

R W Kates and the team had given a proposal for the reconstruction of New Orleans after Hurricane Katrina. The works were done in 4 stages: emergency, restoration, reconstruction, and betterment. Restoration is on track based on historical experience, but the reconstruction is expected to take 8-11 years because of the slow pace of decision-making (R. W. Kates et al., 2006). Even though the authors lack in providing information on socio-cultural and environmental factors contributing to the vulnerability, they highlighted the need for a balance between quick recovery and long-term improvements, suggesting that recovery may continue to decline unless significant changes occur, such as external aid or policy reforms. Even though these constraints are left behind, recovery and reconstruction should happen effectively after a disaster for betterment. The New Zealand authorities are trying to come up with various reconstruction and recovery solutions but still some concerns arise, such as availability, affordability, durability, and many more.

2.6.5. The lingering housing crisis: survivors' struggle after cyclone Gabrielle

Cyclone Gabrielle made impacts not only on the transportation areas but also on the infrastructures, mainly, the housing. The people have either internally displaced themselves in Hawke's Bay due to Cyclone Gabrielle, evacuated their homes permanently, or have undertaken reconstruction of their properties. Some bear imperfections and are always on the lookout for new ways amidst chaos. Residents of Hawke's Bay talk to those preparing to celebrate their second winter out of their houses and about their fight for existence. Steven Galyer, one of the cyclone survivors, seeks a place to stay as it starts to get cold outside. He says that it is just like a dream that would not go away because it reminded him and his wife of when they were homeless after the cyclone. (https://www.nzherald.co.nz/hawkes-bay-today/news/cyclone-gabrielle-the-hawkes-bay-families-who-wont-be-in-their-own-homes-this-winter/RMYPHUE2OREO3HCI75EMZMUPYI/)

Fig.9 Vivian Bell (right) and mum Shirley Galyer are still on the hunt for a permanent home. (https://www.nzherald.co.nz/hawkes-bay-today/news/cyclone-gabrielle-survivors-still-on-hunt-for-a-home-year-after-the-floods/3BQLAH3PABCBRNIA2R6WKZFPRY/?ref=readmore)

It has been one year since the disastrous floods in Hawke's Bay, and Cyclone Gabrielle survivor Vivian Bell is still in the process of finding a new home. A year ago, Bell barely escaped with her life and began to stay in a caravan on a relative's piece of land in Hastings. Last year, on the 14th of February, she was suddenly uplifted from her rental home in Eskdale, a suburb north of Napier, when the floodwaters invaded it, along with her siblings and their spouses who lived in the adjacent houses. Bell expressed appreciation for what she managed to get out alive despite the suffocating pressure that has existed since then over the issue of getting a home (Wang, Kiri. "Cyclone Gabrielle Survivors Still on Hunt for a Home Year After the Floods." *New Zealand Herald*, 2024. Web. 25 Sept. 2024. https://www.nzherald.co.nz/hawkes-bay-today/news/cyclone-gabrielle-survivors-still-on-hunt-for-a-home-year-after-the-floods/3BQLAH3PABCBRNIA2R6WKZFPRY/?ref=readmore).

2.6.6. Community engagement and cultural sensitivity aftermath the cyclone Gabrielle

Minister of Housing Chris Bishop has presented an idea on how the New Zealand housing crisis can be resolved, claiming that land for development will be made readily available. He intends to limit agreements between councils and developers regarding legislated urban growth boundaries and policies. It will be a requirement for Councils to have in their plans land allocated for 30 years' worth of housing growth (The New Zealand Herald, 2024).

In Hawke's Bay, the organization that provides homes, Habitat for Humanity, formed a collaboration with a local body organization to deliver repairs for victims and related families who are in contact with whose houses were severely impacted by Cyclone Gabrielle. The habitats required partnerships, as they knew recovering from cyclones and other disasters effectively could not be a short-term plan. Their mission in Hawke's Bay was to unite people to strengthen and create homes, communities, and a sense of hope (Habitat for Humanity New Zealand. "One Year On Cyclone Gabrielle's Effect on Housing." *Habitat for Humanity New Zealand*, 2024. Web. 25Sept.2024.https://www.habitat.org.nz/impact-stories/one-year-on-cyclone-gabrielles-effect-on-housing). The Ministry for Primary Industries (MPI) allocated substantial funding to aid the recovery of impacted farmers, growers, Māori landowners, and rural communities. In May 2024, the Government proclaimed the Regional Infrastructure Fund (RIF). The fund has $1.2 billion over 3 years to invest in new and existing infrastructure throughout the regions of New Zealand. There are two categories of funding distribution. Resilience infrastructure: projects that improve a region's capacity to cope with or recover from stress or shock, e.g. flood defense structures, and energy safety. Enabling infrastructure: projects that aid the achievement of wider economic results such as enhancing productivity in regional economies (https://www.mpi.govt.nz/funding-rural-support/adverse-events/cyclone-gabrielle-recovery-advice-and-support/.).

The New Zealand Disaster Fund has provided the Hawke's Bay Disaster Relief Trust* with $3 million in total. This was a part of more than $8.5 million which was released by the Trust for rehabilitation of approximately 4600 cyclone-affected families in the region. Waiohiki residents Mischelle and Kim Tyler lost most of their belongings and their home and business on the night of Cyclone Gabrielle when their property adjacent to the Tutekuri River was inundated. Just like many others, they were forced to escape into the night with their dog Brian, and a family that lived next door. They are slowly socializing with family members, spiritual friends, and even members of the community who have helped Mischelle and Kim get the house in shape for settlement. Also, they were able to get help from one of the grants provided by Hawke's Bay Disaster Relief Trust. Some things have been purchased for the grant to help them put back some level of access to their property, but there is still so much work ahead of them. "We have to construct a new water well, remove additional silt, and just work on making the place habitable once again and this fund will certainly assist a great deal." (New Zealand Red Cross. "Staying with Communities for Long-Term Recovery." *New Zealand Red Cross*, 2024. Web. 25 Sept.2024.https://www.redcross.org.nz/about-us/news/our-stories/staying-with-communities-for-long-term-recovery/). Like the New Zealand Red Cross and Habitable for Humanity New Zealand, many organizations came up to help those people who lost houses during the recovery after the heavy flooding and cyclone Gabrielle.

2.6.7. Expert insights on resilient infrastructure after cyclone gabrielle

Experts have provided reactions to building back better after Cyclone Gabrielle. “It is important to prioritize resilience in the design and construction of new infrastructure. This means considering the potential impacts of extreme weather events, such as flooding and landslides, and building infrastructure that can withstand these conditions. Additionally, regular maintenance and inspections can help identify and address issues before they become major problems." commented Professor Regan Potangaroa, Professor of Resilient and Sustainable Built Environment (Maori Engagement), at Massey University. “So, to improve climate resilience we need to stop rebuilding in unsuitable places. If we do build in those places, we need to change how we build and incorporate higher resilient features (using better materials or different parameters). We need to build the above code and take a multi-hazard, intergenerational approach." comments Professor Suzanne Wilkinson, College of Sciences, Massey University.

2.7. Build Back Better (BBB) approach

In 2006, the United States introduced the Build Back Better approach as a response to the recovery processes following the Indian Ocean Tsunami in 2004 (Fernandez, Glenn, and Iftekhar Ahmed, 2019). The core approach focuses on improving post-disaster recovery not as an opportunity but to improve resilience, reduce future risks, and address pre-existing vulnerabilities. The approach gained prominence in the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030 as a critical solution for intensifying disaster resilience (DasGupta, Rajarshi, and Rajib Shaw. 2017). Now, the Build Back Better concept has evolved to encompass various factors from physical infrastructure to community resilience and governance.

Mannakkara and Wilkinson, the researchers included 3 key factors for BBB, which are disaster risk reduction (DRR), community recovery, and effective implementation (Mannakkara, Sandeeka, and Suzanne Wilkinson, 2013). There were some practical challenges because of which the entire process was very slow. As a result, there was a high need for refinement and adaptation of the BBB framework to suit local needs.

This approach has been applied to various post-disaster contexts globally, from the Victorian bushfires in Australia to the reconstruction efforts in Sri Lanka, Japan, and the Philippines (Amaratunga, Dilanthi, and Richard Haigh, 2011). These real-world applications provide insights into both the potential and limitations of BBB. For example, while the framework helped improve resilience in some regions, issues such as political interference, bureaucratic delays, and a lack of community involvement often hindered its full realization. Research indicates that successful BBB implementation requires a balance between theory and the practical realities of local governance, economic constraints, and community needs.

2.7.1. Building Back Better: impacts of government policies

In the build-back better approach, there is a need for proper recovery solutions even though there are issues like bureaucratic delay, socio-political concerns, etc. Improving resilience with a focus on disaster risk reduction is the key aspect where proper recovery strategies should be adapted. There is a high importance to government policies in shaping post-disaster housing and recovery efforts. For example, in Sri Lanka, a coastal exclusion zone policy has been enforced by the government, which prohibits reconstruction within 100 to 200 meters of the shoreline (Shanmugaratnam, Nadarajah, 2005). This policy led to the displacement of many communities to inland areas, despite resistance from those who wished to return to their original homes. The policy caused considerable challenges as it disconnected people from their livelihoods, particularly fishing communities dependent on the coast. In contrast, Aceh experienced a mix of reconstruction both in original sites and in new, safer areas. Reconstruction in the affected zones was prioritized where feasible, but there were also significant efforts to relocate populations at risk to areas less vulnerable to future disasters. The involvement of local communities in Aceh's reconstruction played a critical role in ensuring that the process considered both safety and the cultural and economic needs of the residents (Clarke, Matthew, Ismet Fanany, and Sue Kenny, 2010).

2.7.2. Build Back Better: the role of modular and prefabricated housing in post-disaster recovery

To support build back better approach, the first consideration should be on transforming the affected location by reconstructing infrastructures, and housing for the communities. Housing is the basic need for the victims to survive but it should be made sustainable, and durable and there should be very little disaster risk (Kreimer, Alcira, Margaret Arnold, and Anne Carlin, 2003). The recovery houses must be affordable, durable, easily transportable, there should be less maintenance and labor cost, and eco-friendly thus reducing further disaster risk. By providing a better option for housing, the communities will not get displaced in the aftermath of a disaster. There comes the importance of modular construction methods using prefabricated housing options. The prefabricated housing models yield high speed of deployment, cost effectiveness, durability and resilience, flexibility and adaptability, sustainability, reduced logistical challenges, improved living conditions, and mitigation of socio-economic displacement (Smith, Ryan E, 2010).

2.7.3. Rethinking post-disaster housing: the need for innovative solutions

Traditional housing methods cannot always address the challenges created by post-disaster recovery due to several important factors. Many traditional materials, such as timber and reinforced concrete, inherently lack resilience against environmental hazards in disaster-prone locations. There could be problems like moisture infiltration, rot attack, and corrosion issues, which lead to prolonged maintenance concerns and an increase in finance matters. Furthermore, conventional construction techniques often need more labor and the process is time-consuming, which may delay the provision of essential homes for victims, who suffered a lot in the aftermath of a disaster.

Because of these challenges, there comes an urgent need to explore modular and innovative housing solutions that prioritize adaptability, speed, and durability. Modern approaches, such as prefabricated structures and those using cold steel, not only offer higher sustainability and reduced maintenance processes but also allow for faster deployment in disaster frameworks. These materials have seismic resistance, and can withstand extreme weather conditions, and other environmental challenges, making them ideal for regions frequently impacted by natural hazards.

Moreover, new housing models can incorporate flexibility in design that conventional options often lack. This adaptability enables them to be tailored to the specific needs and contexts of diverse communities, ensuring that the solutions provided are not just temporary fixes but long-term strategies for resilience and sustainability. By embracing these advanced housing solutions, we can create safer, more efficient, and eco-friendly housing options that help the communities to overcome more swiftly and effectively from the aftereffects of disasters. Ultimately, the transition from traditional construction methods to innovative housing methods is highly essential for increasing the resilience of vulnerable individuals and communities, enabling them to thrive in an unpredictable future.

As the insights from experts highlight the importance of resilient infrastructure in the aftermath of Cyclone Gabrielle, it becomes evident that traditional methods of construction may not suffice in addressing the multifaceted challenges posed by natural disasters. The necessity to prioritize resilience in design and construction aligns seamlessly with the call for innovative housing solutions, as both approaches aim to ensure that communities can withstand and recover from extreme weather events. By recognizing the limitations of conventional materials and techniques, we can pivot toward more adaptive and sustainable housing options that not only meet immediate needs but also build long-term resilience. Embracing modular and prefabricated structures will complement the broader goal of developing infrastructure capable of withstanding future disasters, thereby fostering a safer, more sustainable living environment for all.

2.8. Shelter quality and material selection for post-disaster housing in New Zealand

In each disaster event, planners and advisers have also faced concerns with the type and quality of shelter provided to residents or victims. In New Zealand, irrespective of the area, there are different types of housing concepts from bungalows, weatherboard houses, cottages, apartments, tiny houses, temporary houses, villas, Maori homes, townhouses etc, that are built based on location, climate, lifestyle and budget. The choice of materials in post-disaster reconstruction significantly affects the speed of the process (Giulia Celentanoa et al., 2018). Some scientists say local materials like Bamboo, earth, and stone are the most effective choices for post-disaster reconstruction. The choice of materials used in post-disaster reconstruction significantly affects the speed and quality of recovery. The lightweight, prefabricated materials can reduce construction time, improving resilience in disaster-affected areas. A balance must be struck between speed, cost, and long-term sustainability, and urges for more adaptive approaches tailored to specific disaster contexts (Giulia Celentanoa et al., 2018). Even though the study mentions the importance of prefabricated materials in construction speed, balancing the use of fast, industrialized materials with sustainable, locally sourced options remains an underexplored area, calling for more research on long-term sustainability in recovery efforts.

2.8.1. Evaluating construction materials for resilient housing in New Zealand's disaster recovery

Houses in New Zealand are commonly constructed using materials such as bamboo, wood, timber, brick, and concrete, often incorporating proper insulation. While these materials are cost-effective and simplify the construction process, their durability is a concern due to low resistance to seismic activity and wind, as well as high moisture sensitivity.

Steel and concrete are recognized as globally effective materials with strong technical performance, but locally sourced materials like bamboo and wood tend to have a lower environmental impact and reduced costs. Therefore, careful attention should be given to the design of structures built with local materials.

When materials and designs are appropriately chosen, shelters can be created with minimal costs and environmental footprints (E. Zea Escamilla*, G. Habert., 2015). However, this comparison does not consider various factors that can affect shelter performance, including the structure's weight (dead loads), its specific shape, the availability of materials in disaster zones, the type of disaster it needs to withstand, and fire resistance.

Considering these factors, selected reconstruction materials must be durable, cost-effective in terms of long-term maintenance, resilient to climate changes, readily available, and easy to construct. Consequently, discussions regarding the use of steel and concrete in the recovery process are essential.

2.8.2. Evaluating structural alternatives for disaster recovery: the case for steel over reinforced concrete in Nagapattinam, India

Disaster recovery in Nagapattinam district, India, has primarily utilized reinforced concrete (RC) frames; however, this approach has encountered significant issues, such as leaking roofs and cement erosion (Mohan & Choudhury, 2024). Research indicates major challenges in maintaining RC structures, particularly the high costs associated with corrosion and degradation over time (Angst, 2018).

This highlights the potential advantages of using steel structures as a more favorable alternative. Steel, particularly high-strength or corrosion-resistant alloys, offers more predictable maintenance and long-term durability compared to RC, where corrosion often goes unnoticed until severe damage occurs. Moreover, technological requirements such as structural health monitoring and drones are less critical for steel than for RC, as the uniformity of steel makes inspection and maintenance simpler.

Steel also boasts decades of reliable performance, allowing for more effective support of performance-based designs due to better-understood material properties and modern computational tools. From a sustainability perspective, steel is fully recyclable, while concrete has a significant environmental impact due to cement production.

Additionally, the use of steel enables faster construction, as prefabricated components can be assembled quickly, reducing both labor and time costs. Its inherent flexibility allows for easy modifications or expansions, making it adaptable in dynamic environments where infrastructure needs to evolve.

Overall, steel structures present numerous advantages in terms of durability, maintenance, construction efficiency, and environmental sustainability. For post-disaster reconstruction in New Zealand, concrete construction is not an ideal choice due to its expense, time demands, seismic vulnerability, and high maintenance needs.

2.8.3. Evaluating timber and steel in disaster resilience: challenges and innovations in Vanuatu and New Zealand

Vanuatu, located 750 km east of northern Australia, is prone to various natural disasters, including earthquakes, tsunamis, storms, and cyclones (Chelsea Huang, 2023). Researchers have proposed a multi-functional community center that acts as both a community hub and a disaster relief center, utilizing timber construction that blends with the surrounding forest. This design features braced timber columns, galvanized steel connections for added structural strength, and reinforced timber floors supported by concrete footings (Chelsea Huang, 2023). However, the community has faced challenges related to maintenance, particularly after enduring repeated natural disasters.

In New Zealand, timber construction is commonly favored over reinforced concrete for disaster recovery. Nevertheless, one major drawback is that timber frames can rot when exposed to moisture over time. Recently, New Zealand has experienced a shortage of structural wood, revealing vulnerabilities in the building supply amid rising domestic demand and high log exports. While some attribute this crisis to Covid-related disruptions, the issue is more complex. Carter Holt Harvey, a leading wood products manufacturer, has invested $100 million since 2020 to enhance efficiency and increase manufacturing capacity by 40% at its Kawerau and Nelson plants, partly due to the planned closure of its Whangarei plant, which had depleted its structural timber resources (Sands, K. "We Can't See the Wood for the Trees: Understanding New Zealand's Wood Supply Crisis." Stuff, 25 Sept. 2024).

Although many studies advocate for timber due to its sustainability, its maintenance challenges underscore the need for alternative materials like steel in post-disaster situations. Therefore, steel emerges as the best choice for construction in post-disaster reconstruction due to its numerous advantages, including strength, ductility, resistance to seismic activity and high winds, moisture and fire resistance, energy dissipation capacity, prefabrication potential, recyclability, and low maintenance requirements.

2.8.4. Cold-formed steel in post-disaster housing

In Indonesia, a study highlighted the effectiveness of house-shaped cyclone shelters made from steel, which can function as both homes and evacuation centers, as proposed by BRAC University (Mari Miyaji, Kenji Okazaki, Chiho Ochiai, 2020). Cold-formed steel (CFS) has proven to be an economical and effective material for earthquake-resistant permanent housing, particularly in high-risk areas like Yogyakarta. The proposed design features a 36 m^2 two-story structure made of CFS, chosen for its lightweight nature and ease of construction, as well as its ability to withstand seismic forces (R. Alghiffary et al., 2018). Although further testing and collaboration with the cold-formed steel industry are needed to refine the design for quicker deployment in disaster areas, the current proposal meets safety and budget constraints for post-earthquake housing. Cold-formed steel is also popular in New Zealand due to its strengths, such as durability, seismic resistance, and cost-effectiveness.

2.8.5. The resilience of steel structures in post-disaster scenarios

From a post-disaster perspective, steel structures demonstrate a high capacity to endure natural hazards like earthquakes. Decisions regarding whether to repair or demolish multi-story concrete buildings in Christchurch after the 2010-2011 Canterbury earthquakes were complicated and necessitated clear repairability standards and improved decision-making frameworks that account for both economic and structural considerations (Marquis, Frederic, 2015). The Christchurch Art Gallery, with its steel framework, withstood the 2011 earthquake. Similarly, One World Trade Center in New York City features advanced steel frames that have endured significant wind loads and threats such as potential terrorist attacks, withstanding Hurricane Sandy in 2012 without structural damage.

2.9. Chapter Summary

The chapter explores the profound impact of natural disasters on housing recovery in New Zealand, highlighting the increasing severity of events such as earthquakes, cyclones, and floods. It provides an in-depth analysis of the challenges faced during recovery, including funding delays, regulatory complexities, insurance disputes, labor shortages, and the psychological toll on affected communities. Key case studies, such as the Canterbury earthquakes and Cyclone Gabrielle, illustrate the multifaceted nature of these challenges and the prolonged recovery periods experienced by impacted regions.

The chapter also examines New Zealand's evolving approach to disaster recovery, emphasizing the need for innovative housing solutions that are resilient, sustainable, and adaptable. It discusses the potential of modular and prefabricated housing as a response to these challenges, outlining their advantages in terms of speed, durability, and cost-effectiveness. Examples from Christchurch and Hawke's Bay demonstrate how such solutions could be tailored to meet New Zealand's specific regulatory and environmental needs.

Furthermore, the chapter underscores the importance of proactive planning, community-led recovery initiatives, and the integration of resilience into housing design. Lessons from international disaster recovery efforts, coupled with local experiences, emphasize the critical role of governance, stakeholder collaboration, and adaptive strategies in enhancing recovery outcomes. By focusing on the intersection of immediate needs and long-term resilience, the chapter lays the groundwork for exploring specific housing innovations, such as double-wing expandable container homes, as a viable post-disaster recovery solution for New Zealand.

CHAPTER 3

RESILIENT HOUSING ALTERNATIVES – CONTAINER HOMES

3.1. Chapter introduction

In light of the increasing frequency and severity of natural disasters, there is a growing demand for innovative, rapid-response housing solutions that are both resilient and sustainable. Among these, shipping container homes have gained traction as a viable alternative, offering robust construction, cost-effectiveness, and quick deployment. By repurposing decommissioned shipping containers, these structures not only address urgent housing needs but also align with environmental sustainability principles by reducing waste.

This chapter investigates the potential of container homes as a transformative solution for post-disaster housing. It examines their performance across diverse global contexts, drawing from case studies such as the aftermath of Hurricane Sandy, the Tōhoku earthquake, and the Haiti earthquake. A comparative analysis of container homes versus traditional housing methods, including timber, steel, and concrete, highlights their advantages in terms of affordability, speed of construction, durability, and eco-friendliness. Furthermore, the chapter explores the challenges and practical considerations of implementing container homes, particularly in regulatory landscapes like New Zealand's, where stringent building codes may pose unique obstacles.

By critically analyzing the successes and limitations of container housing in disaster recovery, this chapter aims to provide insights into their scalability and adaptability as a long-term housing solution. It also contextualizes their relevance to New Zealand's unique disaster recovery needs, setting the stage for further exploration into localized adaptations and innovations.

This chapter also explores the cultural considerations and practical adaptations necessary to align container housing solutions with the unique values, traditions, and needs of Māori communities in New Zealand. As the nation continues to address housing shortages, particularly in rural areas, container homes present an innovative, affordable, and sustainable option. However, to ensure these homes genuinely serve Māori communities, they must be designed with an understanding of Māori perspectives on home, land (whenua), and community (whānau and hapū). By integrating cultural principles such as kaitiakitanga (guardianship of the environment) and manaakitanga (hospitality), and by embracing kaupapa Māori design elements, container homes can evolve from mere housing solutions into culturally resonant spaces that reflect the identity and aspirations of the communities they serve. This chapter also examines successful container home projects across New Zealand, highlighting the versatility and potential of this housing model.

3.2. Research method

In this chapter, a combination of case study analysis, comparative analysis, and qualitative research methods is used to evaluate the role of container homes in post-disaster housing. The primary method is the examination of case studies from various global disasters. These case studies provide insights into the practical applications, challenges, and effectiveness of container homes as temporary housing solutions. The research then compares container homes with traditional post-disaster housing models and prefabricated houses, focusing on key factors such as cost, speed of deployment, and sustainability.

Additionally, a comprehensive literature review is conducted to contextualize the use of container homes within existing post-disaster housing practices and to explore their evolution as a viable solution. The chapter also incorporates qualitative data from interviews and surveys with displaced individuals and relief agencies, examining the social and economic impacts of container homes on affected communities. This multifaceted approach helps provide a thorough understanding of the advantages, challenges, and practical considerations of container homes in disaster recovery.

This chapter also employs a mixed-methods approach to examine how container homes can be adapted to align with the cultural and practical needs of Māori communities. A literature review provides insights into Māori perspectives on home, community, and sustainability. Case studies of notable container housing projects, illustrate the versatility and potential of container homes in New Zealand. Additionally, a cultural analysis of Māori values informs recommendations for integrating traditional principles into contemporary housing designs. Finally, insights from expert consultations with Māori architects, designers, and cultural advisors offer practical strategies for aligning housing solutions with Māori cultural aspirations. This combination of methods ensures a holistic and culturally grounded approach to the topic.

3.3. A resilient solution for post-disaster housing – container homes

Shipping containers are also ideal for use during natural disasters like tornadoes, hurricanes, and floods. Their robust construction allows them to resist crushing pressure and remain intact even under extreme conditions, making them suitable for temporary shelters, hospitals, and other essential facilities when traditional resources are unavailable. Utilizing shipping containers not only provides sturdy shelter but is also eco-friendly, as it repurposes materials that would otherwise contribute to waste. This realization has led many government agencies and relief organizations to adopt shipping containers for disaster response (https://shippingcontainers.co.nz/container-housing-for-disasters/).

3.3.1. Comparison of container homes with traditional housing materials

In a comparative analysis, container homes are seen as more viable alternatives to timber, steel, and concrete homes, especially when it comes to the cost, time of construction, and environmental effects.

3.3.1.1. Comparative cost analysis

When it comes to cost, container homes are usually the least expensive, most often, they use recycled shipping containers as the main building material. Therefore, they are very affordable compared to steel or concrete homes, which are both costly to buy materials for and to hire specialist labor (Onuorah, U. J, 2020). Timber homes can still be more cost-effective than concrete or steel but still tend to be pricier than container homes due to the cost of sustainable, quality wood. Moreover, container houses can be factory-built and module-configured, which gives the designer a choice of the type of building while keeping the construction costs low.

3.3.1.2. Speed of deployment

Deployment times for container homes are significantly faster than the traditionally built homes (Bertram, Nick, et al, 2019). As the containers are prefab, they can be assembled quickly, so it takes only a few weeks to complete. This is in stark contrast to the construction time of concrete houses which need a lot of manual labor on-site and therefore can take several months to complete. Steel homes incorporate some degree of prefabbing prefabrication, and require skilled workers, but the concrete is still the fastest (McNulty, William H, 1970). Timber houses, especially prefab models, are also deployable on a relatively fast basis; their construction is however taking a longer period to complete than container houses due to the need for ample care in material handling and assembling.

3.3.1.3. Durability analysis

In terms of durability, container homes are just as good as the other models. Shipping containers are designed to withstand bad weather, and with proper insulation and rust treatment, they can be extremely durable, especially in terms of structure (Ataei, Mohammad, 2016). Steel houses are stronger and fire-resistant than container houses; however, containers are also made of steel and are just as durable but are much cheaper. Concrete houses are the most durable with fire, weather, and environmental resilience, but the cost of building and time for them to be completed is very high. Timber houses, owing to their vulnerability to fire, pests, and weather, are not usually more durable unless they are treated regularly (Ridout, Brian, 2000).

5.3.1.4. Sustainability analysis

Green Sustainability is another characteristic of container homes (Islam, H., Zhang, et al 2016). The reuse of containers is an eco-friendly way of reducing the carbon footprint as compared to cutting down trees for timber or manufacturing steel and concrete. In addition, containers are highly transportable, modular, and flexible in a variety of environments, which is a versatile feature seldom seen in traditional homes.

To sum up, even steel and concrete houses are more durable, and timber houses are a natural material, a container house is the most economical, quickest, and most ecological in that it is a mix of all the wonderful qualities.

3.3.2. Case studies of container homes in disaster recovery

3.3.2.1. Innovative shipping container housing for disaster preparation: lessons from hurricane Sandy

Fig.10: Shipping containers as disaster relief unit in us after the hurricane Sandy (https://shippingcontainers.co.nz/container-housing-for-disasters/disaster-relief-examples/#1494372602364-f81de985-df9d)

The deadliest and most destructive hurricane of the 2012 Atlantic hurricane season, Hurricane Sandy, affected parts of the Caribbean, Mid-Atlantic, and Northeastern United States in late October 2012. It affected many states and caused extensive property damage in New York and New Jersey, as well as widespread flooding and loss of life. With climate change speeding up, such storms are forecast to become more frequent and even more powerful in the coming years, leading cities to look for new ways to prepare and recover from disasters.

As the incidence of cataclysmic weather events such as Hurricane Sandy increases, cities like Brooklyn have begun to experiment with multi-story emergency housing built from repurchased cargo containers. Their work represents preparation for the next disaster, like Hurricane Sandy.

In Brooklyn, architects and city planners have diverted these containers into three- and four-story housing complexes to provide temporary shelter for displaced residents. The amenities are necessities that every person should have during their recovery, thus the design of each facility to serve as a home away from home. The complexes offer furniture, cooking spaces, shared bathrooms, living areas, and bedrooms in common with other residents to create a community spirit among its tenants.

Such innovative housing solutions not only meet the immediate needs of those affected by disasters — they represent the future of urban planning in a more resilient age. Cities should be incorporating repurposed shipping container homes into their disaster mitigation and preparedness practices instead of generating waste, as we know they can provide safe and quality living options for those in need (https://shippingcontainers.co.nz/container-housing-for-disasters/disaster-relief-examples/#1494372602364-ed09b04c-21d0).

3.3.2.2. Yasutaka Yoshimura's ex-container project: post-disaster housing solution after the 2011 Tohoku earthquake

Fig.11 container project : Yasutaka Yoshimura architects (https://www.archdaily.com/127534/ex-container-project-yasutaka-yoshimura-architects/11-161)

The 2011 Tōhoku earthquake measured magnitude 9.0–9.1 and occurred on March 11, 2011, off the Pacific coast of Japan. It was a megathrust earthquake along the undersea segment of the region resulting in catastrophic damage, and deaths more than ever occurred in Japan. The earthquake set off a series of colossal tsunami waves, as high as 40.5 meters (133 feet) in some places. In the Sendai region, these waves traveled as much as 10 kilometers (6.2 miles) ashore and decimated entire communities in the wake of significant damage to infrastructure and residences.

Immediately after this catastrophic calamity, there was a need for homes on an urgent basis. Using this urgent problem as the compass, Japanese architect Yasutaka Yoshimura led his initiative by offering an innovative response “Ex Container Project”. The project was created as an emergency, low-cost housing solution for those who had been displaced by the catastrophe.

The Ex-Container Project involved redesigning the used shipping containers for housing, capitalizing on their durability and availability. Yoshimura’s design philosophy emphasized practicality and community needs, allowing for the swift construction of shelters that could withstand future natural disasters. By connecting multiple 20-foot by 20-foot shipping containers, the project created different living environments that included kitchens, sleeping areas, and communal spaces.

The container homes were economical and of good quality. Their design was meant to last even in adverse weather, keeping its occupants safe, while comfortable. The units were more easily changed from one thing to the next, with enough flexibility for families or individuals on a case-by-case basis. The freedom afforded by this container system made it attractive for post-disaster temporary housing (https://shippingcontainers.co.nz/container-housing-for-disasters/disaster-relief-examples/#1494372602364-ed09b04c-21d0)

3.3.2.3. Container relief housing: The Caribbean Lodge as a post-disaster solution after the 2010 Haiti earthquake

The 2010 Haiti earthquake, which hit on January 12, was a destructive magnitude 7.0 event that happened approximately 25 kilometers west of Port-au-Prince, the capital of Haiti. This catastrophic earthquake resulted in extensive damage, with at least 52 aftershocks measuring 4.5 or greater recorded by January 24. About three million people were attacked by the quake, leading to a hilarious crisis characterized by the loss of many lives, the destruction of buildings, and a significant scattering of the community.

After the disaster, there was an urgent need for immediate housing options for millions who were left homeless. This situation triggered innovative approaches to disaster relief, mainly in the realm of housing for temporary purposes. One such initiative was the container relief housing, The Caribbean Lodge in Port-au-Prince.

A great example of how space can be used effectively and a room made comfortable due to reclaimed materials after a disaster, such as the Caribbean Lodge Boasting a range of types including Single and Double- with Twin beds, or Twin bunk beds & Private bathrooms. Their design illustrates a responsible way to build durable and flexible shipping container social housing that meets the needs of its residents.

The Caribbean Lodge is easily one of the most well-appointed locations on this list and that alone makes it worth a rental, even in sunny Miami. The hotel has close access to internet facilities, enabling people to stay in touch with their loved ones and even work or study from afar (https://shippingcontainers.co.nz/container-housing-for-disasters/disaster-relief-examples/#1494372627270-4ae21a72-67c6).

3.3.2.4 Steel-modified container homes: a sustainable housing solution after the 2017 Tubbs fire in Santa Rosa

The Tubbs Fire devastated numerous homes in Santa Rosa, California, in 2017, displacing thousands and creating an urgent need for temporary housing solutions. One of the most innovative responses came from Kaikaina Construction, which built a home for a family affected by the disaster using six steel-modified shipping containers (Cameron, Devin C., 2019). This project aimed to provide a fast, durable, eco-friendly, and cost-effective housing solution, leveraging modular construction to address the family's immediate needs.

The resulting 1,600-square-foot home featured three bedrooms and an open floor plan. Designed as a semi-permanent alternative to temporary housing, it enabled the family to leave their relative's home while waiting for their original house to be rebuilt. Additionally, the house was designed for easy disassembly and reinstallation, highlighting the reusability of shipping containers as a sustainable resource for ongoing disaster relief projects.

3.3.2.5 Comparing post-disaster housing approaches: New Zealand's regulatory rigidity vs. global innovations in container housing

In Brooklyn, post-Hurricane Sandy efforts to use shipping containers for housing faced fewer regulations, allowing for fast-tracked, innovative solutions. The flexibility of U.S. regulations enabled these projects to bypass traditional housing rules, responding swiftly to climate-related threats. In contrast, New Zealand has tight building codes focused mainly on resilience to earthquakes, even houses for temporary needs have to meet high safety policies. This regulatory approach, even though it assures long-term stability, slows the deployment of innovative housing options like container homes, thus creating more challenges.

Post-disaster projects like the Ex-Container Project in Japan and the Caribbean Lodge in Haiti utilized shipping containers due to their durability, availability, and adaptability. These steel-modified containers are designed to withstand harsh weather conditions and can be quickly transported and assembled, providing immediate shelter. Additionally, these containers are modular, allowing for easy disassembly and reuse in future disasters, promoting sustainability. New Zealand's existing housing framework is predominantly based on timber and concrete, especially in response to earthquake hazards. Timber construction is lightweight, flexible, and has good seismic performance, making it a popular choice. Concrete, though more robust, is often used for foundations and critical infrastructure. While these materials are durable and well-suited for New Zealand's seismic landscape, they require longer construction times and higher labor costs compared to the prefabricated container models. Additionally, the use of steel containers, as seen in global disaster responses, offers a level of flexibility and rapid deployment that traditional timber and concrete constructions do not.

In disaster-prone areas like Japan and Haiti, the focus on rapid deployment of temporary housing, like Yasutaka Yoshimura's Ex-Container Project, proved critical in providing shelter for displaced communities immediately after a disaster. These solutions prioritized speed and practicality, aiming to restore normalcy and reduce displacement as quickly as possible. New Zealand's housing framework focuses on long-term resilience rather than immediate deployment. Following the Christchurch Earthquake (2011), many temporary housing solutions were timber-framed, with an emphasis on long-term, earthquake-resistant design rather than temporary, quickly deployed shelters. While these solutions provided stability, they lacked the speed and modularity seen in international container housing models.

3.3.3. Research in disaster housing model - a comparative analysis with container homes

Various disaster housing models exist to provide temporary or long-term shelter for victims who lose their homes during a disaster. These models are designed with key priorities in mind, such as quick deployment, cost-effectiveness, and resilience to future disasters. This raises the question: why choose container homes over other disaster housing solutions?

The disaster housing model, as described by Saumyang Patel and Makarand Hastak (2013), offers a strategic framework to enhance post-disaster housing responses. It emphasizes the rapid provision of quality temporary homes, with a goal of constructing 200 houses within 30 days. The model's key elements include pre-disaster planning, response trade-offs, post-disaster execution, simulation, and feedback. However, the framework falls short in detailing established protocols for ensuring rapid housing deployment after a disaster.

In contrast, container homes have demonstrated significant effectiveness in post-disaster scenarios, particularly in countries like New Zealand. After the Christchurch earthquake in 2011, New Zealand adopted container homes as an immediate housing solution for displaced communities. Their prefabricated design facilitated quick deployment, as these homes could be transported and set up in affected areas with minimal time and effort. This practicality, coupled with their durability and adaptability, makes container homes a compelling choice for disaster relief housing.

3.3.3.1. A comparative study of FEMA trailers and container homes in post-disaster housing: lessons from hurricanes Andrew and Katrina

Fig.12. FEMA trailers for Katrina victims (https://www.usatoday.com/story/news/nation/2015/08/28/fema-trailers-brought-shelter-problems-katrina-victims/71342988/)

In 1992, in the South Florida region, Hurricane Andrew struck the land and destroyed around 47,000 homes. Around 3,500 victims were given houses in FEMA trailers located in 12 parks as shelter for temporary use till they were placed at their permanent homes (Saumyang Patel and Makarand Hastak, 2013). Many of the victims faced social and health-related troubles as they lived in those trainers for more than two years. Hurricane Katrina was named the most destructive hurricane in US history where almost 1,800 people lost their lives on the Gulf Coast and thousands of people got displaced to other places in the country (Levitt, Jeremy I., and Matthew C, 2009).

140,000 trailers have been given by FEMA to the regions affected by Hurricane Katrina.

The FEMA trailer users found the positioning of the house unsafe, crowded, and the least attractive. This leads to issues like elevated domestic violence, insomnia, suicide rates, and depression. Due to the toxic atmosphere, the construction materials, the small living space for a joint family, and security conditions, many people have shown post-traumatic symptoms, bronchial problems, and nervous disorders like headache, vomiting, skin rashes, aches, and pain, loss of appetite or overeating, social withdrawal, and isolation. Children avoided schools and showed aggressive behaviors. This forced many people to find an alternative housing option. FEMA trailers used formaldehyde in construction material which caused respiratory and nervous system issues among the inhabitants (Costa, Solange, and J. P. Teixeira, 2015).

Unlike FEMA trailers, which were often criticized for their poor construction materials, container homes are built using steel shipping containers, which are structurally sound and able to withstand extreme weather conditions. They provide a more permanent and secure living solution. Also, Container homes offer flexibility in design and can be used for both temporary and permanent housing. The design could be customized based on the number of inhabitants of a family.

With proper design, container homes offer great ventilation, insulation, and space in comparison to FEMA trailers, making them healthier and more comfortable for long-term habitation. Moreover, Container homes can be prefabricated and shipped to disaster sites, ready for immediate setup, unlike FEMA trailers, which often face delays due to logistical and bureaucratic bottlenecks.

3.3.3.2. Overcoming housing challenges in post-earthquake recovery: lessons from Belice earthquake and the promise of container homes

In 1968, Western Sicily, Italy, was devastated by the Belice earthquake, creating widespread destruction and long-term damage to the housing and infrastructure. The Earthquake sequence with 5 tremors of magnitude 5, destroyed ten villages, 231 people were killed, and more than 100,000 people lost their houses (Davis, Ian, and

David Alexander, 2015). The existing local buildings were random rubble masonry with heavy timber roofs, became highly vulnerable and many of the buildings collapsed completely.

Recovery processes including housing were a big challenge following the earthquake. In the immediate recovery, wooden prefabricated dwellings of 35-40 square meters were given to the victims, but a year later, many people were still living in tents due to inadequate housing supply. A combination of planned and ad-hoc housing options, including prefabricated wooden structures and barracks, were provided, but these solutions were not always practical. For instance, barracks in Gibellina were deserted because they were too far from the fields where the victims worked and later, they were occupied by migrant squatters (Booth, Sally S, 1997).

The reconstruction processes were very slow and it took more than 20 years to complete (Wiskemann, Elizabeth, 1971). In some locations, though new towns and anti-seismic construction methods were introduced, the planning was haphazard, and big, grandiose projects, such as creating avant-garde architectural settlements, were categorized over functional housing needs. For example, the air museum was created by Gibellina, a project that failed to fully meet the housing needs of the victims (Williams, David, 2015).

There were many issues faced by the residents including no adequate shelter for years, impractical location as mentioned above, bureaucratic inefficiency, corruption, and links to organized crime (Davis, Ian, and David Alexander, 2015). Moreover, prolonged displacement caused serious mental health issues including stress, depression, and trauma, and public health risks from inadequate living conditions, sanitation, and lack of healthcare access.

The prolonged and problematic housing crisis could be solved to some extent if the post-disaster housing was by using container houses. In contrast to the used post-disaster housing options in Sicily, usage of the container homes will not take 20 20-year recovery period. This is because the container homes have a high speed of deployment, easily transported and set up, offering quicker housing solutions for the affected communities. Unlike the wooden prefabricated houses and barracks used after the Belice earthquake which are not always durable, the container homes which are made up of sturdy steel offer high durability and can be used in any harsh climatic conditions. Their structural framework ensures a long-term housing option, which is safer, reducing the need for frequent repairs or replacements.

The slow and bureaucratic reconstruction efforts after the Belice earthquake involved significant financial and logistical inefficiencies. The container homes which are prefabricated and modular, are highly affordable and there is low maintenance offered. Once deployed, they can be reused or repurposed, which reduces waste and the overall cost of reconstruction. Container Homes could be placed anywhere based on the resident's need, close to the victim's workplace, and social hubs, addressing the need for proximity and reducing the socio-economic impact of displacement.

3.4. Cultural sensitivity considerations for indigenous communities in New Zealand

Adapting container homes for Māori communities requires a nuanced understanding of their unique cultural values, traditions, and social structures. Māori culture is deeply connected to the land (whenua) and emphasizes the importance of community (whānau and hapū), sustainability (kaitiakitanga), and holistic wellbeing (hauora). As New Zealand continues to face housing shortages, particularly in rural areas, it is important to find innovative and practical solutions that can be tailored to meet the specific needs of Māori. By integrating traditional Māori design elements, fostering communal living, and promoting eco-friendly practices, container homes can serve not only as functional living spaces but also as reflections of cultural identity and community resilience. This approach ensures that the homes are more than just shelter; they embody the values and aspirations of the communities they serve, ultimately contributing to the preservation and revitalization of Māori culture and heritage.

3.4.1. A māori approach to home

The Māori perception of home is deeply rooted in a sense of connection to people and community rather than being tied solely to a physical structure. For Māori, home is not simply a house, but a place where whānau (family) and extended relationships are fostered, making it a space of belonging and safety. Whakapapa, or genealogical ties, play a central role in how Māori understand home. It is a base that connects not only the living but also ancestors and future generations. This idea of home is less about the house itself and more about the relationships and community connections that define it. Participants in the study emphasized that their sense of home is grounded in these non-physical aspects, making home a dynamic and emotionally rich space (Boulton, Amohia, et al. 2022).

The relationship with whenua (land) is another critical aspect of Māori perceptions of home. For Māori, land is not merely a physical location or an economic asset but a fundamental part of their identity and spiritual well-being. The connection to ancestral land holds immense emotional and spiritual significance. Many Māori express a deep attachment to the land that their tūpuna (ancestors) occupied, seeing it as a source of strength and comfort (Hakopa, Hauiti. 2019). This connection to land is considered vital for their sense of place and identity, especially for those living in their tribal areas, where proximity to the land enhances spiritual and physical nourishment. Even for urban Māori, the connection to ancestral land remains a significant part of their identity, though their sense of home may evolve in more fluid, adaptable ways (Rameka, Lesley, 2018).

Home, for Māori, is also associated with safety and belonging (Boulton, Amohia, et al, 2022). This sense of safety extends beyond physical protection and includes emotional and spiritual dimensions. For many, a home is a place where they feel comfortable, accepted, and free to be themselves. It is a space where they can feel a spiritual connection, knowing that their tūpuna are close by, providing a sense of safety that is deeply rooted in their cultural and spiritual practices. The marae, or community centers, and the surrounding environment often contribute to this feeling of safety, making home more than just a dwelling—it is where one feels spiritually secure (Menzies, Diane, et al. 2022).

The cultural dimensions of Māori perceptions of home highlight the importance of cultural practices like manaakitanga (hospitality) and the ability to support extended family during times of need (Moeke-Pickering, Taima Materangatira, 1996). The idea of home for Māori includes the necessity of spaces large enough to accommodate these cultural responsibilities, especially during times of crisis or community gathering, such as funerals or when family members need care. Current housing policies, which focus primarily on physical structures, often fail to account for these cultural needs, making it difficult for Māori to practice their traditions and maintain their sense of home. In this context, the paper suggests that a more holistic and culturally grounded approach to housing and wellbeing is necessary to truly meet Māori housing needs.

3.4.2. Adapting container homes for māori communities: a cultural and sustainable approach

Adapting container homes to meet the needs and values of Māori communities requires a deep understanding of Māori cultural principles, such as a connection to the land (whenua), communal living (whānau and hapū), and sustainability (kaitiakitanga). One of the first steps in this adaptation is incorporating Māori design elements that reflect their cultural identity (Marques, Bruno, Greg Grabasch, and Jacqueline McIntosh, 2021).

Māori architecture, known as kaupapa Māori, often features symbols, carvings (whakairo), and woven designs (raranga) that tell stories and connect people to their ancestors (McRae-Tarei, Jacqueline, 2021). Container homes could incorporate these design motifs in a contemporary way, ensuring that the homes not only serve as functional living spaces but also reflect the cultural heritage of the community. The layout of these homes could be inspired by the traditional wharenui (meeting house), with communal living spaces that support social gatherings, fostering a strong sense of belonging and connection.

Communal living is central to Māori culture, where the values of whānau (family) and hapū (sub-tribe) guide social structures (Nikora, Linda Waimarie, 2007). Container homes can be adapted to support these values by focusing on shared spaces and flexible layouts that accommodate collective living. For example, instead of individual, isolated homes, modular clusters of container homes could be designed to create small communities, where families share common spaces like kitchens, dining areas, and gardens. This approach aligns with the Māori concept of collective responsibility and support.

Additionally, container homes could be designed with intergenerational living in mind, creating spaces that allow elders (kaumātua) and younger family members to live together while maintaining privacy. This supports the transmission of knowledge across generations and ensures that older members of the community are cared for within the family unit.

A key principle in Māori culture is kaitiakitanga, or the guardianship of the natural environment (Kawharu, Merata, 2020). This value emphasizes sustainability and a responsibility to protect the earth. Container homes, by their nature, already align with sustainable practices by repurposing materials and reducing construction waste. However, to truly reflect Māori values, these homes can be further adapted with eco-friendly materials and technologies. For instance, container homes can be outfitted with renewable energy systems like solar panels, rainwater harvesting systems, and composting toilets. This would enable off-grid living, particularly in rural areas, reducing the environmental footprint and supporting the community's self-sufficiency. These measures align with the Māori concept of living in harmony with the environment and caring for the land for future generations.

Marae (meeting grounds) are a vital part of Māori community life, serving as places for ceremonies, celebrations, and gatherings (Bennett, Adrian John Te Piki Kotuku, 2007). Container homes could be adapted to support the functions of marae by providing flexible and expandable spaces that can be used during large gatherings, such as tangihanga (funerals) or hui (meetings).

During these events, container homes could be configured to offer additional accommodation or communal spaces, supplementing the existing marae buildings. The flexibility of container homes also means they can be easily reconfigured for various purposes, including temporary shelters or kitchens, ensuring that the needs of the community are met during significant events. This adaptability would be particularly beneficial in rural areas where housing and infrastructure might be limited.

Affordability is another important consideration for many Māori communities, especially those in rural areas that face economic challenges. Container homes offer an affordable housing solution, as they are generally less expensive to build and can be quickly assembled compared to traditional homes. This cost-effectiveness makes them a viable option for communities looking to address housing shortages or create new developments.

Moreover, by involving local Māori businesses and tradespeople in the construction and design of these homes, the community can also benefit economically. This approach not only helps to build local skills and create jobs but also ensures that the homes are designed with an understanding of Māori cultural values, resulting in spaces that are truly tailored to the community's needs.

Finally, the Māori concept of hauora, or holistic wellbeing, is essential when designing container homes. Māori wellbeing is interconnected, encompassing physical, mental, and spiritual health. To support this, container homes must prioritize healthy living environments. This can be achieved through well-ventilated and well-insulated designs that reduce moisture buildup, a common issue in New Zealand's humid regions. Access to natural light and outdoor spaces would also enhance mental and spiritual well-being, as connection to nature is a key aspect of Māori life. Gardens or green roofs could provide spaces for growing traditional Māori crops or native plants, further connecting the home to Māori horticultural traditions.

3.4.3. Container homes - not a new concept for New Zealand

3.4.3.1. Mountain-view container cabin in Glenorchy

Fig.13 Container retreat in Glenorchy

(https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

Fig.14 View from the bedroom and lounge room

(https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

The recently built Glenorchy Mountain Retreat is less a container home and more a container haven. The small home is made from a single converted shipping container located in the picturesque Glenorchy region of New Zealand. The cabin house has a modern design, featuring large windows that provide breathtaking views of the surrounding mountains.

3.4.3.2. Grand designs container home on Waiheke

Fig.15. A grand design - The exterior of Waiheke's finest container home (https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

Fig.16. The Backyard of Waiheke’s container home

(https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

Featured on a 2022 episode of Grand Designs, this stunning home is a showcase in what can be achieved with the humble shipping container. Designed by architect Chris McCarthy, the home's complex configuration pushed its five 20ft and two 10ft shipping containers' structural integrity to their limits. A home that skilfully blurs the lines between the final modern masterpiece and the industrial containers that ground (https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

3.4.3.3. Iconic container home in Wellington

Fig.17 Iconic container home (https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

Fig.18 Refrigerated container homes converted in cozy living space (https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

Nestled on a rocky outcrop, this iconic Happy Valley container home stands as one of the pioneers in the country. The three-bedroom residence evolved gradually, beginning with a single container in 2003, followed by the addition of a second in 2007, ultimately reaching its current three-level design. Built from refrigerated containers, the 90m2 home is fully insulated and features a spiral staircase, an outdoor shower, a media room, and a waterfall.

6.3.3.4. Off-the-grid container cabin just outside Coromandel town

Fig.19 Stunning location where the off-the-grid container cabin located (https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

Fig.20. A beautiful view from the bedroom ((https://scfcontainers.co.nz/news-articles/shipping-container-homes-in-new-zealand-from-design-to-planning-to-inspiration/)

Just a short drive of less than thirty minutes from Coromandel Town, you'll find the delightful Ahurewa Eco Retreat. Constructed in 2020, this cabin made from a shipping container is completely off-the-grid and self-sufficient. The cozy retreat features a bedroom, a living area with a kitchen, and a bathroom, all harmoniously nestled in the native bush environment.

3.5. Chapter summary

This chapter explores the role of container homes as an innovative, resilient, and cost-effective solution for post-disaster housing. By analyzing global case studies, including the aftermath of Hurricane Sandy, the 2011 Tōhoku earthquake, and the 2010 Haiti earthquake, the chapter illustrates the practicality and adaptability of container homes in addressing urgent housing needs. These examples demonstrate container homes' rapid deployment, durability, and sustainability, making them an effective alternative to traditional housing models.

Through a comparative analysis, the chapter highlights the advantages of container homes over conventional materials like timber, steel, and concrete, particularly in terms of affordability, construction speed, and environmental benefits. Unlike FEMA trailers and other temporary housing options, container homes are shown to provide superior structural integrity, design flexibility, and reusability, making them suitable for both short-term relief and long-term recovery efforts.

This chapter contextualizes the Māori concept of home, emphasizing its strong ties to community, land, and spiritual wellbeing. It highlights the cultural, emotional, and social dimensions that define a Māori home, demonstrating the importance of designing housing solutions that reflect these values.

The discussion then transitions to practical considerations for adapting container homes to Māori needs. Recommendations include the incorporation of traditional design elements, flexible layouts for intergenerational and communal living, and eco-friendly features that align with kaitiakitanga principles. Examples of successful container housing projects further underscore the adaptability and potential of this housing model to serve Māori communities.

Finally, the chapter reflects on the broader implications of culturally sensitive housing solutions, emphasizing their role in preserving Māori heritage, fostering community resilience, and promoting sustainable living. By combining innovation with cultural respect, container homes can offer a transformative approach to housing that meets both functional and spiritual needs.

CHAPTER 4

A NEW VERSION OF CONTAINER HOMES

4.1. Chapter introduction

This chapter explores foldable and expandable container homes as an innovative housing solution, particularly for post-disaster recovery in New Zealand. These structures, made from prefabricated galvanized cold steel, provide rapid deployment, cost-effectiveness, and modular adaptability, making them suitable for addressing temporary and transitional housing needs. Hebei JiaCheng's double-wing foldable container homes are analysed as a convenient product for this research, focusing on their thermal performance, seismic resistance, modularity, weather resistance, sustainability, and affordability.

The chapter evaluates the potential of these homes to meet New Zealand's unique environmental, regulatory, and societal needs, especially in the wake of disasters like Cyclone Gabrielle in Hawke's Bay. It also addresses key regulatory challenges, including compliance with New Zealand's building codes, resource consent processes, and uniformity across councils. Drawing on international case studies, the chapter outlines how container homes can contribute to resilient, sustainable, and affordable housing recovery solutions in disaster-affected regions.

4.2. Research method

This study employs a mixed-methods approach to assess the viability of double-wing foldable and expandable container homes as post-disaster housing solutions in New Zealand. It begins with an extensive review of the literature on container homes, prefabricated housing, and post-disaster recovery strategies, focusing on structural performance, thermal insulation, environmental sustainability, and adaptability. International case studies, such as container housing projects implemented after major disasters, are analysed to extract insights into their effectiveness and challenges in rapid deployment and long-term use. These are contextualized within the specific conditions and needs of New Zealand, particularly in areas like Hawke's Bay, which was significantly impacted by Cyclone Gabrielle.

The research also incorporates a detailed compliance assessment of container homes against New Zealand's building code and regulatory requirements, covering aspects like seismic and wind resistance, durability, fire safety, and energy efficiency.

Collaboration with an engineer provides critical data on structural performance, while additional research explores thermal performance, insulation, and other factors. To further validate findings, consultations with industry experts, local authorities, and community stakeholders help identify practical challenges and regulatory barriers. This approach ensures a comprehensive evaluation of container homes, emphasizing their cost-effectiveness, resilience, and adaptability as a post-disaster housing solution.

4.3. Foldable cum expandable container homes

A folding container house is a new type of residential building (Pérez-Valcárcel, Juan, et al, 2024). It is an improvement based on ordinary prefabricated houses. It adopts a foldable design and can be quickly unfolded when needed to provide a temporary housing solution. On average, installing a folding container house takes only five minutes. The proposed solution is a prefab house concept using cold steel to address post-disaster housing requirements in New Zealand, the double-wing foldable and expandable container homes made of galvanized cold steel, which is a Hebei JiaCheng Product from China. These structures could be rapidly deployed and assembled, providing temporary or transitional housing in the aftermath of a disaster. The modular and prefabricated nature of these container homes may align with the need for efficient and resilient post-disaster reconstruction. The foldable container design offers several critical benefits that address New Zealand's unique environmental challenges, but we need to analyze to what extent they align with the compliance.

4.3.1. Thermal performance of foldable and expandable container homes

One of the primary advantages is its thermal performance, which can be tailored to New Zealand’s diverse climate. The design allows for increased insulation, utilizing modern materials such as spray foam or vacuum-insulated panels to minimize heat loss in colder regions and prevent overheating in warmer areas. Additionally, passive solar design can be incorporated, maximizing solar heat gain in winter and limiting it in summer. This improves energy efficiency and reduces reliance on heating or cooling systems, which is particularly beneficial for the country’s temperate climate.

Hebei Jiacheng’s foldable and expandable containers use high-quality insulation materials designed to maintain comfortable internal temperatures. The walls of their modular homes feature thick, insulated panels, such as the 75 mm panels used in their houses, which help in heat retention and protection against cold temperatures. This makes the homes energy-efficient, reducing reliance on heating and cooling systems, important in areas like New Zealand where both cold winters and mild, temperate climates exist. However, a detailed analysis is needed to check the compliance of the model in New Zealand.

4.3.2. Seismic resistance of foldable and expandable container homes

New Zealand is situated in an active seismic zone, and the foldable container’s seismic resistance is another crucial benefit. The rigid steel structure of shipping containers, made from corten steel, is highly durable and capable of withstanding significant seismic forces. These containers can be designed with flexibility, allowing them to absorb rather than resist seismic energy, reducing the risk of structural damage. Anchoring the containers to reinforced foundations further enhances their stability, making them an ideal choice in earthquake-prone areas like Wellington or Christchurch. The lightweight and compact nature of these homes also makes them less vulnerable to collapse during seismic events, enhancing safety for residents.

Hebei Jiacheng's foldable and expandable containers use light steel frames and advanced assembly methods, such as galvanized high-strength steel components, making them highly resistant to earthquakes, a critical feature given New Zealand's seismic activity. The buildings employ a "cage structure," ensuring flexibility and durability under seismic load, minimizing potential damage. However, a thorough analysis is required to assess the model's compliance with New Zealand standards in terms of seismic resistance.

4.3.3 Modularity and expandability of foldable and expandable container Homes

The modularity and expandability of foldable containers are especially useful for meeting New Zealand’s housing needs in remote or difficult-to-access areas. These homes can be transported in compact form, making delivery to rugged or disaster-affected regions more cost-effective. Once on-site, they can be quickly expanded to provide immediate shelter. The flexible floor plans allow homeowners to adapt the space according to their needs, which is important in both urban and rural settings. In addition, containers can be stacked to create multi-level housing, offering a solution to increase density in urban areas or make efficient use of small plots of land.

The foldable and expandable nature of Hebei JiaCheng's home allows rapid deployment and adaptability in different locations, aligning with New Zealand's need for versatile housing solutions in disaster recovery or temporary setups. These homes can be quickly assembled or expanded on-site with minimal environmental impact, as they are prefabricated, minimizing waste. The modular design also permits various configurations, such as combining units for larger spaces or stacking them for efficient land use, which is beneficial in areas with space constraints or diverse terrain

4.3.4. Weather resistance and durability of foldable and expandable container homes

Weather resistance and durability are also significant strengths of foldable container homes. In a country exposed to heavy rainfall, strong winds, and flooding, the waterproof and wind-resistant nature of these structures is advantageous. The corten steel construction is highly resistant to corrosion, which is particularly important in coastal areas where salt-laden winds can degrade other building materials. These homes can also be elevated on platforms, reducing the risk of flood damage, a key consideration for regions prone to rising waters or storm surges.

The Hebei JiaCheng homes are designed to resist harsh weather, with reinforced materials and water-resistant features such as widened gutters and sealed connections to prevent water leakage and wind damage. This makes the design well-suited to New Zealand's frequent storms and heavy rainfall. The materials used, including galvanized steel and high-strength corrugated iron, contribute to the long-term durability of these buildings. With proper maintenance, these structures can last for over 30 years, making them a reliable solution for both temporary and long-term housing needs. A comprehensive analysis is essential to evaluate the model's durability and weather resistance in line with New Zealand's regulatory standards.

4.3.5. Sustainability of foldable and expandable container homes

Foldable container homes align with New Zealand's commitment to sustainability. The use of recycled shipping containers reduces the demand for new building materials and decreases construction waste. These homes can also be equipped with off-grid technologies, such as solar panels and rainwater harvesting systems, making them ideal for remote locations where infrastructure may be limited. This eco-friendly approach to housing supports New Zealand's environmental goals while offering practical solutions for resilient, sustainable living spaces.

The foldable and expandable container homes of Hebei Jiacheng are designed with sustainability in mind, using recyclable materials like steel and environmentally friendly insulation. The production process minimizes waste, and the modular nature allows for reusability, reducing the environmental impact of construction and demolition.

4.3.6. Affordability of foldable and expandable container homes

Foldable and expandable container homes offer an affordable solution for various housing needs, particularly in post-disaster recovery, due to their cost-effective materials and construction methods. One of the primary factors contributing to their affordability is the use of recycled shipping containers. These containers are widely available and relatively inexpensive compared to traditional building materials like bricks, concrete, and steel. Since shipping containers are mass-produced with standardized dimensions, they allow for uniformity in design, which reduces material waste and speeds up construction processes. Moreover, the use of durable steel in these containers ensures long-lasting structures with minimal maintenance costs, further enhancing affordability over time.

Labor costs are another area where these homes offer savings. Many foldable and expandable container homes are prefabricated in factories, allowing for greater production efficiency. Prefabrication means that much of the labor-intensive work, such as electrical wiring, plumbing, and insulation, is completed off-site in a controlled environment. This reduces the need for skilled labor at the construction site, which significantly cuts down on labor expenses. Additionally, the modular nature of these homes means they can be assembled quickly, often within a few days, compared to the weeks or months required for traditional home construction. This rapid assembly is especially valuable in emergency housing situations, where speed and cost control are essential.

Another major factor contributing to the affordability of container homes is the reduced need for extensive foundation work. Shipping containers are designed to be structurally strong and self-supporting, which allows them to be placed on simpler, less expensive foundations. In many cases, these homes can be set on lightweight foundation systems, such as concrete piers, which are quicker and cheaper to install than the deep foundations required for conventional homes. This not only saves on material costs but also reduces the amount of heavy machinery and labor needed to prepare the building site. Together, these elements make foldable and expandable container homes a highly cost-effective housing solution for both individuals and communities in need of affordable and rapidly deployable living spaces.

The cost efficiency of Hebei JiaCheng's foldable and expandable container homes is one of its primary benefits. With reduced on-site labor, quick installation, and minimal waste, these buildings provide a more affordable solution compared to traditional construction methods. The structures also save on transportation costs, as multiple units can be packed and transported compactly. However, a comprehensive analysis is essential to evaluate the foundation stability and ensure the model's compliance with New Zealand's regulatory standards.

4.3.7. Post-disaster recovery and rapid deployment

In the wake of a natural disaster, New Zealand's remote and earthquake-prone regions may require rapid, temporary, or even permanent housing solutions. Quick Deployment makes foldable containers to set up quickly after an event like an earthquake or flood. Their ability to fold flats for transport and expand on-site means that affected communities can have functional homes in a short amount of time. They are reconfigurable for Emergency Use. The modular design allows for easy reconfiguration such as emergency shelters, clinics, or communal spaces, providing not only homes but also essential services to communities during recovery efforts (Ashfaq, Aashir. 2023).

4.4. Foldable and expandable containers for Hawke’s Bay housing recovery after cyclone Gabrielle

Container Homes have proven to be an efficient solution for temporary and long-term housing in disaster recovery contexts due to their durability, cost-effectiveness, and rapid deployment. Following disasters such as Hurricane Sandy in the U.S. and the 2011 Tōhoku earthquake in Japan, container homes were deployed as immediate housing solutions, providing shelter and essential facilities for displaced communities. These homes often repurposed from existing shipping containers, are designed to withstand extreme weather conditions, making them highly suitable for disaster-prone areas like Hawke's Bay.

The key advantage of foldable and expandable containers lies in their modularity. These units can be transported flat, reducing logistical challenges, and then expanded on-site to create spacious and functional living environments. With the capacity to include bedrooms, kitchens, and communal spaces, container homes can meet the diverse needs of families affected by disasters. The modular design also allows for future scalability, enabling units to be reconfigured or expanded as necessary, thus providing flexibility for both temporary and permanent housing needs. The detailed evaluation will help to determine if the model can be effectively implemented within New Zealand's building codes and council regulations.

4.4.1. Case studies in post-disaster housing: global lessons for Hawke’s Bay

The effectiveness of container homes in post-disaster recovery has been demonstrated in several international case studies. In the aftermath of Hurricane Sandy, Brooklyn city planners utilized shipping containers to build multi-story emergency housing complexes. These units were designed to provide all necessary amenities while creating a sense of community among displaced residents. The rapid deployment of these container homes helped mitigate the housing crisis, offering a model for future urban disaster recovery.

Similarly, after the 2011 Tōhoku earthquake in Japan, the *Ex-Container Project* led by architect Yasutaka Yoshimura provided a timely and cost-effective housing solution for displaced populations. By redesigning used shipping containers, the project delivered durable, low-cost homes that were able to withstand future natural disasters. These container homes were quickly deployed, offering safe and comfortable living environments for those affected. The success of this project highlights the adaptability of container homes in disaster recovery, a lesson that can be applied to Hawke's Bay.

4.4.2. Benefits of container homes for housing recovery in Hawke's Bay

The advantages of foldable and expandable container homes for Hawke's Bay housing recovery are numerous. One of the most significant benefits is the speed of deployment. In contrast to traditional housing methods, which can take months or even years to complete, container homes can be assembled within weeks, providing an immediate solution to the displacement crisis following Cyclone Gabrielle. The prefabricated nature of these units reduces the need for skilled labor on-site, thus minimizing construction time and costs.

Another crucial benefit is durability. Container Homes are designed to withstand extreme conditions, including high winds, floods, and seismic events, making them particularly suited to the environmental challenges faced in New Zealand. By using container homes, Hawke's Bay can reduce the likelihood of future housing damage during natural disasters, thus enhancing community resilience. Furthermore, the use of steel shipping containers ensures that these homes are highly durable, requiring minimal maintenance and repairs over time.

The environmental sustainability of container homes also aligns with New Zealand's commitment to reducing carbon emissions and promoting eco-friendly practices. By repurposed existing materials, container homes minimize the environmental impact of construction. Additionally, foldable and expandable containers can be equipped with renewable energy systems, such as solar panels and rainwater harvesting, contributing to sustainable living practices in disaster recovery contexts.

Cost is a major consideration in post-disaster housing recovery, and container homes offer a more affordable alternative to traditional construction methods. The use of recycled shipping containers significantly reduces material costs, and the modular nature of these homes allows for factory-based prefabrication, which further lowers expenses. This is particularly important for communities like Hawke’s Bay, where budget constraints may limit the scale and speed of housing recovery efforts.

Moreover, foldable and expandable container homes offer long-term benefits. Their modular design enables easy reconfiguration, allowing them to serve as temporary shelters in the immediate aftermath of a disaster and be repurposed for permanent housing or other community functions over time. This flexibility ensures that container homes remain an asset to the community, even after the initial recovery phase has passed.

However, a comprehensive analysis is essential to evaluate the model's compliance with New Zealand's regulatory standards. This assessment will need to consider various aspects, including structural integrity under local seismic and wind loads, durability, thermal insulation, energy efficiency, and fire safety. Additionally, understanding how the model meets specific requirements for different climate zones and hazard categories, such as flood resilience, is crucial for its viability in New Zealand's unique environment. This detailed evaluation will help determine if the model can be effectively implemented within New Zealand's building codes and council regulations.

4.5. Regulatory barriers for foldable and expandable container homes in New Zealand

While container homes and other prefabricated solutions offer significant advantages, such as affordability, sustainability, and rapid construction, a range of regulatory, logistical, and social barriers must be addressed for their successful implementation in New Zealand. Building codes, consent processes, zoning regulations, financial challenges, public perceptions, logistical constraints, and environmental compliance are all critical factors that builders and developers must navigate. Collaboration among builders, designers, local councils, and communities will be essential to effectively tackle these challenges, paving the way for innovative housing solutions that can help address New Zealand's housing needs. By fostering an environment of cooperation and open dialogue, it may be possible to overcome these barriers and unlock the full potential of container homes in the housing market.

4.5.1. Inconsistent treatment across districts: a key barrier to prefabricated housing

The implementation of prefabricated housing solutions, including container homes, in New Zealand faces several significant barriers due to existing legal frameworks, building codes, and consent processes like PS1/PS2 consents. One of the primary challenges is the inconsistency in how prefabricated housing is treated across different regions. While 84% of district plans in New Zealand do not impose additional barriers to prefabricated housing, the remaining 16% apply different rules (Gurran, Nicole, 2011). These rules often treat prefabricated homes in the same category as relocated buildings, which triggers extra resource consent requirements. Originally, relocated building rules were designed to address issues with older buildings being moved onto new sites, such as potential structural degradation or aesthetic concerns. However, these rules are now applied to new prefabricated homes, which creates unnecessary regulatory burdens. This inconsistent treatment of prefabricated housing, depending on the district, poses a barrier to the widespread adoption of prefabricated and container homes (Kennerley, T. 2021).

4.5.2. Resource consent delays: a detriment to prefabricated housing

The resource consent process itself presents a barrier in regions where additional permissions are required for prefabricated housing. For instance, in Palmerston North, obtaining resource consent for prefabricated homes requires a deposit and a bond, along with a waiting period of up to 20 working days for approval. While these costs and delays may seem modest, they create a deterrent for developers and potential homeowners. In comparison, non-prefabricated homes in the same areas are not subject to these additional costs or time delays, making traditional construction methods more appealing. Even though prefabricated homes are supposed to offer cost and time savings through off-site construction, these advantages are often diminished by the additional legal requirements and the resource consent process, thus discouraging investment in prefabricated housing (Kennerley, T. 2021).

4.5.3. Complex compliance with building codes and PS1/PS4 consents

The building codes and PS1/PS4 consent requirements for prefabricated housing add another layer of complexity. Prefabricated homes are typically built off-site and then transported to the final location, which introduces logistical challenges when it comes to compliance with local building codes. PS1 and PS4 consents, which deal with structural design and performance standards, are necessary for any type of construction in New Zealand. However, with prefabricated homes, demonstrating compliance at both the factory stage and the installation stage can be more difficult. Local building officials may require additional inspections and documentation to ensure the homes meet specific site conditions, adding time and cost to the process. This can complicate what should be a streamlined approach to construction and result in developers or homeowners facing delays in getting prefabricated homes approved (Kennerley, T. 2021).

4.5.4. Lack of uniform regulations across councils

Another significant issue is the lack of uniform regulations across different councils. While some district plans treat prefabricated homes like any other type of housing, others have specific rules that create extra barriers. For example, some councils apply relocated building rules to prefabricated homes, even though the two types of structures are fundamentally different. Prefabricated homes are new constructions, whereas relocated buildings are typically older structures being moved to a new site. The lack of a standardized approach across New Zealand’s councils creates uncertainty for developers and discourages innovation in prefabricated housing solutions. In regions where additional resource consent requirements exist, the process can be more costly and time-consuming, further complicating the adoption of prefabricated homes.

4.5.5. Regulatory reforms and standardization: key to expanding prefabricated housing like container homes

To overcome these barriers, regulatory reforms and improved communication between the building sector and local councils are necessary. One of the key suggestions for improvement is to streamline the resource consent process, particularly in regions where unnecessary regulations are imposed on prefabricated housing. This could include revising district plans to remove the application of relocated building rules to prefabricated homes in general residential zones. For councils that unintentionally require additional consents for prefabricated homes, updating these plans to reflect the nature of modern prefabrication techniques would help reduce these obstacles. Additionally, ensuring greater national consistency through the adoption of standard definitions for prefabricated homes could help create a more predictable and supportive environment for this housing sector. Such measures would help reduce the unintended regulatory barriers currently limiting the uptake of prefabricated solutions like container homes across New Zealand.

4.6. Chapter summary

This chapter provides a comprehensive evaluation of foldable and expandable container homes as a potential solution for housing recovery in New Zealand. The modularity and expandability of these container homes enhance their practicality, allowing for compact transportation and customizable configurations, making them especially suitable for deployment in remote or space-constrained locations. Additionally, the cost-effectiveness of these homes is highlighted, with prefabrication and efficient use of recycled containers significantly reducing construction expenses, making them an affordable option for post-disaster housing recovery.

However, the chapter also identifies several regulatory challenges that hinder the widespread adoption of these housing solutions. These include inconsistencies in how prefabricated housing is treated across different districts, delays in resource consent processes, and difficulties in demonstrating compliance with local building codes. Recommendations to address these issues focus on streamlining regulatory processes and standardizing definitions, which would facilitate broader adoption and utilization of container homes. By addressing these factors, foldable and expandable container homes could present a promising, sustainable, and compliant solution for housing recovery in disaster-prone regions like Hawke’s Bay.

CHAPTER 5

DOUBLE-WING EXPANDABLE CONTAINER HOMES: DESIGN, APPLICATIONS, AND COMPLIANCE

5.1. Chapter introduction

This chapter delves into the innovative design and practical application of double-wing foldable and expandable container homes as versatile solutions for housing needs, particularly in disaster recovery scenarios. The chapter examines the structural design, material specifications, compliance with building codes, and environmental adaptability of these modular housing units. By exploring their durability, cost-efficiency, and sustainability, this analysis highlights their potential to address housing shortages in diverse contexts, with a focus on regulatory and market considerations.

5.2. Research methods

The research methods used in this chapter focus on a multifaceted approach to analyzing double-wing expandable container homes. A detailed examination of the products manufactured by Hebei Jiacheng Integrated Housing Co., Ltd. serves as a foundation, offering insights into their design, specifications, and practical applications. This includes an in-depth review of the technical documentation provided by the manufacturer, such as structural calculations, certifications, and producer statements. These documents were essential in understanding the compliance of the container homes with both local and international building standards, including the New Zealand Building Code and ISO 9001.

The analysis also incorporates a regulatory review, evaluating how these container homes meet structural, fire safety, thermal, and environmental performance standards. Comparative assessment techniques were employed to analyse key material performance metrics such as heat insulation, fireproof grading, and seismic and wind resistance. Additionally, the research evaluates design features like customization options, mobility, and foundation adaptability, linking these aspects to site-specific requirements and usability in diverse climatic conditions.

5.3. Hebei Jia Cheng integrated housing co., ltd - The Manufacturer

Fig.21 The company - Hebei JiaCheng, China
(https://www.jiachenghouse.com/aboutus/1.html)

Hebei Jiacheng Integrated Housing Co.,LTD was established on December 22, 2021, with its headquarters located in the economic development zone of Fucheng County, Hengshui City, Hebei Province. Its subsidiaries include Beijing Huayu Risheng Steel Structure Co., LTD, Shanxi Huayu Risheng Steel Structure Co., LTD, Shanxi Huadong Prefabricated Housing Co., LTD. Hebei Jia Cheng Integrated Housing is a steel structure construction engineering technology enterprise that integrates scheme design, production, sales, installation, maintenance, and upkeep. The company has a complete set of production facilities such as an independent molding workshop, automatic welding workshop, automatic colour plate production workshop, and general assembly workshop. The organization gradually established a sales service center centered on Hebei and radiating the whole country. They provide a safe, eco-friendly, intelligent, and comfortable combined building space, adhering to the corporate vision of leading global convenience and green houses and creating quality life.

Fig.22 The factory unit - Hebei JiaCheng Integrated Housing
(https://www.jiachenghouse.com/factory_equipment/1.html)

The company has an industry- leading professional research and development team, design center, advanced manufacturing capacity and strong production capacity to meet the needs of the customers. The company has various production and installation experiences, equipped with corresponding special equipment and a stable team of skilled workers, which can meet the installation and construction needs of multiple regions at the same time. According to the “one belt, one road” proposed by the state, the international center is specifically established, and its products are exported to Europe, Africa, Southeast Asia, North America, South America, Australia, and the Middle East.

A large number of building components are produced and processed in the workshop. The types of components mainly include exterior wall panels, interior wall panels, laminated plates, balconies, air conditioning panels, stairs, precast beams, precast columns, and many more. A large number of assembly operations on site are greatly reduced compared with the original cast-in-situ operations. The company adopted integrated design and construction of architecture and decoration. Ideally, the decoration can be carried out simultaneously with the main construction. With high standardization in the design, the components have more standards, the production efficiency is higher, thus the corresponding cost will be less. With digitalization, the performance of the whole prefabricated building will be higher. The produced container homes meet the requirements of green building.

5.4. Double-wing foldable and expandable container homes - Hebei JiaCheng’s product

Fig.23 Double-wing foldable and expandable container home (https://www.jiachenghouse.com/products_details/25.html)

The double-wing expansion house is also called the double-wing folding house. They are made up of galvanized high-strength square pipe, galvanized angle iron, and other light steel materials as the frame, and the anti-corrosion double-sided colour steel composite plate is used as the wall. The frame uses high-strength hinges for steel connections. After reasonable design, it has expanded nearly three times. Expanded houses of 20 feet and 40 feet can be made, which can also be customized according to the customer’s needs.

A basic folding house is composed of top frame assembly, bottom frame assembly, corner column, and server interchangeable wallboards. Modular design concepts and production technology are adopted to modularize a box house into standard parts, which can be assembled or hoisted to the site. The product adopts special cold-formed galvanized steel components. The enclosure and the thermal insulation materials are made up of non-combustible materials. Plumbing and electrical units are prefabricated in the factory and are assembled on-site.

The folding part of the house contains a special hinge connection with a plastic gasket to fold and protect the rain leakages through the connection. They can be folded repeatedly and recycled and meet the emergency living standard. The product has a life span of more than 30 years with an A grade in fire protection and has anti-seismic resistance of Grade 10, wind resistance is ≥120 KM/Hour and 99.99% waterproof, 0.506317W/(m^2·K) of heat insulation, ≥30 DB OF sound resistance. The foundation has low geological requirements and can still meet the requirements of structural design safety in places with poor geological conditions.

Table 1 General specifications of double-wing foldable and expandable container home (https://www.jiachenghouse.com/products_details/25.html)

FACILITIES	**VALUES**
LIFE SPAN	More than 30 years
EARTHQUAKE RESISTANCE	Grade 10
HEAT INSULATION	0.506317W/(m^2·K)
ROOF LIVE LOAD	≥1.0KN/㎡
FIREPROOF GRADE	A
WATER PROOF	99.9999%
SOUND RESISTANCE	≥30DB
WIND RESISTANCE	≥120 KM/Hour
FLOOR LIVE LOAD	≥2.5KN/㎡

5.5. A guide to choosing foldable cum expandable container houses

Expandable container houses have gained popularity for their innovative design, flexibility, and sustainability. Based on the customers' needs, choosing the right expandable container house involves careful consideration of various factors. There is a comprehensive which will assist in navigating the selection process.

5.5.1. Purpose and intended use

When deciding on the main purpose of an expandable container house, it’s essential to clarify whether it will be used as a residential dwelling, commercial space, or for industrial purposes. Each of these uses has distinct requirements, and the design should align with those needs:

Residential Dwelling: If the container house is for living purposes, the focus will be on creating a comfortable, functional home environment. This includes features like insulation for temperature control, plumbing, electrical systems, windows for natural light, and possibly modular interior layouts. Also consider aesthetics and how well the design fits into its surrounding environment. Expanding sections can create additional living space, such as bedrooms or living areas.

Commercial Space: For businesses, the design would focus more on flexibility, accessibility, and functionality. Depending on the business type, the layout might include open workspaces, customer areas, meeting rooms, or storage areas. Expandable sections could create more room for office work, retail displays, or service areas. Durability, branding, and efficient use of space would be key considerations.

Industrial Setup: If the container house will be used in an industrial setting, the design may prioritize strength, storage capacity, and ease of transport. It might be used as an on-site office at construction sites, storage for equipment, or temporary housing for workers. Expandable designs could provide extra workspace, equipment storage, or even temporary housing for employees. In this context, the container should be highly durable, weather-resistant, and easy to deploy in different environments.

Understanding the primary purpose helps ensure that the expandable container house is optimized for intended use, whether that’s comfort for residents, functionality for businesses, or ruggedness for industrial applications.

5.5.2. Size and configuration

When planning for an expandable container house, it's important to evaluate whether a single expandable module will meet the customer’s needs or if a multi-module configuration would be more practical. Here's a deeper look into these aspects:

5.5.2.1. Single expandable module vs. multi-module configuration

- Single Expandable Module: A single module may be sufficient if users need a compact, cost-effective solution for a small space, such as a tiny home, office, or temporary setup. It can expand horizontally to create additional space for a living room, bedroom, or workspace, depending on the intended use. The simplicity of a single module offers advantages such as ease of transport, faster setup, and lower costs. However, it may have limitations in terms of space and customization, especially for more complex needs.
- Multi-Module Configuration: A setup with multiple interconnected modules offers greater flexibility and more room for customization. These modules can be arranged in various configurations, such as side by side, stacked vertically, or in an L-shape, depending on the user's available space and intended layout. A multi-module design is ideal if the customer requires larger living or working areas, such as for a family home, a larger office space, or an industrial setup. Additionally, it allows for the integration of different functional zones, such as separating sleeping, working, and common areas. Multi-module setups provide more design options and scalability but come with higher costs, more complex logistics, and potentially longer installation times.

5.5.2.2. Expandable dimensions: horizontal, vertical, and multi-directional expansion

- Horizontal Expansion: Most expandable container houses are designed to expand horizontally, with sections extending outward to create additional floor space. This type of expansion works well in areas where there is plenty of ground space available, such as open plots, rural settings, or construction sites. Horizontal expansion increases the width and length of the container, creating larger interior rooms, wider hallways, or open-plan areas. It’s a great option for living rooms, bedrooms, or office spaces where more lateral space is needed for comfort and functionality.

- Vertical Expansion: Some container homes are designed to expand vertically, allowing for additional floors or a loft-style setup. Vertical expansion is ideal for urban or densely populated areas where ground space is limited. This design creates multi-level living or working areas, with floors dedicated to different functions—such as bedrooms upstairs and living or working spaces below. Vertical expansion is also suitable for industrial or commercial applications where stacking containers can maximize the use of vertical space, such as creating multiple levels of office space or storage.
- Multi-Directional Expansion: Advanced designs offer multi-directional expansion, where sections can extend both horizontally and vertically, providing maximum flexibility. This type of design allows for a more dynamic and spacious layout, with the ability to create separate areas for different uses. Multi-directional expandable container houses can be ideal for larger homes, commercial properties, or industrial spaces where maximizing both the width and height is crucial. However, these designs are often more complex to build and install and may require specialized equipment or expertise.

5.5.2.3. Choosing the right configuration for particular space

- Available Space: Assess the size and shape of the area where the container house will be placed. If the user has a wide-open plot, horizontal expansion might be the easiest solution. For narrow or restricted spaces, vertical expansion could be a better choice. Multi-directional expansion may work well in larger, less constrained areas where both height and width can be optimized.
- Specific Spatial Needs: Consider what the space will be used for. For instance, if the container house will serve as a family home, the user may want separate bedrooms and living areas, which could be achieved through horizontal expansion. If it’s an office or retail space, the customer might prefer a multi-module or vertical setup to maximize usable square footage without expanding the building’s footprint.

Understanding the right configuration—whether single or multi-module—and how the container house can expand (horizontally, vertically, or both) will help to choose the best design to meet the specific needs. Each option has its pros and cons, so aligning the design with available space and intended purpose is essential for optimal functionality and comfort.

5.5.3. Material and construction

When evaluating the quality of materials used in the construction of an expandable container house, you are making a long-term investment in durability, safety, and comfort. Let's break down the key aspects you should focus on:

5.5.3.1. Material quality: structural integrity and longevity

- High-Quality Steel: The foundation of most container houses is the steel frame, which forms the core structure. High-quality, corrosion-resistant steel is essential for ensuring the structural integrity and longevity of the expandable container house. Steel provides strength, making it highly resistant to external forces like wind, pressure, and heavy loads. For an expandable container home, the steel should be flexible enough to withstand the movements required for expansion but robust enough to remain stable in both expanded and retracted states. Look for houses made from *w*eathering steel, Corten steel, Cold formed steel which is specifically designed to resist rust and degradation in harsh environments.
- Durable Finishes: The finish on the exterior and interior surfaces plays a significant role in the overall durability of the container house. High-quality paint coatings, for example, help protect the steel from rust, moisture, and ultraviolet (UV) radiation. Anti-corrosive treatments, as well as waterproofing materials, are critical for longevity, especially if the container house is in areas prone to heavy rainfall, snow, or coastal salt exposure. Additionally, exterior finishes such as composite panels or fiber cement can further protect the structure while also providing better insulation and fire resistance.
- Weather Resistance: The materials used must be capable of withstanding local environmental conditions. In regions with extreme weather—whether it's heavy rains, snowfall, high humidity, or strong winds—ensuring that the materials are weather-resistant is crucial. Seals around windows, doors, and expandable sections should be waterproof and airtight to prevent leaks or drafts. Look for

weather-stripping, high-quality sealants, and rust-proof joints to guarantee that the house remains secure in varying climates.

5.5.3.2. Weather resistance and exposure to harsh conditions

- Roofing: The roof of an expandable container house must be designed to handle heavy rains, snowfall, and intense sunlight. Metal roofing with protective coatings or specialized roofing materials like thermoplastic polyolefin (TPO) or ethylene propylene diene terpolymer (EPDM) can provide excellent weather resistance. These materials are not only durable but also highly resistant to UV radiation, which helps prevent the roof from deteriorating under intense sunlight. Additionally, ensure that drainage systems are well-designed to prevent water from pooling on the roof, especially if the house expands horizontally and creates new rooftop surfaces.
- Windows and Doors: Double-glazed windows and well-insulated doors help maintain indoor temperatures and can also contribute to overall weather resistance. Double glazing offers enhanced protection against heat loss in cold climates and heat gain in hot regions opt for windows and doors with weatherproof seals to prevent drafts, moisture penetration, and potential damage from strong winds.

5.5.3.3. Insulation properties: ensuring comfort and energy efficiency

Insulation is a critical aspect of container houses, particularly since steel structures can be poor insulators on their own. Without proper insulation, the container house may become unbearably hot in the summer and extremely cold in the winter. High-quality insulation ensures the container house remains energy-efficient and comfortable, regardless of the outside temperature.

- Types of Insulation: The most used types of insulation in container houses include:
    - Spray Foam Insulation: This is one of the best choices for container homes due to its ability to fill small gaps and seams, ensuring that there are no drafts or air leaks. It offers excellent thermal performance,

particularly for regions with extreme weather conditions. Closed-cell spray foam also adds structural rigidity to the walls and ceilings.
    - Rigid Foam Insulation Panels: These are effective and commonly used in walls and ceilings. They provide high R-values (a measure of insulation effectiveness) and are resistant to moisture, making them a good choice for container houses in humid or rainy environments.
    - Rock Wool Insulation: Material: Made from volcanic rock or basalt spun into fibers. Fire-resistant, moisture-resistant, good soundproofing, and provides thermal insulation. It's denser and heavier than foam insulations. Often used in walls, ceilings, and floors, as well as for fireproofing in commercial and industrial settings. R-value is approximately 3.0 to 3.3 per inch.
- Thermal Bridging: Steel can act as a conductor, allowing heat or cold to pass through the structure, creating what's known as a thermal bridge. Insulation needs to be strategically installed to prevent thermal bridging, especially around joints, corners, and the expandable sections. High-quality insulation materials, combined with techniques like using thermal breaks or wrapping the entire container in an insulating layer, can mitigate this issue.
- Roof and Floor Insulation: The roof and floor are often areas where significant heat loss or gain can occur. Insulating these areas properly is just as important as the walls. For floors, rigid foam boards or spray foam can provide a solid thermal barrier, while for roofs, thicker insulation is typically required to combat heat gain from direct sunlight.

5.5.3.4. Climate-specific considerations

- Hot Climates: In regions with extreme heat, the container house will need reflective materials on the exterior to reduce heat absorption, as well as insulation with a high R-value to prevent heat from entering the living space. Ventilation systems, shading (like overhangs or awnings), and insulated roofs can help maintain cooler temperatures inside.
- Cold Climates: In colder regions, thick insulation and air-tight construction are crucial for retaining heat. Special attention should be given to preventing condensation, which can lead to mold or rust over time. Materials like spray

foam that act as both an insulator and a vapor barrier are excellent choices in these environments.

Evaluating the quality of materials and insulation in an expandable container house is essential for its durability, energy efficiency, and occupant comfort. High-quality steel ensures structural integrity, while durable finishes and weather-resistant features protect the house from harsh environmental conditions. Effective insulation, whether through spray foam, rigid panels, or other methods—ensures a stable indoor climate, even in extreme temperatures. By considering these factors, the customer can choose a container house that meets your specific needs and provides long-term comfort and protection.

5.5.4. Mobility and transportation

When considering mobility for an expandable container house, and evaluating the foundation requirements, there are several important factors to take into account to ensure the house is both transportable and stable once it is set up. Here's a more detailed exploration of these aspects:

5.5.4.1. Mobility: transporting expandable container house

- Ease of Transportation: If mobility is a priority, the user should focus on how easily the expandable container house can be transported from one location to another. Features such as foldable walls, retractable roofs, and modular sections that are compact for transport are essential for reducing the overall size of the structure during transit. Compact designs make it easier to load the container house onto trucks or shipping containers and meat transportation regulations, such as height and width limits for road transport.
- Foldable Walls: Foldable or collapsible walls allow the container house to shrink down in size during transportation. These walls can fold inward or downward, making the overall footprint of the structure smaller and more manageable for transport. Once at the new site, the walls can be extended or unfolded to restore the house to its full size.
- Retractable Roofs: A retractable roof is another key feature in mobile container houses. These roofs can either fold down to make the house more compact or collapse inward to reduce height for transportation. This feature not only makes

transportation easier but also helps protect the roof structure during transit. In some cases, retractable roofs can allow for vertical expansion when needed, providing an additional living or working space once the house is reassembled.

- Modular Design: Expandable container houses that are designed with modularity in mind are often easier to transport. Each module can be packed separately, making it possible to transport multiple sections in one trip or move the house in stages if needed. Modular designs also allow for easier customization and reconfiguration at the destination, offering flexibility in how the house is set up based on the available space or terrain.
- Durability During Transport: Mobility should never compromise the structural integrity of the container house. Look for houses made from high-quality materials that can withstand the rigors of transportation, such as being loaded onto flatbed trucks or shipped across long distances. Reinforced corners, sturdy frames, and shock-absorbing features can protect the house during transportation, preventing damage that could impact its structural soundness.
- Ease of Setup and Disassembly: A key aspect of a mobile container house is how quickly and easily it can be set up and disassembled. The more efficiently the house can expand and collapse without the need for heavy machinery or specialized labor, the more practical it will be for frequent relocation. Some designs feature integrated systems that allow the house to be expanded with minimal manual labor, such as hydraulic or pneumatic mechanisms for walls and roofs. This makes it easy to deploy and retract the house in a short amount of time, making it ideal for temporary housing, pop-up offices, or industrial applications like construction site shelters.
- Transportation Costs: Mobility also affects transportation costs. The more compact the house can become, the lower the transportation costs will likely be. Compact and lightweight designs reduce the number of trips required, the size of the transport vehicle needed, and the overall fuel consumption, making it a cost-effective solution for those who plan to relocate the container house frequently.

5.5.4.2. Foundation requirements: flexibility and stability

- Foundation Flexibility: One of the major advantages of container houses is their flexibility when it comes to foundation requirements. Unlike traditional homes, which often require deep foundations and significant groundwork, many container houses can be placed on simpler, more cost-effective foundations. Depending on the design, a container house might be able to sit on a variety of foundation types, ranging from permanent to more temporary setups.
- Concrete Slabs: A concrete slab is one of the most stable and durable foundation types for a container house. It provides a flat, even surface that supports the entire structure, ensuring that the house remains level and stable. A concrete foundation is ideal for long-term installations where mobility is not a primary concern. It is especially recommended in areas prone to soil movement, heavy rainfall, or where the ground may shift over time. However, the need for a concrete foundation can limit the house's mobility, as it requires more significant site preparation and it is harder to relocate once the house is installed.
- Gravel or Crushed Stone Base: For more temporary or mobile installations, a gravel or crushed stone foundation may be sufficient. This type of foundation provides good drainage, preventing water from pooling under the house and reducing the risk of rust or corrosion. A gravel base is easier to set up than concrete, and the house can be more easily moved from this type of foundation. It’s an ideal solution for short-term setups, such as temporary housing or mobile offices that need to be moved frequently. However, this foundation may not provide as much stability as a concrete slab, especially on uneven terrain or in areas prone to flooding.
- Pier or Pile Foundation: In cases where the terrain is uneven or the house needs to be elevated (such as on a sloped lot or in a flood-prone area), a pier or pile foundation may be required. This involves driving posts or piers into the ground and resting the container house on top. Pier foundations are advantageous for sloped or uneven terrain, as they allow the house to sit above the ground, avoiding contact with moisture or water. This type of foundation is also more flexible than a concrete slab because it allows the house to be

removed or relocated more easily, making it a good option for semi-permanent installations.

- Skid Foundation: A skid foundation, made from wood or steel beams, offers a very mobile solution. This type of foundation allows the container house to be placed directly on the ground or on top of beams, making it easy to move without leaving a permanent foundation behind. It's commonly used for container homes designed to be highly portable and is ideal for temporary installations where the house will be moved frequently. The skid foundation offers quick setup and removal but may not provide the same level of stability or insulation as more permanent foundation types.
- Adjustable Foundation: Some expandable container house designs offer adjustable foundation systems, which allow the house to be placed on a range of surfaces, even uneven terrain. These foundations use adjustable legs or supports that can be modified to fit the contours of the land. This system is beneficial for those who need to place their container house on rugged or irregular terrain without the need for extensive site preparation. The adjustable foundation system ensures that the house remains level and secure, even on challenging landscapes.
- No Foundation (Temporary Placement): In some cases, especially for short-term or pop-up applications, the container house may not require a formal foundation at all. It can simply be placed on a flat, firm surface such as compacted dirt, asphalt, or existing pavement. While this offers the highest level of mobility, it is not recommended for long-term use due to potential issues with stability, drainage, and structural stress over time.

5.5.4.3. Foundation and climate considerations

- Cold Climates: In colder regions, you may need a foundation that accounts for frost heaving, where the ground expands and contracts due to freezing temperatures. A deep foundation, such as piers that go below the frost line, can prevent the house from shifting due to freeze-thaw cycles.
- Wet or Flood-Prone Areas: If your container house will be placed in a flood-prone area, elevation through a pier foundation can protect it from water

damage. Ensuring the foundation allows for proper drainage and ventilation underneath the house is crucial to preventing rust and mold.

When mobility is a key factor, assessing how easily the expandable container house can be transported is critical. Features like foldable walls, retractable roofs, and modular designs contribute to easier transportation without sacrificing structural integrity. Additionally, understanding the foundation requirements ensures that the container house can be securely placed in different environments, from concrete slabs to gravel bases or even uneven terrain. For maximum mobility and flexibility, choose a container house with adaptable foundation options that can be easily set up, disassembled, and moved as needed, all while maintaining comfort and safety.

5.5.5. Customization and additional features

When selecting an expandable container house, it's crucial to assess the level of customization for the interior layout as well as the availability of essential utilities and amenities. Both of these factors determine how well the space will meet the customer’s personal, business, or industrial needs.

5.5.5.1. Customization of the interior layout

- Pre-Designed Interiors: Some expandable container houses come with standard, pre-designed interiors that are optimized for functionality and efficiency. These layouts are often created to maximize space in compact environments, offering pre-installed partitions, storage, and basic fixtures like lighting and plumbing. Pre-designed interiors are great for individuals or businesses looking for a turnkey solution that requires minimal input and setup time. However, these layouts may not suit everyone’s specific needs, and the lack of flexibility might limit how the customer can personalize the space.
- Customizable Layouts: Many expandable container houses offer the option for extensive interior customization. With these, the user can decide the placement of walls, partitions, doors, windows, and other elements to create a layout that best suits your lifestyle or operational needs. Customizable layouts are ideal for those who want to personalize the interior design, making it adaptable for

different functions such as living areas, offices, or workspaces. The customer may have the freedom to:

  - Add or remove rooms.
  - Adjust room sizes by moving partitions.
  - Modify the floor plan to suit specific uses, such as adding a workshop area, home office, or entertainment room.
  - Choose custom cabinetry, countertops, and storage solutions.
  - Select different flooring, wall materials, and finishes to match your aesthetic preferences.

- Modular Interior Elements: Some expandable container houses are designed with modular interior components, which allow for even greater flexibility. For instance, the user might be able to install removable or foldable partitions that can be reconfigured based on their current needs. Modular furniture, such as fold-out beds or tables, can maximize usable space in small areas. This level of customization is especially useful for spaces that need to serve multiple purposes, such as a home office that doubles as a guest room.
- Open-Plan vs. Sectioned Layouts: Depending on the user's needs, the user may opt for an open-plan layout, where fewer internal walls give the impression of a larger space. This design works well in living areas, studios, or offices where open sightlines and fluid movement are essential. Alternatively, the customer might prefer a more sectioned layout with distinct rooms for different purposes, such as separate bedrooms, living rooms, or workstations. The ability to customize the layout allows the customer to choose the setup that best suits their intended use.
- Interior Design Options: Customization isn't limited to the layout; many container house manufacturers allow the user to choose from a range of interior design options. They may have the opportunity to select different color schemes, materials for walls and floors, lighting options, and finishes for fixtures and fittings. This can help create a cohesive aesthetic, whether they are aiming for a minimalist, modern look or a more cozy, traditional feel.
- Custom Features and Fixtures: For those with specific needs or preferences, container houses may allow the customer to customize features such as:

    - Built-in Storage: Closets, shelving, and cabinets can be tailored to maximize space in smaller areas.
    - Lighting: Different types of lighting (e.g., recessed lighting, track lighting, or pendant lights) can be installed to suit their aesthetic and functional needs.
    - Flooring: the customer can select from various flooring materials, such as hardwood, tile, vinyl, or carpet, depending on their preferences for comfort, durability, and style.
    - Windows and Doors: The number and placement of windows and doors can be modified to optimize natural light, ventilation, or privacy.

5.5.5.2. Availability of essential utilities and amenities

- Plumbing: When choosing an expandable container house, it's essential to consider how the plumbing system will be integrated. Some container houses come pre-installed with plumbing for kitchens, bathrooms, and laundry areas, while others may require additional installations. If the container house is fully equipped, it will likely include:
    - Water Supply and Wastewater Systems: These systems are essential for sinks, showers, toilets, and washing machines. Some homes come with pre-installed water tanks or can be connected to a municipal water supply.
    - Hot Water Systems: Tankless water heaters or small water tanks can be pre-installed to provide hot water for showers and sinks.
    - Sustainable Options: If the customer is interested in off-grid living, some container houses may offer sustainable plumbing solutions, such as rainwater collection systems or composting toilets.
- Electrical Wiring: Many container homes come pre-wired for electricity, providing lighting, outlets, and power connections for appliances and devices. The electrical system may include:
    - Standard Wiring: Fully equipped container homes will have wiring that supports typical residential or commercial electricity needs, including outlets in all rooms, lighting fixtures, and power points for appliances.

    - Solar Power: If the user plans to live off-grid or in an eco-friendly way, some container homes may come equipped with solar panels or offer the option to install them. In these cases, the electrical wiring will be compatible with solar energy systems and possibly battery storage units.
    - Energy Efficiency: Some expandable container houses are designed to be energy-efficient, with low-energy lighting systems (e.g., LED lighting) and energy-efficient appliances, reducing overall power consumption and utility costs.
- Heating, Ventilation, and Air Conditioning (HVAC) Systems: Climate control is a crucial factor for both comfort and energy efficiency in a container house. The availability of HVAC systems can vary, and some container houses may become fully equipped, while others require additional installations:
    - Heating Systems: This could include electric heaters, underfloor heating, or more advanced systems such as heat pumps. For regions with cold winters, efficient heating is essential, and some container homes are designed to integrate small wood-burning stoves or radiators.
    - Cooling Systems: Air conditioning or ventilation systems are necessary for warm climates. Some expandable container houses may come with built-in AC units or ductless mini-split systems that provide both heating and cooling in an energy-efficient manner.
    - Ventilation: Proper ventilation is important for maintaining air quality and regulating temperature. Container houses often come with vent systems that help circulate air, preventing mold and dampness. This is especially important if the house is in a humid or rainy climate.
    - Energy-Efficient HVAC: If the house is pre-equipped with an HVAC system, it’s important to check its energy efficiency. Energy-efficient systems not only reduce utility bills but also contribute to a more sustainable lifestyle.
- Kitchen and Bathroom Facilities: The kitchen and bathroom are two of the most critical areas to consider when assessing the utilities of a container house. Some houses come fully equipped, while others may offer basic facilities that need further customization:

    - Kitchen Amenities: Fully equipped container houses may come with built-in cabinets, countertops, sinks, and appliances such as stovetops, ovens, microwaves, and refrigerators. In more customizable setups, the user can select your kitchen appliances and layout, choosing energy-efficient models or even space-saving options like compact dishwashers or foldable kitchen counters.
    - Bathroom Facilities: A pre-equipped container house will typically come with bathroom essentials such as a shower, sink, toilet, and water heater. For more customized setups, the user can select their preferred style of bathroom fixtures, such as walk-in showers, bathtubs, or eco-friendly toilets. If they are interested in off-grid living, they may also explore alternative solutions like composting toilets or water-saving fixtures.
- Sustainable Utilities: In addition to traditional utilities, many expandable container homes can be equipped with sustainable technologies, such as:
    - Solar Power: Solar panels for electricity generation, coupled with battery storage systems, can provide a renewable power source for off-grid living.
    - Water Recycling: Greywater recycling systems can be installed to reuse water from sinks and showers for gardening or flushing toilets.
    - Energy-Efficient Appliances: Many container homes offer energy-efficient appliances such as low-energy refrigerators, induction cooktops, or solar water heaters, reducing energy consumption and promoting eco-friendly living.

When evaluating an expandable container house, the level of interior customization and the availability of utilities and amenities are key factors. Whether the user prefer a pre-designed interior or wants the freedom to create a personalized layout, understanding the customization options for partitions, fixtures, and fittings is crucial for making the space functional and tailored to your specific needs. Equally important are the essential utilities such as plumbing, electrical wiring, HVAC systems, and kitchen and bathroom facilities. Some container houses come fully equipped with these features, while others may require additional installations or offer sustainable, off-grid options for self-sufficient living. The right combination of customization and amenities will ensure that the user's expandable container house is not only functional but also comfortable and efficient for long-term use.

5.5.6. Regulations and permits

In New Zealand, the use of container houses as alternative housing or commercial spaces is growing in popularity, but it is important to ensure compliance with local building codes and regulations before proceeding with any container house project. Different regions may have specific rules, and there are national standards that must be adhered to for legal approval. Here's a detailed explanation of the key factors to consider when building a container house in New Zealand, focusing on building codes, regulations, and permits.

5.5.6.1. Building codes and standards in New Zealand

In New Zealand, building codes and regulations are primarily governed by the Building Act 2004 and the New Zealand Building Code (NZBC). These codes set out the minimum standards for all buildings, including container homes, to ensure they are safe, healthy, and durable.

- Building Act 2004: This is the key legislation that governs all building work in New Zealand. It sets the rules for construction, alteration, demolition, and maintenance of buildings, ensuring they are safe and sustainable. All container houses must comply with the Building Act.
- New Zealand Building Code (NZBC): The NZBC establishes performance standards for different aspects of construction, such as structure, fire safety, insulation, sanitation, ventilation, and energy efficiency. A container house must meet these standards, just like any other type of building.

Some key areas of the NZBC that is needed to comply with for container homes include:

- Structural Integrity (B1): Container homes must be strong enough to withstand environmental factors such as wind and earthquakes, which are especially relevant in New Zealand due to the country's high seismic activity.

- Durability (B2): The materials used must be durable and suitable for New Zealand’s climate, particularly given the risk of corrosion due to coastal environments.
- Fire Safety (C): Container homes must comply with fire safety standards, including fire-resistant materials and appropriate escape routes.
- Energy Efficiency (H1): The container house must meet insulation and energy efficiency standards to ensure it is suitable for New Zealand's varying climate conditions.

5.5.6.2. Obtaining building consent

Before constructing or installing a container house in New Zealand, the user will need to apply for building consent. This is a legal requirement for most building work in the country, including container homes. Building consent ensures that the proposed work complies with the Building Code and that the finished structure will be safe and habitable.

- Application Process: Building consent applications are typically lodged with the local council. The customer will need to submit detailed plans and specifications of your container house, including design drawings, engineering reports, and information on materials used.
- Specific Requirements for Container Homes: Since container homes are non-traditional buildings, councils may require additional information on structural integrity and weatherproofing, especially if the container is repurposed from a shipping container. The customer may need to provide documentation that demonstrates the container’s suitability for use as a dwelling or workspace, such as an engineer's certification or manufacturer’s guarantee called Producer Statement or PS1.

The producer statement system is intended to provide Building Consent Authorities (BCAs) with reasonable grounds for the issue of Building Consent or a Code Compliance Certificate, without having to duplicate design or construction checking undertaken by others. The producer statement system is intended to provide Building Consent Authorities (BCAs) with reasonable grounds for the issue of a Building Consent or a Code Compliance Certificate, without having to duplicate design or construction checking undertaken by others (https://simpli.govt.nz/required-documents). In considering whether to accept a producer statement, a council will normally assess the credentials of the author to ensure that person has the appropriate experience and competence in their field of expertise. Producer statements are typically used for specialist work, such as engineering, or where there is a proprietary product that is installed by appointed contractors. Aspects of this work will be outside the council's in-house expertise and a producer statement can assist the council when they are determining whether the building work complies with the Building Code. Councils will use their judgment and internal processes when considering producer statements and how much weight to give them.

PS 1 – Design

PS 2 – Design Review

PS 3 – Construction (often used by the installers of proprietary systems)

PS 4 – Construction Review

5.5.6.3. Steps for acquiring PS1

This is Intended to use by a suitably qualified independent engineering design professional in circumstances where the Building Consent Authorities (BCA) accepts a producer statement for establishing reasonable grounds to issue a Building Consent. For approaching the council, there should be the PS1 from the Structural Engineer, Architect, Civil Engineer, and Geotechnical Engineer as each engineer checks different works in the project. Submitting the documents to the Engineering team or consultancy is needed to acquire producer statements. The documents include:

5.5.6.3.1. Restricted building work

If Restricted Building Work is part of the work being undertaken, a form 2a Memorandum from Licensed Building Practitioner/s: Certificate of Design Work for each type of building work being undertaken must be provided. This includes engineers and/or consultants who have been part of the design work. If applying for Owner / Builder exemption to complete the Restricted Building Work, complete the Statutory Declaration as to Owner Builder form. If restricted building work forms are completed outside of the portal, then attach to the architectural specifications document (Form 2B).

5.5.6.3.2. Proof of ownership

The 'proof of ownership' must be current and should be less than three months old.

5.5.6.3.3. Architectural plans

These are the plans or drawings that accompany an application. The drawings must be to scale and adhere to specific sheet sizes that are consistent throughout the entire set of project drawings. Each drawing should have a unique number that follows a logical sequence, along with a title that includes the designer's and owner's names, the project address, and a date for version control. Elevations, sections, and details should be clearly labeled and cross-referenced, with back-references included where necessary. The drawings need to be unambiguous, ensuring they do not contradict each other, any supporting documentation, or drawings from other disciplines.

Table 2 Standard scale of architectural plans (https://simpli.govt.nz/required-documents)

Drawing Type	**Normal Scale**
Location Plan	0.388888889
Site plan	0.111111111
Floor plan	1:100 or 1:50
Foundation plans	1:100 or 1:50
Bracing plans: subfloor, deck, wall and ceiling/roof	1:100 or 1:50
Plumbing and drainage	0.111111111
Fire protection plan	1:100 or 1:50
Elevations	1:100 or 1:50
Sections	1:100 or 1:50
Details	1:05

5.5.6.3.3.1. Architectural specification

The Building Act defines plans and specifications, stating that a specification outlines how a building should be constructed, altered, demolished, or removed.

A specification provides a detailed description of the dimensions, construction methods, materials, and products to be used, including product names and manufacturer identification numbers or references. It should also outline the acceptable standards of workmanship that have been or will be completed, and it should be prepared by a designer, architect, engineer, or another qualified individual.

An effective specification will be tailored to the specific site rather than offering a range of options or generic statements. It should be clear, concise, accurate, and comprehensive, presenting information in a logical sequence that is easy to follow, while avoiding repetition or irrelevant details. This clarity helps ensure high-quality workmanship and can save time and money during the consent and construction processes.

Additionally, the information must be consistent and coordinated, both within the different sections of the specification and with the accompanying drawings.

The specification should be defined:

- the extent of work to be carried out
- quality of the materials
- How materials should be placed and fixed
- details about products required for compliance
- acceptable standards for each trade or aspect of the construction

The architectural specifications should include (but are not limited to):

- Architectural Specification
- Truss Supplier Information

- ❖ Manufacturers Installation details
- ❖ Appraisals / Codemark Certificates
- ❖ Specified / proprietary product info and certificates (eg):
    - ➢ Balustrade
    - ➢ Structural members (LVL, I-Beams, etc)
- ❖ H1 Calculations
- ❖ Bracing Schedules
- ❖ Water Heater Details
- ❖ Storm Water Detention System
- ❖ Alternative Solution Justification
- ❖ External moisture risk matrix
- ❖ Weathertightness Reports / QA documents
- ❖ Lift Documentation
- ❖ Change of use Report/s
- ❖ Other supporting document/s

5.5.6.3.3.2. Truss supplier info

NZS3604:2011 section 10.2.2.3 mandates that roof truss layouts and fabricator statements must be submitted for all roof truss systems. These documents should be specific to the location or site, include the issue date, and provide details related to the specific design. Additionally, they must contain all necessary information as outlined in NZS3604:2011 section 10.2.2.3 to ensure the trusses are installed according to their specific design. This includes identifying supporting structures, such as load-bearing walls, and specifying the locations of truss-to-truss and truss-to-supporting structure fixings.

5.5.6.3.3.3. Manufacturers installation details

When a manufacturer's product, such as a cladding system, is proposed, relevant product information and installation details must accompany the application.

Manufacturer’s product information may consist of product data, testing information, specifications, scope of use, compliance with building codes, and installation details. For any specific product or system proposed, only the pertinent details should be provided. There is no need to submit the entire product manual, as this can save time and prevent confusion and delays on site. If the product has undergone independent testing and received a product certificate or appraisal, this should be included with the application.

5.5.6.3.3.4. Appraisals / codemark certificates

Appraisals, such as those conducted by BRANZ, confirm that a thorough and independent evaluation of building products, materials, systems, and design and construction methods has been performed. This ensures that a product is suitable for its intended use and complies with the Building Code. A codemark, or product certificate, is a voluntary certification scheme that offers a clear and reliable way to demonstrate that a building product meets the standards set by the New Zealand Building Code. This can apply to a building or construction method, building design, or building material.

According to Section 19 of the Building Act, a building consent authority is required to accept a current product certificate as proof of compliance with the building code. It's important to note that a product certificate or appraisal may come with specific limitations and can be updated or withdrawn as requirements change. Providing the most recent appraisal will help ensure that the specified product is indeed fit for its intended purpose.

Specified / proprietary product info and certificates (e.g.):

- Balustrade
- Structural members (LVL, I-Beams, etc.)

5.5.6.3.3.5. H1 calculations

Homes in New Zealand need to have sufficient insulation to ensure they achieve the appropriate level of thermal resistance (R-value) for their specific location. An H1 – Energy efficiency assessment must be provided to confirm how the compliance method has been established. Compliance can be demonstrated through:

- schedule method
- calculation method

5.5.6.3.3.6. Bracing schedules

Foundation systems and wall bracing must be designed to ensure that the bracing capacity surpasses the bracing demand. Bracing schedules, plans, and installation details for bracing elements should be provided. The bracing can be determined using:

- NZS:3604
- Proprietary software (such as GIB Ezybrace or BRANZ bracing calculation)
- Specific engineer design (SED).

5.5.6.3.3.7. Water heater details

The specifics of the hot water supply system, including the location, type, size, venting, overflow, structural or seismic support, water temperature, and piping materials, should be provided based on the type of water heater.

5.5.6.3.3.8. Stormwater detention / retention system

The requirements for a Storm Water Detention or Retention System will depend on the regulations set by the relevant Territorial Authority. If a tank is necessary, detailed information must be supplied by a qualified professional.

5.5.6.3.3.9. Alternative solution report/s

An alternative solution refers to any part of a building design that shows compliance with the Building Code while differing either completely or partially from the Acceptable Solutions or Verification Methods. The applicant for building consent (or their representative, such as an architect, engineer, or builder) must present the Building

Consent Authority (BCA) with proof that the proposed work will satisfy the performance requirements of the Building Code. Additional information regarding alternative solutions can be found on the MBIE website.

5.5.6.3.3.10. External moisture risk matrix

An external moisture risk matrix must be provided when using the acceptable solution E2/AS1 to demonstrate compliance with E2 – External Moisture. A risk score can be calculated for each external face of the building, allowing for the selection of appropriate claddings from E2/AS1 Table 3 based on these scores. Alternatively, the highest risk score can be applied to all walls. (The weathertightness risk matrix may also be included in the Architectural drawings.) Additional information regarding the weather-tightness risk matrix is available on the MBIE website. Note: Acceptable solutions can be utilized for various levels of weather tightness risk, with a maximum score of 20. If the score exceeds 20, evidence of an alternative solution must be provided, as mentioned above.

5.5.6.3.3.11. Weather tightness reports / QA documents

In cases where recladding is planned, relevant supporting information should be included, detailing the approach for situations where the existing timber framing is found unsuitable for new cladding (for example, if the framing is damaged or rotten). If a building surveyor's report has been obtained from a qualified expert indicating that timber remediation is unlikely to be necessary, this report must accompany the application. Conversely, if the report states that timber remediation will be needed, it is advisable to submit this report to support the application. Timber remediation may be necessary and should be overseen by a qualified expert, documented through a Quality Assurance (QA) program. If timber remediation is required and qualified experts are unavailable for supervision, this may result in significant delays, including the preparation, submission, and approval of an amendment to your consent.
Note: It is highly recommended to seek specialist advice for all recladding projects.

5.5.6.3.3.12. Lift documentation

When a lift is proposed, the application must include relevant information from the supplier. This information encompasses installation details, specifics about the car and doors, installation specifications, pit drainage details, producer statements, and any applicable codemarks (product certificates).

5.5.6.3.3.13. Change of use reports

Section 115 of the Building Act pertains to buildings that are undergoing a change of use. If a building's use is to be changed, the owner must inform the council of this change in writing. The proposed change cannot proceed until the council provides written confirmation that the requirements of the Building Act have been met. Changing a building's use may trigger specific requirements, including the need to comply 'as nearly as is reasonably practicable' (ANARP) with the current provisions of the Building Code outlined in section 115(a) or (b) of the Building Act. Supporting information must be provided to demonstrate how the requirements of Section 115 have been addressed.

5.5.6.3.3.14. Altering existing building information

Section 112 of the Building Act addresses alterations to existing buildings. Making alterations to a building can invoke certain requirements, such as:

- ensuring the building continues to comply with the Building Code to at least the same extent as before the alteration, and
- complying 'as nearly as is reasonably practicable' (ANARP) with current Building Code requirements for:
    - means of escaping from fire
    - access and facilities for people with disabilities
- undertaking seismic work so that the building is no longer earthquake-prone (for a substantial alteration (defined in regulations) to an earthquake-prone building).

Appropriate supporting information is to be provided outlining how the requirements of Section 112 have been addressed.

5.5.6.3.4. Structural plans

structural plans or drawings that accompany an application that visually communicates how a building is proposed to be constructed, altered, demolished, or removed. All drawings should contain an appropriate drawing number following a logical sequence, contain a drawing title with the designer's and owner's name, and the project address, and be dated for version control. Elevations, Sections, and Details are to be labeled and cross-referenced and backreferenced where appropriate.

Table 3 Standard scale of structural plans (https://simpli.govt.nz/required-documents)

Drawing Type	**Normal Scale**
Location Plan	0.388888889
Site plan	0.111111111
Floor plan	1:100 or 1:50
Foundation plans	1:100 or 1:50
Bracing plans: subfloor, deck, wall and ceiling/roof	1:100 or 1:50
Plumbing and drainage	0.111111111
Fire protection plan	1:100 or 1:50
Elevations plan	1:100 or 1:50

5.5.6.3.4.1. Structural specifications

A specification is a detailed description of the dimensions, construction, materials, and products to be used (by product name and manufacturer identification number or reference) and the acceptable standards of workmanship, etc., of work done or to be done, prepared by an architect, engineer, etc.

The specification should be defined:

- the extent of work to be carried out
- quality of the materials
- How materials should be placed and fixed
- details about products required for compliance
- acceptable standards for each trade or aspect of the construction

The structural engineering specifications should include if applicable to the work being proposed**:** (but not limited to)

- Structural Engineer Producer statements
- LBP memorandum (engineer)
- Design features reports
- Structural calculations
- Initial Seismic Assessment (ISA)
- Detailed Seismic Assessment (DSA)
- Geotech Reports
- Other supporting document/s

5.5.6.3.4.2. Structural engineer producer statements

The PS1 is regarded by the council as a 'formal opinion' from a professional, indicating that the specified aspects of the building work will comply with the building code, provided that the work is completed properly according to the plans and specifications submitted with the application. As part of its producer statement policy, the Building Control Authority may use a Producer Statement to help establish 'reasonable grounds' that the building code provisions would be met if the work is completed in line with the accompanying plans and specifications. Producer statements must adhere to the ‘Engineering New Zealand’ practice note titled ‘Guidelines on Producer Statements.’

5.5.6.3.4.3. LBP memorandum (Engineer)

If Restricted Building Work is part of the work being undertaken, a form 2a Memorandum from Licensed Building Practitioner/s: Certificate of Design Work for each type of building work being undertaken must be provided. This includes engineers and/or consultants who have been part of the design work. If applying for Owner / Builder exemption to complete the Restricted Building Work, complete the Statutory Declaration as to Owner Builder form. If restricted building work forms are completed outside of the portal, then attach to the architectural specifications document (Form 2B).

5.5.6.3.4.4. Design features reports

Design Features Reports (DFR) are brief documents created by structural engineers that summarize a building’s structural philosophy and outline key considerations and design methodologies. This includes design actions, load paths, geotechnical conditions, foundations, and lateral load-resisting systems. A DFR serves as a reference for future owners and engineers working on the building, providing a clear understanding of the structural design parameters. Design Features Reports are beneficial for Building Consent Authorities (BCAs) and other reviewers when evaluating compliance with the Building Code. MBIE and councils are promoting the use of a Design Features Report during the design phase to clarify the design methodology and highlight areas where critical inspections are necessary.

5.5.6.3.4.5. Structural calculations

Structural calculations are essential for verifying that a specific building element or design meets the performance requirements outlined in the New Zealand Building Code. These calculations or specific engineer designs (SED) must adhere to the appropriate verification methods or standards.

When SED is necessary, it is crucial that an engineer with the relevant expertise and experience in the specific engineering field interprets the requirements of the cited Standards. An engineer who is chartered under the Chartered Professional Engineers of New Zealand Act 2002 meets this criterion. These calculations need to be included in the building consent application documents, even if accompanied by a producer statement, as they are integral to the design plans and specifications.

Calculations assist the building consent authority in understanding the design assumptions made when evaluating proposals that require SED. It is important to note that calculations should only be submitted for unique designs that necessitate specialized input, rather than for trusses or other mass-produced engineering designs. When submitting calculations in support of a building consent application, they must:

- Be clear, legible, and accurate.
- Include a table of contents.
- Have all pages titled, numbered, and signed.
- Reference relevant Standards and include in-text clauses.
- Contain sketches and drawings as necessary.
- Provide sufficient commentary throughout to explain the design process and assumptions.
- Include a design features report that outlines key design assumptions and inputs.

5.5.6.3.4.6. Initial Seismic Assessment (ISA)

An Initial Seismic Assessment (ISA) using the Initial Evaluation Procedure (IEP) is usually the first step in determining if a building is at risk of earthquake damage. The IEP evaluates the building's ability to withstand earthquakes as a percentage of the strength required for a new building designed for that location (%NBS). According to the law, buildings that have less than 34 percent of the strength needed for a new structure are classified as earthquake-prone.

An experienced professional engineer must complete the ISA to ensure a valid assessment. The ISA offers a general idea of the expected seismic rating of a building, considering factors such as its type, age, construction materials, structural design, overall size, intended use, the ground it sits on, and any noticeable structural weaknesses.

5.5.6.3.4.7. Detailed Seismic Assessment (DSA)

A Detailed Seismic Assessment (DSA) is a comprehensive quantitative evaluation aimed at determining a building's earthquake rating in terms of %NBS, providing a more accurate assessment than what is available from an Initial Seismic Assessment (ISA).

DSAs may be initiated if an ISA indicates a rating below or close to 34%NBS, necessitating a more thorough evaluation to confirm the building's earthquake-prone status. Property owners might also opt for a DSA if they wish to gain a deeper understanding of their building's seismic performance. A DSA may be necessary to support a building consent application for seismic strengthening work on an existing structure or if the building is changing its use.

Like the ISA, the DSA can be conducted at various levels of detail based on the situation and the required reliability. It is the responsibility of the assessing engineer to comprehend the reliability of the chosen assessment method and to communicate this effectively to the end user of the DSA.

5.5.6.3.4.8. Geotech reports

A geotechnical 'Geotech' report is a specialized document that confirms the conditions of the ground and soil. Geotech reports typically detail the ultimate bearing capacity of the ground for each lot, the presence of expansive clay, the depths of topsoil, any uncertified fill that may require specific site investigation, and any stability issues that could affect the boundaries of a building platform.

5.5.6.4. Zoning and land use regulations

In addition to building consent, the user must also ensure that your container house complies with local zoning and land use regulations. These regulations vary depending on the area and determine how land can be used, including whether container homes are permitted in specific zones.

- Zoning Restrictions: Some areas may have restrictions on the use of container homes, particularly in residential or environmentally sensitive zones. Urban areas may have stricter regulations regarding aesthetic integration with surrounding properties, while rural areas may allow more flexibility.
- Height, Size, and Setback Rules: Local zoning rules also govern the height, size, and placement of buildings on a plot of land. Container houses must comply with these restrictions, which vary between councils. For example, there may be limits on how close a container house can be placed to a property boundary (setback rules), or restrictions on the number of containers that can be used.
- Resource Consent: In some cases, even if you have building consent, the user may also need to apply for resource consent. This is required if the container house project might impact the environment, such as in areas with heritage protection or those prone to flooding or erosion. Resource consent is also needed for projects that don't comply with local planning rules, such as building in a zone where container homes are not normally permitted.

5.5.6.5. Transport and temporary accommodation considerations

In New Zealand, container houses are often used for temporary accommodation, such as on construction sites or for disaster relief, as well as for more permanent living. If your container house is intended to be a mobile or temporary dwelling, different regulations may apply.

- Temporary Accommodation: For container homes intended as temporary accommodation, such as on a construction site, the user may not need to meet all the same requirements as a permanent structure. However, the building will still need to comply with safety and health standards, such as having adequate sanitation, ventilation, and emergency exits.
- Transportation Regulations: If the customer plans to transport the container home frequently (such as moving between properties or construction sites), it must also comply with New Zealand's transport regulations. This includes

meeting size and weight restrictions for moving buildings on public roads, which are regulated by the New Zealand Transport Agency (NZTA).

5.5.6.6. Health and safety regulations

Another important consideration when building or living in a container house in New Zealand is compliance with health and safety regulations. Container homes must provide a healthy living environment, free from hazards such as dampness, mold, and poor ventilation.

- Healthy Homes Standards: If the user is renting out your container house as a residential dwelling, it will need to meet the Healthy Homes Standards introduced by the New Zealand government. These standards set minimum requirements for heating, insulation, ventilation, moisture, and drainage. Container houses must have adequate insulation, heating systems, and ventilation to ensure the health and safety of occupants.
- Fire Safety: Fire safety is a critical aspect of New Zealand's building code. For container homes, this includes the use of fire-retardant materials, proper installation of smoke alarms, and clear escape routes in case of emergency. If the container house is used in a high-density area, additional fireproofing and safety measures may be required.

5.5.6.7. Additional environmental and sustainability considerations

New Zealand places a strong emphasis on sustainability and environmental responsibility, which may influence the design and approval process for container houses.

- Sustainability Practices: Many councils encourage the use of sustainable building practices, such as the installation of solar panels, rainwater collection systems, and energy-efficient appliances. While not always mandatory, adopting sustainable technologies can help speed up the consent process and align with New Zealand's goals for reducing carbon emissions.
- Eco-Friendly Design: If the user aims to create an eco-friendly container home, consider using sustainable materials, incorporating passive solar design, and optimizing energy efficiency to reduce environmental impact. Some regions

may have specific programs or incentives to support sustainable housing projects.

5.5.6.8. Common challenges and considerations

- Corrosion and Weatherproofing: Given New Zealand's coastal climate, container homes must be adequately protected against corrosion. This is especially important for areas near the sea, where salt air can accelerate rust and weaken structural integrity. Special coatings or cladding may be required to meet durability standards.
- Thermal Performance: Shipping containers were not originally designed as habitable structures, and they can have poor insulation and thermal performance. Ensuring proper insulation (especially under the H1 clause of the Building Code) is crucial to make the container comfortable in New Zealand’s varying climate, particularly in regions with cold winters or hot summers.

In New Zealand, building or installing a container house requires careful consideration of local building codes, zoning regulations, and the necessary permits. Ensuring compliance with the Building Act 2004 and the New Zealand Building Code is essential to guarantee the safety, durability, and legality of the structure. The client must also navigate zoning laws and, in some cases, apply for resource consent, especially if the container house is located in a restricted area. Additionally, sustainability and health standards play a significant role in the approval process. By working closely with local councils and understanding the regulatory landscape, the client can avoid legal issues and ensure that the container home is safe, efficient, and legally compliant in New Zealand.

5.5.7. Budget for an expandable container house

When considering the purchase of an expandable container house, it's crucial to weigh the initial cost against its long-term benefits. While the upfront cost may vary depending on factors like customization, size, location, and installation needs, it's important to approach the investment holistically. The long-term advantages, such as durability, versatility, sustainability, and potential cost savings, can significantly offset the initial expenditure.

5.5.7.1. Initial cost of an expandable container house

The upfront costs of an expandable container house include several components:

- Purchase Price: The base cost of the container house itself, which will vary based on size, materials, customization, and whether it is fully equipped or requires additional work.
- Delivery and Installation Costs: Depending on the distance from the manufacturer and the complexity of the setup, transportation, and installation can be added to the initial expenses.
- Customization: If you opt for customizations like advanced HVAC systems, solar power, or high-end interior finishes, these will increase the cost.
- Permits and Legal Fees: Securing the necessary building and zoning permits, as well as potential resource consent, can add to the cost.
- Site Preparation: Preparing the site for installation, including leveling, foundation work, or utility connections (e.g., plumbing, electricity), may incur additional expenses.
- Utilities and Infrastructure Setup: Depending on whether the container home comes pre-installed with essential utilities, we may need to spend more on electrical wiring, plumbing, septic systems, or water supply installations.

However, despite these initial costs, an expandable container house often proves to be more affordable compared to traditional housing or commercial buildings.

5.6. ISO 9001:2015 Quality management system certification for Hebei Jiacheng Integrated Housing Co., Ltd.

The certificate shown in Appendix B is an ISO 9001:2015 Quality Management System certification awarded to *Hebei Jiacheng Integrated Housing Co., Ltd.* This certification signifies that the company has implemented and maintains a quality management system in compliance with the internationally recognized ISO 9001:2015 standard. ISO 9001:2015 sets the benchmark for quality management practices worldwide and is designed to help organizations consistently meet customer and regulatory requirements while continuously improving their operations. Obtaining this certification assures clients and stakeholders that the company is committed to quality, efficiency, and customer satisfaction.

The certification scope covers the manufacturing of containers, specifically integrated houses. Integrated housing solutions, often created from modified containers, are used as temporary or modular structures for various purposes. The quality standards for such products must ensure safety, durability, and functionality. By obtaining this ISO certification, *Hebei Jiacheng Integrated Housing Co., Ltd.* demonstrates its adherence to stringent quality practices in producing these housing units. The certification guarantees that the company follows structured procedures for quality control, reducing the likelihood of errors, defects, or quality inconsistencies in its products.

Key details of the certificate include the certificate number, *115423Q0414R0S*, and the company's Unified Social Credit Code, *91131128MA7F3LF10X*, which serves as a unique identifier for businesses in China. The company's registered and production addresses are both located in the Fucheng County Economic Development Zone, Hengshui City, Hebei Province, China, adding transparency regarding the location of its operations. The certificate is issued by *Liaoning Zhongxin Certification Service Co., Ltd.*, an accredited certification body that conducted audits and verified that the company's practices align with the ISO 9001:2015 standard.

The certificate is valid from August 4, 2023, to August 3, 2026, subject to the company's ongoing compliance with ISO 9001 requirements. During this period, the company will undergo periodic audits by the certification body to ensure it consistently meets the standard. Non-compliance could lead to the suspension or withdrawal of the certificate, emphasizing the need for the company to maintain its quality practices continuously. Additionally, the certificate mentions that it does not cover administrative or mandatory licenses that might be required by other specific industry regulations, meaning that the company may need other permits or approvals beyond this ISO certification.

ISO 9001:2015 focuses on several key areas, including customer satisfaction, process efficiency, leadership, and continual improvement. To meet these requirements, companies must develop a customer-focused approach, engage employees in quality management, adopt a systematic process approach, and make decisions based on data and analysis. Furthermore, they must strive for continual improvement by addressing risks and taking corrective actions when necessary. These principles help create a solid foundation for consistent quality and operational excellence.

This certification brings multiple benefits. For customers, it provides assurance that the company follows a structured approach to quality, minimizing risks related to product reliability. For *Hebei Jiacheng Integrated Housing Co., Ltd.*, the certification can enhance its reputation, help attract new clients, and provide a competitive edge in the market, especially in international business. Internally, the ISO certification improves efficiency, reduces errors, and promotes a quality-focused culture within the company, leading to a positive working environment and potential cost savings. In summary, the ISO 9001:2015 certification serves as a testament to *Hebei Jiacheng Integrated Housing Co., Ltd.*'s commitment to high standards in the manufacturing of integrated housing solutions, ensuring quality and customer satisfaction.

5.7. Verification of conformity certificate for folding container house by Hebei Jiacheng Integrated Housing Co., Ltd.

This document given in Appendix A is a *Verification of Conformity* certificate issued by ICR Co., Ltd., an organization that provides certification services. The certificate number is ICR/VC/HE240115. It certifies that Hebei Jiacheng Integrated Housing Co., Ltd., based in Fucheng County, Hengshui City, Hebei Province, China, has met specific standards for its folding container house product.

ICR Co., Ltd. is an independent certification body that provides testing, inspection, and certification services for various products and industries. Organizations like ICR help ensure that products comply with specific standards, such as safety, quality, and regulatory requirements. By issuing a *Verification of Conformity* certificate, ICR validates that a product meets the specified regulatory standards, allowing manufacturers to demonstrate compliance and gain market acceptance, especially in regions with strict safety and quality requirements like the European Union.

The certificate specifies that the product types include folding houses, mobile houses, double-wing expansion boxes, and packing box rooms, all manufactured by Hebei Jiacheng Integrated Housing Co., Ltd. The certificate verifies compliance with the *CPR* (Construction Products Regulation) standard EN 1090-1:2009+A1:2011, which is a European standard for steel and aluminum structures, ensuring the structural integrity and safety of the product in construction applications.

The assessment, conducted by Hebei Jiacheng Integrated Housing Co., Ltd., confirms that the product adheres to the regulations, with test report number CE-HR20240122-HBJC-1. The certificate was issued on January 22, 2024, and is valid until January 21, 2029. It includes a note that this verification was issued voluntarily and does not guarantee that all essential requirements listed in the Declaration of Conformity are met. The document is signed by the CEO of ICR Co., Ltd. and includes the ICR verification seal, the company's website, and contact information. The edition is noted as 5.1.0.8 of 01.03.2023.

5.8. Foldable prefab home (20ft or 37.17 square meter) - 2-bedroom double - wing expandable container home

Fig.24 Double - wing container home - 20ft
(https://www.jiachenghouse.com/products_details/22.html)

Fig.25 Double - wing container home - 20ft
(https://www.jiachenghouse.com/products_details/22.html)

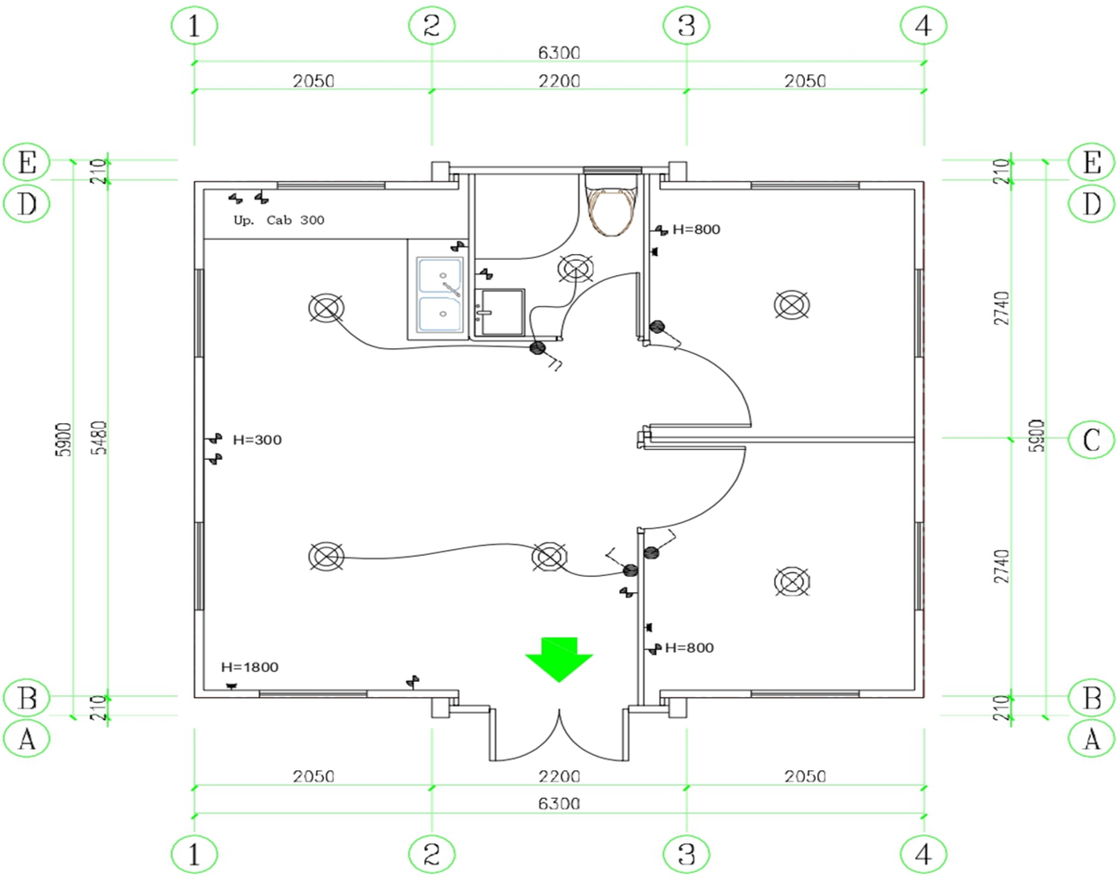

Fig.26 Floor plan - 20ft (37017 m2) double wing expandable container home - CAD Drawing – all dimensions are in millimeter (https://www.jiachenghouse.com/products_details/22.html)

Fig.27 3D floor plan - 20ft double wing expandable container home (https://www.jiachenghouse.com/products_details/22.html)

5.8.1. Specifications of 20ft double-wing expandable and foldable container home

Fig.28 Key components of the double-wing foldable container home (https://www.jiachenghouse.com/products_details/25.html)

The 20ft double-wing foldable and expandable container home is a cutting-edge solution that addresses both the immediate and long-term housing needs of disaster-affected regions. Its design focuses on durability, sustainability, and ease of construction, making it highly adaptable for regions like New Zealand that face severe natural disasters such as cyclones, floods, and earthquakes.

One of the key strengths of this model is its longevity, with a projected lifespan exceeding 30 years. This makes it not just a temporary shelter but a long-term housing solution. Its waterproof rating of 99.999% ensures that it can withstand heavy rain and flooding, which are common in post-cyclone scenarios. Additionally, the earthquake resistance grade of 10 highlights its ability to remain structurally sound even during significant seismic events. Given New Zealand's seismic activity, this feature makes the container particularly suitable for the region. Furthermore, its sound resistance rating of ≥30dB contributes to the overall comfort of the occupants by minimizing external noise, which is crucial in densely populated or high-activity areas.

The container is also built to endure extreme weather conditions, with a heat insulation value of 0.506317W/(m²·K). This high level of insulation ensures that the interior of the

home remains thermally regulated, reducing reliance on external heating or cooling systems. This is especially beneficial in post-disaster scenarios where access to electricity or heating might be limited. The wind resistance of ≥120KM/hour further reinforces the home's suitability for cyclone-prone areas, ensuring that it can withstand strong winds without compromising its structural integrity.
From a structural standpoint, the home is engineered to bear substantial weight, with a roof live load capacity of ≥1.0KN/㎡ and a floor live load capacity of ≥2.5KN/㎡. This makes it robust enough to support multiple occupants and their belongings, ensuring safety and comfort. Its fireproof grade of A, which is the highest rating, demonstrates the structure's ability to resist fire hazards, providing an added layer of safety, particularly in disaster-stricken areas where fire outbreaks are a concern.

The container's size and portability are also major advantages. When fully expanded, the interior space measures 5640mm in length, 6140mm in width, and 2240mm in height, offering ample living space for families or groups. However, the container's innovative design allows it to fold into a compact size of 5900mm by 2200mm by 2480mm, making it easy to transport to remote or disaster-affected areas. This foldable feature is particularly beneficial in emergencies where rapid deployment of housing is critical.

The frame structure is built using galvanized square tubes and a fold system made of Q235 steel, a high-strength material known for its durability and resistance to corrosion. This is essential for long-term use in varying weather conditions, as the frame will not degrade easily, even in coastal areas with high humidity or saltwater exposure. The flooring uses an 18mm cement base, combined with bamboo rubber boards on the sides, which offers a sustainable and strong foundation. Bamboo is a renewable resource, adding to the sustainability aspect of the design, while also providing durability under heavy use.

The walls and insulation are constructed using a 75mm sandwich board, which incorporates materials such as rock wool or expandable polystyrene (EPS). These materials offer excellent thermal and sound insulation while being lightweight, which is important for maintaining the container's portability. The EPS material is also fire-resistant, adding to the overall safety features of the home. Additionally, the container is equipped with a fully functional electrical system, adhering to national standards for wiring and circuit protection. It includes a circuit breaker system and LED lighting, ensuring energy efficiency and safety.

For security and comfort, the container is equipped with a standard steel anti-theft door and double-glazed plastic steel windows, which provide both insulation and protection. These doors and windows can be customized based on the specific needs or preferences of the occupants, offering flexibility in design and use.

Overall, the container home provides a comprehensive solution for post-disaster recovery, combining durability, ease of deployment, and adherence to safety standards. Its modular, expandable design makes it ideal for rapid construction and deployment in disaster-hit areas, while its long lifespan ensures that it can serve as a permanent housing solution if needed. By integrating modern materials and construction methods, it offers a high degree of resilience against natural disasters like cyclones and earthquakes, as well as the flexibility to meet local building codes and council approvals.

This container home model represents a promising solution for New Zealand's post-disaster housing needs, particularly in regions like Hawke's Bay, which was severely affected by Cyclone Gabrielle. Its balance of cost-effectiveness, durability, and sustainability aligns with the goal of providing safe and affordable housing solutions in the wake of natural disasters.

Table 4. Specifications of 20ft double-wing foldable and expandable container home (https://www.jiachenghouse.com/products_details/22.html)

Section	Feature	Value
General Specifications	Life Span	More than 30 years
	Waterproof	99.999%
	Earthquake Resistance	Grade 10
	Sound Resistance	≥30dB
	Heat Insulation	0.506317W/(m²·K)

	Wind Resistance	≥120KM/Hour
	Roof Live Load	≥1.0KN/m²
	Floor Live Load	≥2.5KN/m²
	Fireproof Grade	A
Dimensions	Extended Size (mm)	L5900 × W6300 × H2480
	Interior Space (mm)	L5640 × W6140 × H2240
	Folding Size (mm)	L5900 × W2200 × H2480
	Weight (kg)	2500
Frame Structure	Main Beam	Galvanized Square Tube 80 × 100 × 2.5mm Q235
	Column	Galvanized Fold 150 × 210 × 2.0mm Q235
	Sub-frame	Galvanized Square Tube 40 × 60 × 1.5mm Q235
	Box Lifting Head	Galvanized 210 × 150 × 160 × 4mm Q235
	Hinge	Galvanized Thickened Hinge Q235
Flooring	Intermediate Floor	18mm Cement Floor
	Sides Floor	18mm Bamboo Rubber Board
Insulation and Walls	Sidewall	75mm Sandwich Board, double-sided 0.35mm colour roll (Rock Wool or EPS options)
	Partition	50mm Sandwich Panel, coloured steel plate substrate double-sided 0.35mm
	Top Panel	50mm Sandwich Panel, coloured steel plate substrate double-sided 0.35mm

Electrical System	Wiring	National Standard Wire (Customized Options Available)
	Circuit Breakers	2P63A total, 2P43A/2P32A/1P20 shunt leakage protectors
	Lighting	Six anti-LED ceiling lamps
	Sockets	Standard international three-hole sockets
Doors and Windows	Entrance Door	Standard steel anti-theft door (Custom options available)
	Windows	Standard plastic steel double-glass casement windows (930 × 930 × 6; 500 × 500 × 1 mm options available)

5.8.2. Step-by-Step Transformation of a Foldable, Expandable Container Home

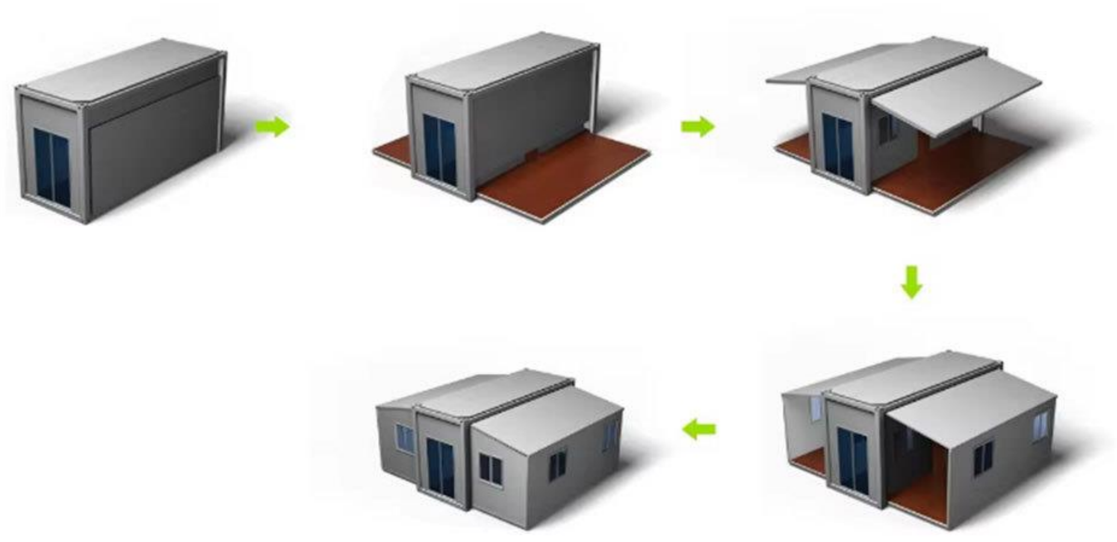

Fig.29. Step-by-step transformation to a house
(https://www.jiachenghouse.com/products_details/25.html)

The image shown above visually explains the step-by-step transformation of a foldable, expandable container home.

5.8.2.1. Initial compact container (Top Left):

In its initial state, the home is fully folded and resembles a standard shipping container. This compact form allows for easy transportation and storage, making it convenient for delivering to disaster-stricken areas. The size at this stage is minimal, indicating that it could be easily shipped via truck or ship to remote or damaged locations.

5.8.2.2. Unfolding the base (Top Middle):

In the second stage, the home begins to expand. The container's sides start to open, and the base or flooring expands outward. This expansion likely doubles the width of the living space. The flooring that is unfolded creates a foundation on which further parts of the home will rest. This step shows how the home can be rapidly deployed once on-site.

5.8.2.3. Expanding the roof (Top Right):

The roof sections begin to unfold next, creating a covered shelter and extending the living space even further. This expansion demonstrates how the container transforms from a simple box-like structure into a more functional home with extended coverage for both sides. The roof likely provides insulation and weather protection, critical in post-disaster environments where shelter from the elements is essential.

5.8.2.4. Double-wing expansion (Bottom Left):

By this stage, the container home is nearing its final form, with the side walls fully unfolded. This "double wing" design means both sides of the container open outwards, providing significantly more internal space. It transforms into a fully functional living area, more than doubling its original width. This extended structure could accommodate more people or provide separate rooms for different functions, such as sleeping, dining, or storage.

5.8.2.5. Fully expanded home (Bottom Right):

In the final stage, the home has fully expanded to its intended size, taking on the appearance of a traditional house complete with doors, windows, and a proper roof. It no longer resembles a compact shipping container but instead resembles a permanent, spacious living structure. The inclusion of windows ensures ample ventilation and natural light, enhancing comfort for long-term occupancy. Additionally, the solid walls and sturdy roof indicate durability and strong weather resistance, making the structure well-suited for post-disaster recovery scenarios.

5.8.3. Interior facilities, electrical appliances, and material display for the foldable container home

Fig.30. showcases the utilities and finishing materials included in the foldable container home, creating a functional, comfortable, and complete living space.(https://www.jiachenghouse.com/products_details/25.html)

Essential sanitation and kitchen facilities form the core of the design. The sink and toilet, standard in both the bathroom and kitchen, provide fundamental hygiene capabilities. A shower unit is also included, offering a modern, space-efficient solution for bathing while ensuring user comfort. The kitchen area features a well-equipped cabinet and sink, combining storage and washing facilities for food preparation. These elements ensure the container home caters to the basic needs of daily living, making it versatile for both short-term emergency housing and long-term residential use.

Additionally, the design allows for customization based on local preferences. For example, kitchen countertops are designed to be made of marble, with options for customers to choose their preferred color and texture.

Fig.31. Some of the style layouts of kitchen cabinets (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

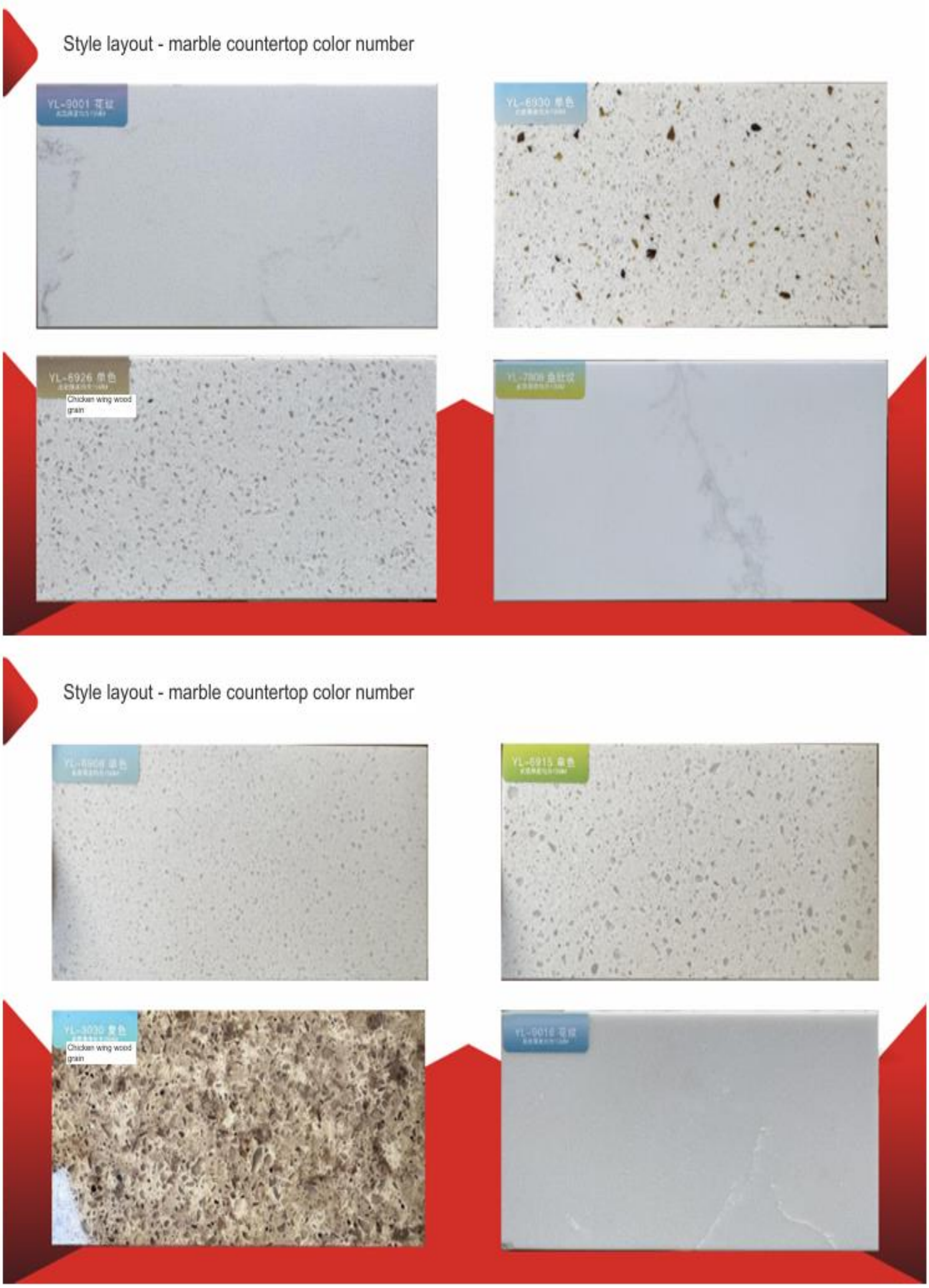

Fig.32 Some of the style layouts of marble countertop (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

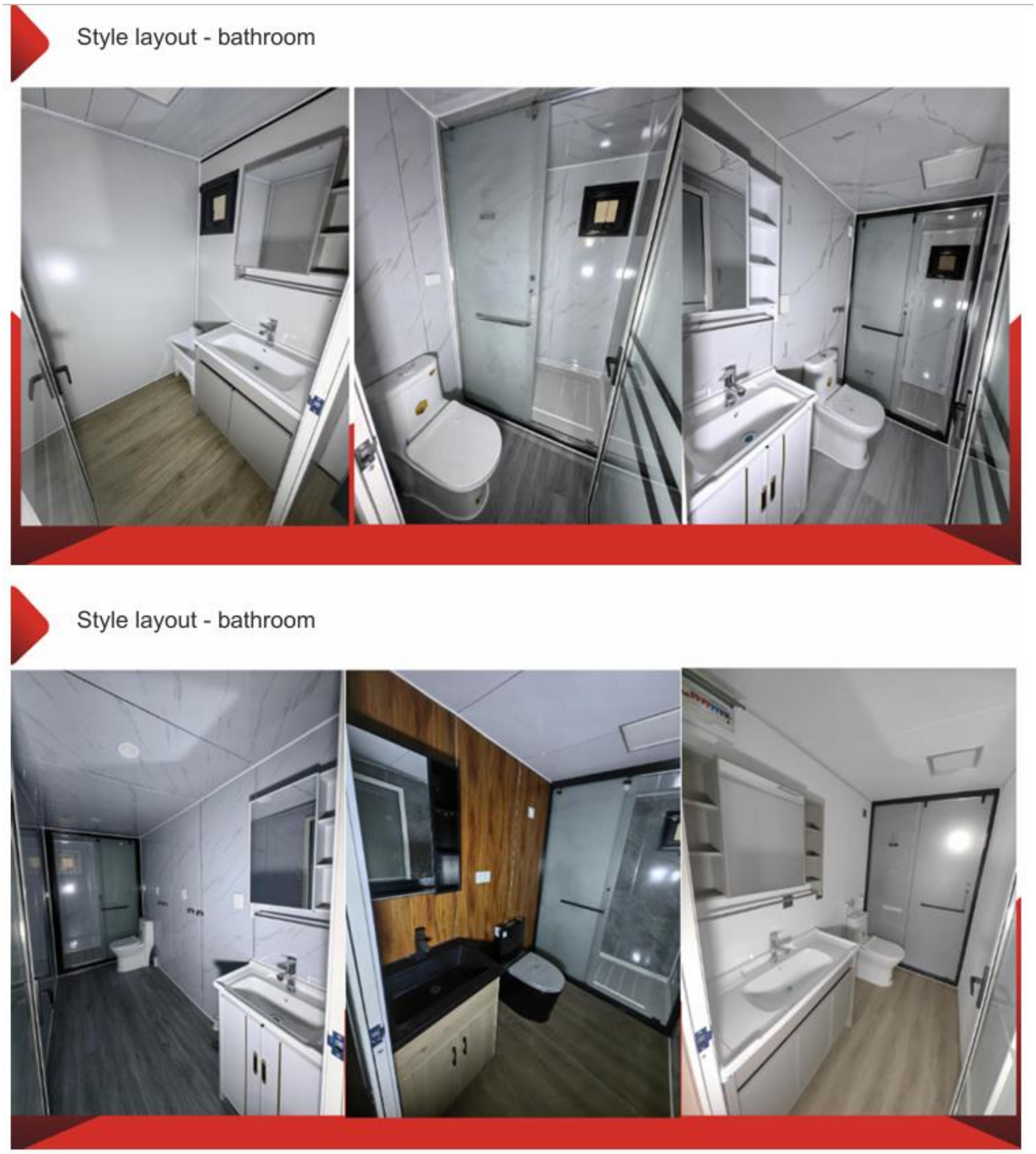

Fig.33 Some of the style layouts of the bathroom (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

Fig.34 Some of the style layouts of doors (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

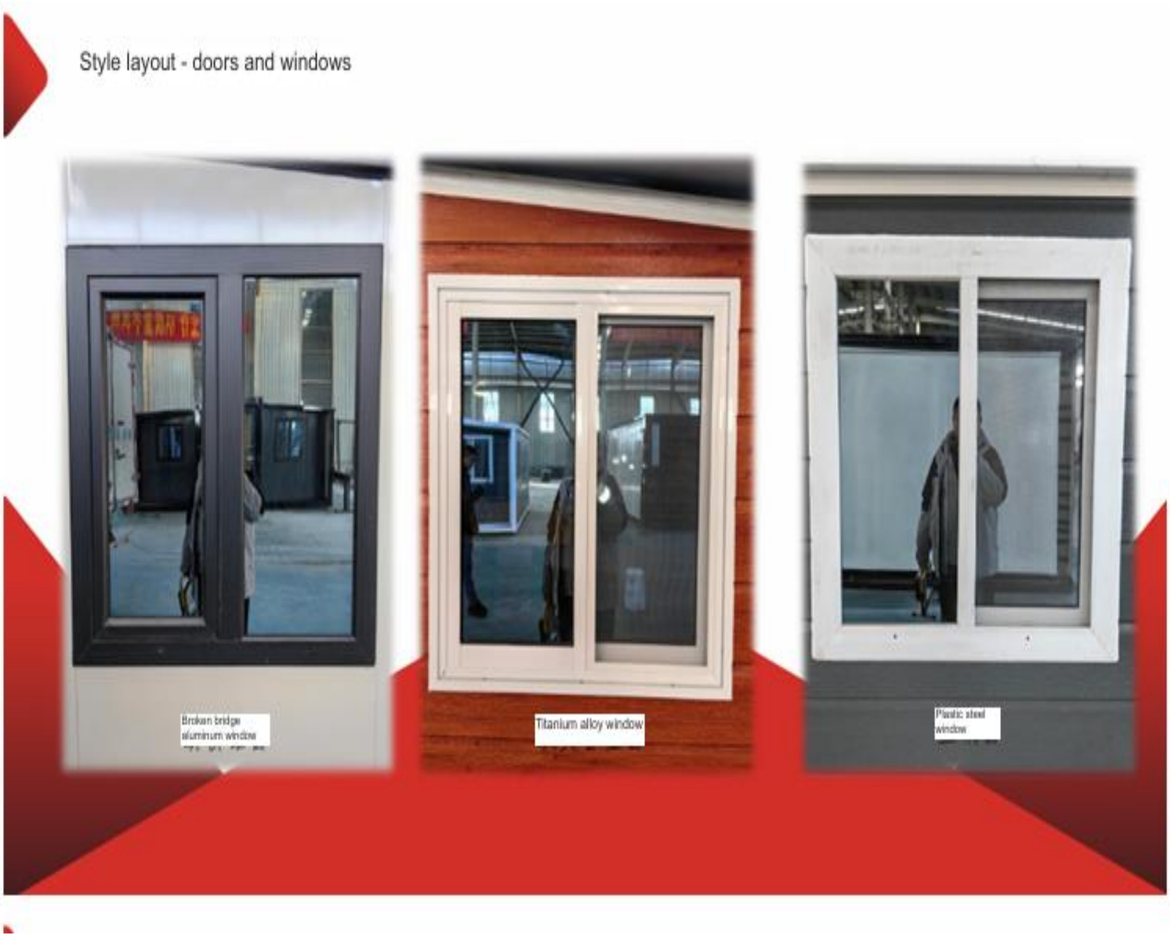

Fig.35 Some of the style layouts of windows (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

There are a variety of electrical appliances and systems that provide efficient energy usage within the container home. Power outlets with various plug types are included to ensure compatibility with different devices, allowing residents to power essential appliances and electronics. A circuit breaker box is also part of the setup, providing a critical safety feature by preventing electrical overloads and short circuits. Proper ventilation is facilitated through the installation of a ventilation fan, which helps maintain air quality and comfort, especially in the compact space of a container home. The image also suggests a well-planned lighting system, using efficient LED lights or similar fixtures that ensure good illumination throughout the home while conserving energy.

Fig.36 Some of the style layouts of electrical distributions (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

The material display emphasizes the type of building materials used in the construction and finishing of the container home. The flooring options shown in the image demonstrate a variety of textures, colors, and finishes, allowing for customization based on user preference or the specific use case of the home. These materials are designed to be durable, waterproof, and easy to clean, all of which are essential in a post-disaster housing scenario where resilience and low maintenance are key. Insulating materials are also likely to ensure that the container home remains comfortable across different weather conditions, providing temperature regulation and soundproofing for better living conditions.

Fig.37 Some of the style layouts of UV board interior wall panel (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

Fig.38 Some of the style layouts of SPC floor - stone plastic floor (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

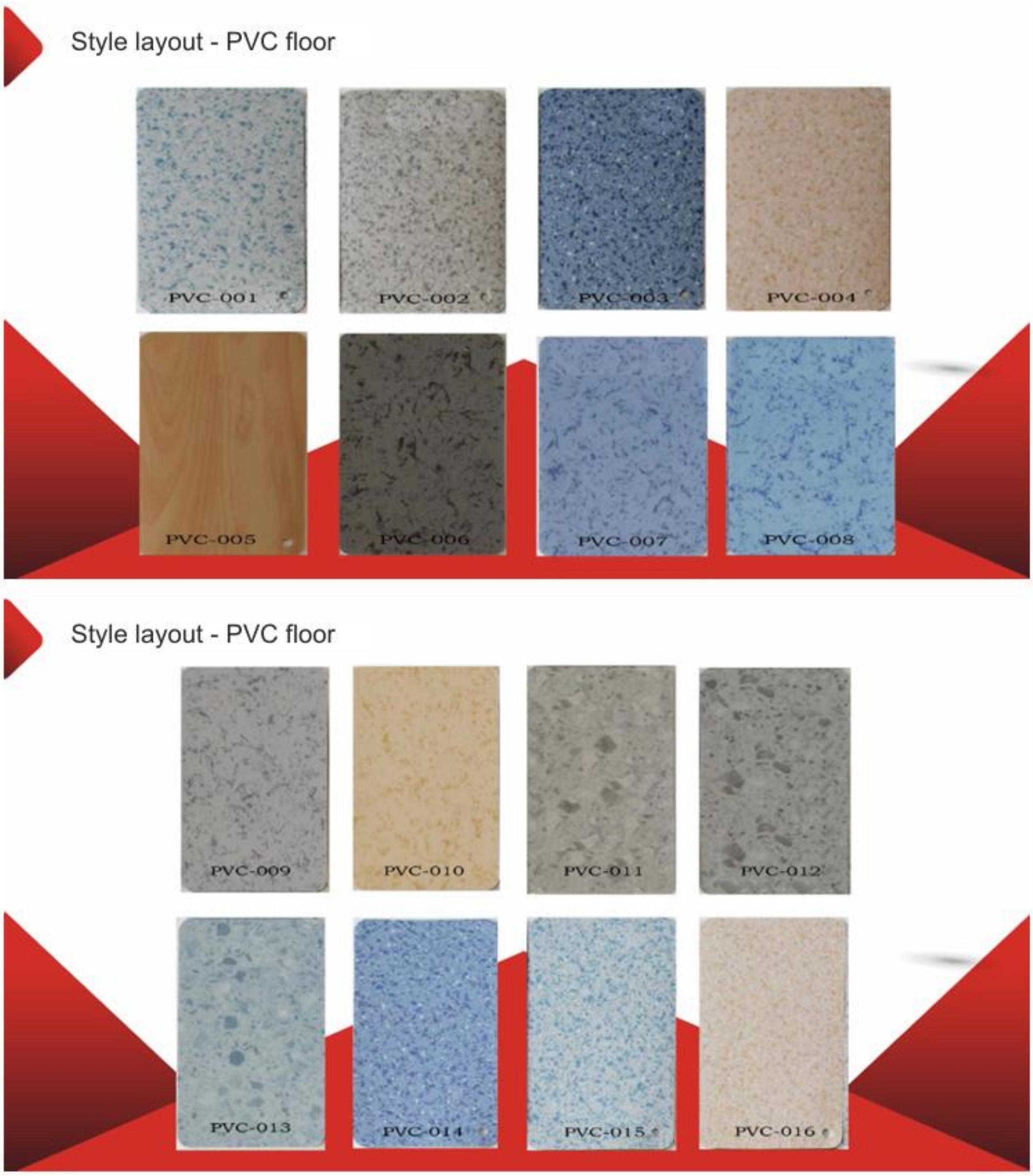

Fig.39 Some of the style layouts of PVC floor (source: material customizations brochure of Hebei JiaCheng Integrated Solutions)

5.8.4. Cost of 37.17 square meters - 2 bedroom - double wing expandable and foldable container home

Table 5: Cost of main areas of 37.17 square meter house

(https://www.jiachenghouse.com/products_details/22.html)

COST OF HOUSE - 37.17 SQUARE METER	
PARTICULARS	**USD (DOLLARS)**
Empty Room (Living/Dining)	$3300
Bedroom 1	$180
Bedroom 2	$180
Kitchen	$300
Bathroom	$570
Wall Material (Metal Carved Board)	$450
Roof	$2000
Balcony	$500

Table 6: Cost of windows and doors of 37.17 square meter house

(https://www.jiachenghouse.com/products_details/22.html)

Doors and windows

Type	Plastic Steel	Aluminum Alloy	Broken Bridge Aluminum
Door	$150	$250	$350
Window	$40	$57	$85

Table 7: Total cost of 37.17 square meter house

(https://www.jiachenghouse.com/products_details/22.html)

Total USD and NZD

Door/Window Combination Houses	**USD Total**	**NZD Total**
Plastic steel/Plastic Steel	$7,670	$13,047

Plastic Steel/Aluminum Alloy	$7,687	$13,076
Plastic Steel/Broken Bridge Aluminum	$7,715	$13,123
Aluminum Alloy/Plastic Steel	$7,770	$13,217
Aluminum Alloy/ Aluminum Alloy	$7,787	$13,246
Aluminium Alloy/Broken Bridge Aluminum	$7,815	$13,293
Broken Bridge Aluminum/Plastic Steel	$7,870	$13,387
Broken Bridge Aluminum/Aluminum Alloy	$7,887	$13,416
Broken Bridge Aluminum/Broken Bridge Aluminum	$7,915	$13,463

The table outlines the total costs of building a 37.17-square-meter house using different combinations of door and window materials. The materials are grouped into three types: Plastic Steel, Aluminum Alloy, and Broken Bridge Aluminum. Each combination affects the overall cost of the house in both USD and NZD.

Explanation of the Columns:

- Door/Window Combination: This column lists the material choice for doors and windows. Each row shows a specific combination, with the door material listed first, followed by the window material.
- USD Total: The total cost of constructing the house in U.S. Dollars, depending on the selected door and window materials.
- NZD Total: The equivalent total cost in New Zealand Dollars for each material combination.

Breakdown of combinations:

- Plastic Steel/Plastic Steel: Using Plastic Steel for both doors and windows results in the lowest total cost, at USD 7,670 (NZD 13,047).
- Plastic Steel/Aluminum Alloy: Choosing Plastic Steel for the door and Aluminum Alloy for the windows increases the cost slightly to USD 7,687 (NZD 13,076).
- Plastic Steel/Broken Bridge Aluminum: Using Plastic Steel for the door and Broken Bridge Aluminum for the windows brings the cost to USD 7,715 (NZD 13,123).
- Aluminum Alloy/Plastic Steel: Choosing Aluminum Alloy for the door and Plastic Steel for the windows brings the total cost to USD 7,770 (NZD 13,217).
- Aluminum Alloy/Aluminum Alloy: Using Aluminum Alloy for both doors and windows results in a cost of 7,787 USD (13,246 NZD).
- Aluminum Alloy/Broken Bridge Aluminum: Aluminum Alloy doors with Broken Bridge Aluminum windows cost USD 7,815 (NZD 13,293).
- Broken Bridge Aluminum/Plastic Steel: Using Broken Bridge Aluminum for the door and Plastic Steel for the windows increases the cost to USD 7,870 (NZD 13,387).
- Broken Bridge Aluminum/Aluminum Alloy: A combination of Broken Bridge Aluminum for doors and Aluminum Alloy for windows costs USD 7,887 (NZD 13,416).
- Broken Bridge Aluminum/Broken Bridge Aluminum: The most expensive combination, using Broken Bridge Aluminum for both doors and windows, totals USD 7,915 (NZD 13,463).

5.8.5. Cost comparison of 37.17-square-meter container house versus traditional housing options in New Zealand

In comparing the rates of the 37.17 square meter container house with existing housing options in New Zealand, it is evident that this alternative housing model presents a more cost-effective solution. The total cost of the container house, based on different combinations of door and window materials, ranges from approximately NZD 13,047 to NZD 13,463. This price includes basic construction elements like bedrooms, kitchen, bathroom, balcony, wall material, and roof, but excludes any land costs, which would need to be considered in New Zealand's housing market.

In contrast, conventional housing prices in New Zealand are significantly higher. As of recent data, the average cost per square meter for a standard house can vary widely depending on the region but generally falls within the range of NZD 2,500 to NZD 4,000 per square meter. For a conventional house of similar size (around 37 square meters), this would result in an estimated total cost of NZD 92,500 to NZD 148,000, a figure substantially above the container house's cost.

This comparison highlights the container house as a viable, affordable alternative for those seeking entry-level housing options, especially in areas with inflated property prices. The lower initial investment could make it appealing for individuals or families seeking affordable housing solutions, or for developers aiming to create sustainable, low-cost housing developments. However, additional considerations like insulation, utilities setup, and long-term durability need to be factored into the decision-making process when comparing the container house to traditional builds.

Typical 2-bedroom houses in New Zealand, which are significantly larger than 37.17 square meters (usually between 70–100+ square meters), generally have much higher costs. Here's a breakdown of average costs:

1. Average market price for 2-bedroom homes:
    - In cities like Auckland and Wellington, the average price for a standard 2-bedroom house can range from NZD 500,000 to NZD 900,000 depending on location and property condition.
    - In smaller towns or rural areas, a 2-bedroom home might cost NZD 350,000 to NZD 600,000.
2. Prefabricated or modular 2-bedroom homes:
    - A prefabricated or modular 2-bedroom home of around 70–100 square meters typically costs between NZD 100,000 and NZD 300,000 for the basic structure, excluding land, utilities, and site preparation.
    - Full setup with additional features and utilities often pushes this price higher.

3. Container homes in New Zealand:
    - Container homes are a more affordable option, with small 1- or 2-bedroom units typically starting from around NZD 30,000 to NZD 100,000 for a basic fit-out.
    - Higher-end container homes with more amenities can cost NZD 100,000 to NZD 200,000 or more.

The 37.17-square-meter container house you're considering is a low-cost option relative to traditional housing, even compared to typical container homes in New Zealand. With its total cost of around NZD 13,047 to NZD 13,463, it is well below even the lower range of prefabricated or small modular homes, making it an economical choice for those looking for a compact, budget-friendly living space. However, the space is significantly smaller than a traditional 2-bedroom home, making it more suited as a minimalist or secondary dwelling rather than a primary residence for families.

5.8.6. Compliance testing report for rohs 2 directive: analysis of hazardous substances in container house materials

This report mentioned in Appendix C, dated September 24, 2024, summarizes the testing and certification results for a sample container house submitted by Hebei Jiacheng Integrated Housing Co., Ltd. Conducted by Dongguan Jun'an Testing & Certification Co., Ltd., this analysis evaluates compliance with the RoHS 2 Directive (2011/65/EU), particularly for hazardous substances like heavy metals and certain phthalates in construction materials.

The RoHS 2 Directive (2011/65/EU), also known as the Restriction of Hazardous Substances Directive, is a regulation adopted by the European Union to restrict the use of certain hazardous materials in electrical and electronic equipment. Originally implemented in 2002 and updated in 2011, RoHS 2 builds upon the initial directive to enhance safety standards and minimize environmental impact.

The primary goal of the RoHS 2 Directive is to protect human health and the environment by restricting the use of ten specific hazardous substances in various products. These substances include:

- Lead (Pb)
- Mercury (Hg)
- Cadmium (Cd)
- Hexavalent chromium (CrVI)
- Polybrominated biphenyls (PBB)
- Polybrominated diphenyl ethers (PBDE)
- Dibutyl phthalate (DBP)
- Butyl benzyl phthalate (BBP)
- Di-(2-ethylhexyl) phthalate (DEHP)
- Diisobutyl phthalate (DIBP)

These substances are commonly used in manufacturing electronics and electrical components, but their toxicity poses risks to both human health and the environment. RoHS 2 sets specific concentration limits for each substance, and compliance is mandatory for products marketed within the EU. The directive applies to a wide range of electrical and electronic equipment, including household appliances, IT and telecommunications equipment, lighting, and medical devices. Manufacturers and suppliers must ensure that their products comply with RoHS 2, which often involves testing, certification, and proper labeling.

The container house sample, identified by models in series such as CC, SR, and others, underwent testing for the presence of hazardous substances including cadmium (Cd), lead (Pb), mercury (Hg), hexavalent chromium (CrVI), polybrominated biphenyls (PBBs), and polybrominated diphenyl ethers (PBDEs). The report details specific tests performed on materials ranging from structural elements like H-beams, steel plates, and pipes to interior components like wall panels, flooring, and insulation materials.

Testing methodologies followed standards like IEC 62321 and involved techniques such as ICP-OES and GC-MS for accurate substance detection. All measured values for hazardous substances were "Not Detected" (N.D.), indicating that concentrations were below the detection limits and confirming compliance with RoHS standards. The report is exhaustive, covering 30 components and confirming a pass in all categories, certifying the container house materials as safe per the specified guidelines.

In terms of broader implications, this report validates the environmental compliance of the container house, making it suitable for markets with strict regulations on hazardous substances, thus supporting sustainable building practices.

5.9. Chapter summary

This chapter is a vast chapter that examines the structural design, material specifications, compliance with building codes, and environmental adaptability of the double-wing expandable foldable container homes. The chapter explained the manufacturer details, product details, and specifications including floor plans, interior facilities, electrical appliances at homes, test reports, and certifications. A guide has been given by the manufacturer on how to choose a suitable container home based on the requirements. However, a detailed analysis must be executed to check whether this container home will comply with the housing standards of New Zealand.

CHAPTER 6

SYSTEM MASS COMPLIANCE AND SITE-SPECIFIC COMPLIANCE

6.1. Chapter introduction

This chapter evaluates the system compliance of double-wing expandable foldable container homes in New Zealand, focusing on mass compliance with the New Zealand Building Code (NZBC). System compliance ensures that a housing solution can be broadly approved for use across multiple locations without site-specific reviews, provided minor adjustments are made to local conditions. The assessment includes key regulatory clauses covering structural safety, durability, fire safety, energy efficiency, and material standards. This evaluation assesses the viability of the container homes for post-disaster recovery in Hawke's Bay following Cyclone Gabrielle.

This chapter also explores the site-specific compliance requirements necessary for deploying double-wing expandable container homes in Hawke’s Bay, New Zealand, by the New Zealand Building Code (NZBC). The discussion emphasizes the adaptation of general compliance systems to address the region's unique environmental and regulatory challenges. By focusing on key factors like seismic performance, wind resistance, fire safety, durability, insulation, and flood mitigation, this chapter provides a comprehensive guide to customizing modular housing systems for local conditions. The aim is to ensure that these homes are safe, durable, and well-suited to the hazards and demands of the Hawke's Bay environment.

6.2. Research methods

This chapter employs a comprehensive approach to evaluate the system compliance of double-wing expandable foldable container homes with New Zealand Building Code (NZBC) standards. A detailed regulatory review is conducted, focusing on key clauses such as B1 (Structural Safety), B2 (Durability), C1-C6 (Fire Safety), and H1 (Energy Efficiency). This is complemented by a comparative analysis that examines the container homes' specifications against NZBC requirements, particularly in areas such as seismic and wind load resistance, fire ratings, thermal insulation, and material standards. A case study approach is utilized, centering on Hawke's Bay, which presents specific challenges such as high seismic activity, strong winds, and coastal environmental conditions. The chapter also reviews the materials used in the container homes, including Q235 steel and EPS insulation, to assess their compatibility with

New Zealand's standards. Additionally, thermal resistance (R-values) is calculated, and the wind and seismic resistance capabilities of the model are assessed based on the provided technical specifications.

This chapter also employs a multidisciplinary research approach to address site-specific compliance requirements for double-wing expandable container homes in Hawke's Bay, New Zealand. It begins by reviewing existing literature, including the New Zealand Building Code (NZBC) and related standards like NZS 1170 and NZS 3604:2011, to establish baseline compliance criteria for seismic, wind, and durability requirements. Technical specifications from the container home's model are compared with NZBC standards to identify potential gaps in compliance, such as durability, thermal insulation, and moisture resistance. Quantitative methods are used to calculate seismic, and wind loads specific to Hawke's Bay's conditions, incorporating factors like peak ground acceleration, hazard coefficients, and historical weather data.

Secondary data sources, such as climate and hazard reports from the Hawke's Bay Regional Council and technical guidelines like the Central Hawke's Bay District Council's geotechnical investigation policies, are analysed to determine environmental challenges like flooding, soil liquefaction, and wind exposure. The study also utilizes engineering design principles to evaluate the structural integrity and performance of the container home under these conditions, proposing adaptations such as raised foundations and enhanced waterproofing. Compliance with accessibility, fire safety, and energy efficiency standards is assessed using technical documentation, product specifications, and relevant regulatory requirements. Together, these methods provide a robust framework for tailoring container home designs to the specific environmental and regulatory challenges of Hawke's Bay.

6.3. Evaluating system mass compliance for double-wing expandable foldable container homes in New Zealand

System Compliance refers to the process of ensuring that a building system or product meets all regulatory and performance standards across its intended applications, allowing it to be widely approved for use without the need for site-specific compliance checks each time it is installed. For housing, system compliance involves meeting structural, durability, fire safety, energy efficiency, and other critical standards as outlined in the New Zealand Building Code. Achieving system compliance enables a product to be deemed fit for use in multiple locations, subject to minor adjustments for local conditions, thus streamlining approval processes and enhancing its adaptability across diverse environments.

In New Zealand, mass compliance for housing primarily involves meeting structural and building code standards that ensure homes are safe, resilient, and meet the country's seismic and environmental requirements.

All building work in New Zealand must comply with the **NZBC**. Relevant sections for mass compliance include:

6.3.1. Structural safety (clause B1 - structure)

This clause is used to ensure that buildings can withstand loads including wind, earthquakes, snow, and other natural forces. For container homes, meeting these standards is crucial, especially in earthquake-prone and high-wind areas like Hawke's Bay. The performance criteria demand that structures have a low probability of rupturing, becoming unstable, or collapsing, as well as a low probability of causing loss of amenity due to undue deformation or degradation. It also emphasizes the need to account for various physical conditions affecting stability, such as gravity loads, temperature, wind, earthquakes, and other environmental factors. Additional considerations include the consequences of failure, the intended use of the building, and the effects of uncertainties in construction activities. Proper sitework is also essential to ensure stability during construction and prevent damage to surrounding property. Lastly, the demolition process must avoid premature collapse, and sitework should account for changes in ground conditions and environmental factors.

6.3.1.1. Seismic performance

Structures must be designed to withstand seismic forces based on the location’s seismic zoning.

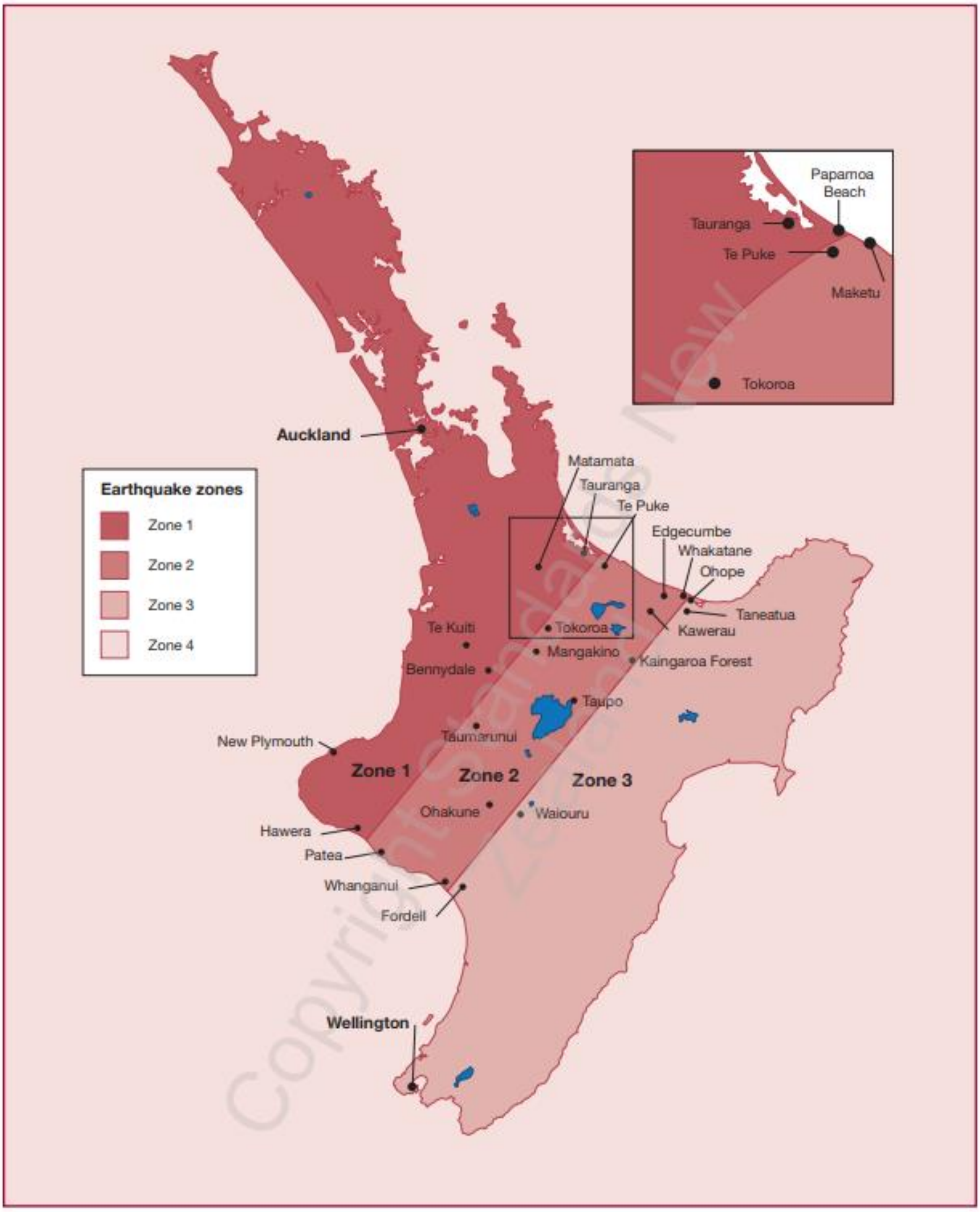

Fig.40 Earthquake Zones according to NZS 3604:2011 “Timber-Framed Buildings” (https://www.standards.govt.nz/shop/nzs-36042011)

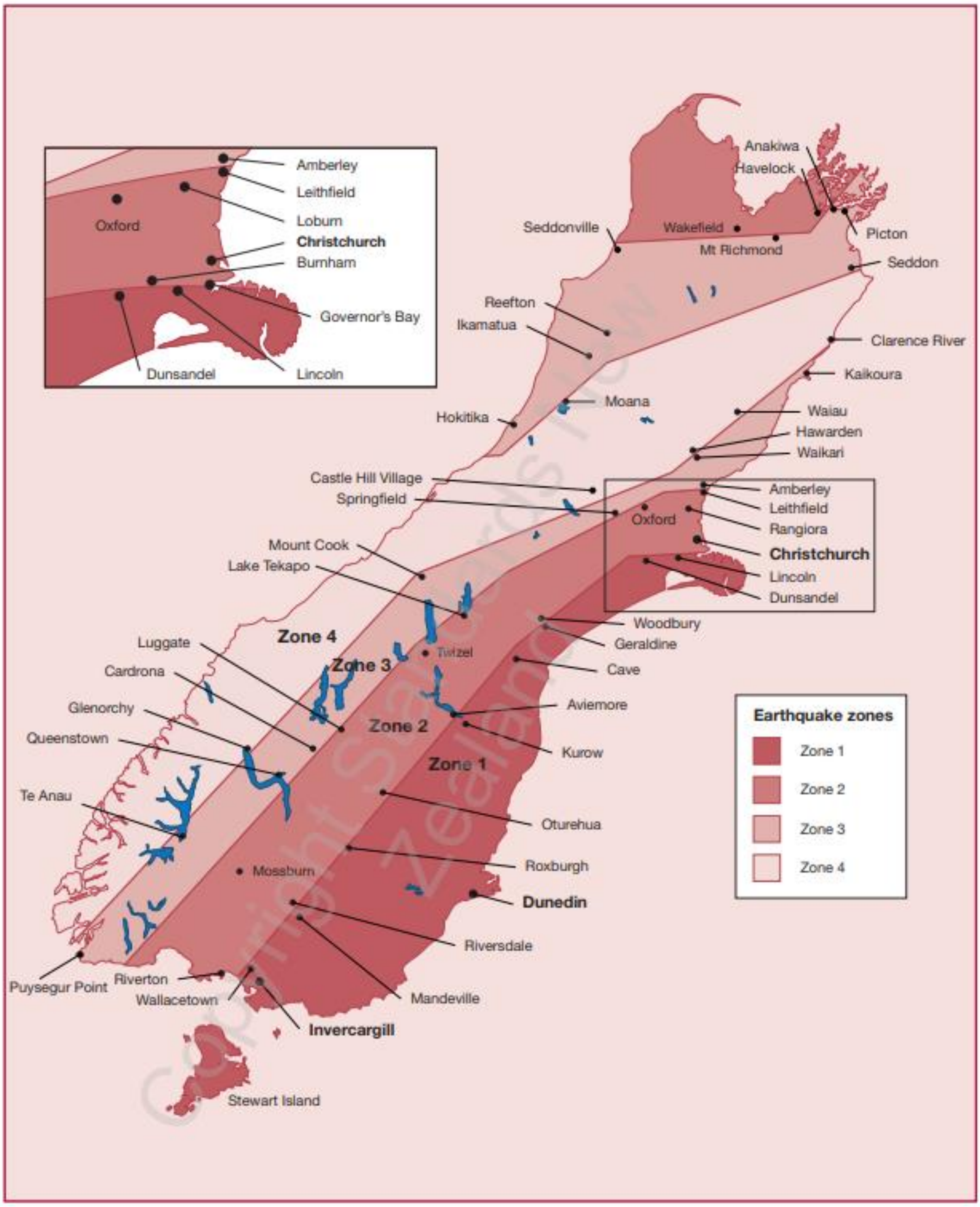

Fig.41, Earthquake Zones (continued) according to NZS 3604:2011 “Timber-Framed Buildings” (https://www.standards.govt.nz/shop/nzs-36042011)

In New Zealand, seismic resistance values are determined by several factors, including the location’s seismic risk zone, the type of structure, and its intended use.

The New Zealand Building Code (NZBC) Clause B1 (Structure) requires buildings to be designed and constructed to withstand seismic forces as specified by the New Zealand Standards, particularly NZS 1170.5 for earthquake loading. New Zealand is divided into different seismic zones, with Zone 1 (Northland) having the lowest seismic risk and Zone 4 (Wellington and Marlborough) having the highest. Each zone has corresponding earthquake hazard factors that influence design calculations.

Hazard Factors (Z):

- Zone 1: Low (e.g., Northland) - Hazard factor (Z) around 0.13
- Zone 2: Medium-Low (e.g., Auckland) - Hazard factor 0.16
- Zone 3: Medium (e.g., Christchurch) - Hazard factor 0.30
- Zone 4: High (e.g., Wellington) - Hazard factor 0.40

These hazard factors modify the intensity of ground acceleration that a structure is designed to withstand.

The NZBC requires different levels of structural resistance depending on the importance level of a building:

- **IL1**: Low-risk structures (e.g., agricultural buildings) - Minimal seismic requirements.
- **IL2**: Standard structures (e.g., residential homes) - Designed for 1-in-500-year seismic events.
- **IL3**: Higher-risk structures (e.g., schools, hospitals, assembly halls) - Designed for 1-in-1,000-year seismic events.

According to the double-wing foldable expandable container home, the seismic resistance is Grade 10. The grading system in China ranges from Grade 1 (low resistance, typically for structures not critical to human safety) to Grade 10 (very high resistance). Grade 10 buildings are designed to withstand extreme seismic events, similar to New Zealand’s IL3. New Zealand's system is more detailed in considering different performance levels and the intended use of the building (importance level), while China’s grading system is more focused on the structural capacity to resist seismic forces. Therefore, the specific model we have chosen for the housing recovery in Hawke’s Bay after the Cyclone Gabrielle impact has mass compliance in terms of earthquake resistance according to NZBC.

6.3.1.2. Wind loads

Buildings must resist wind loads specific to their geographic location.

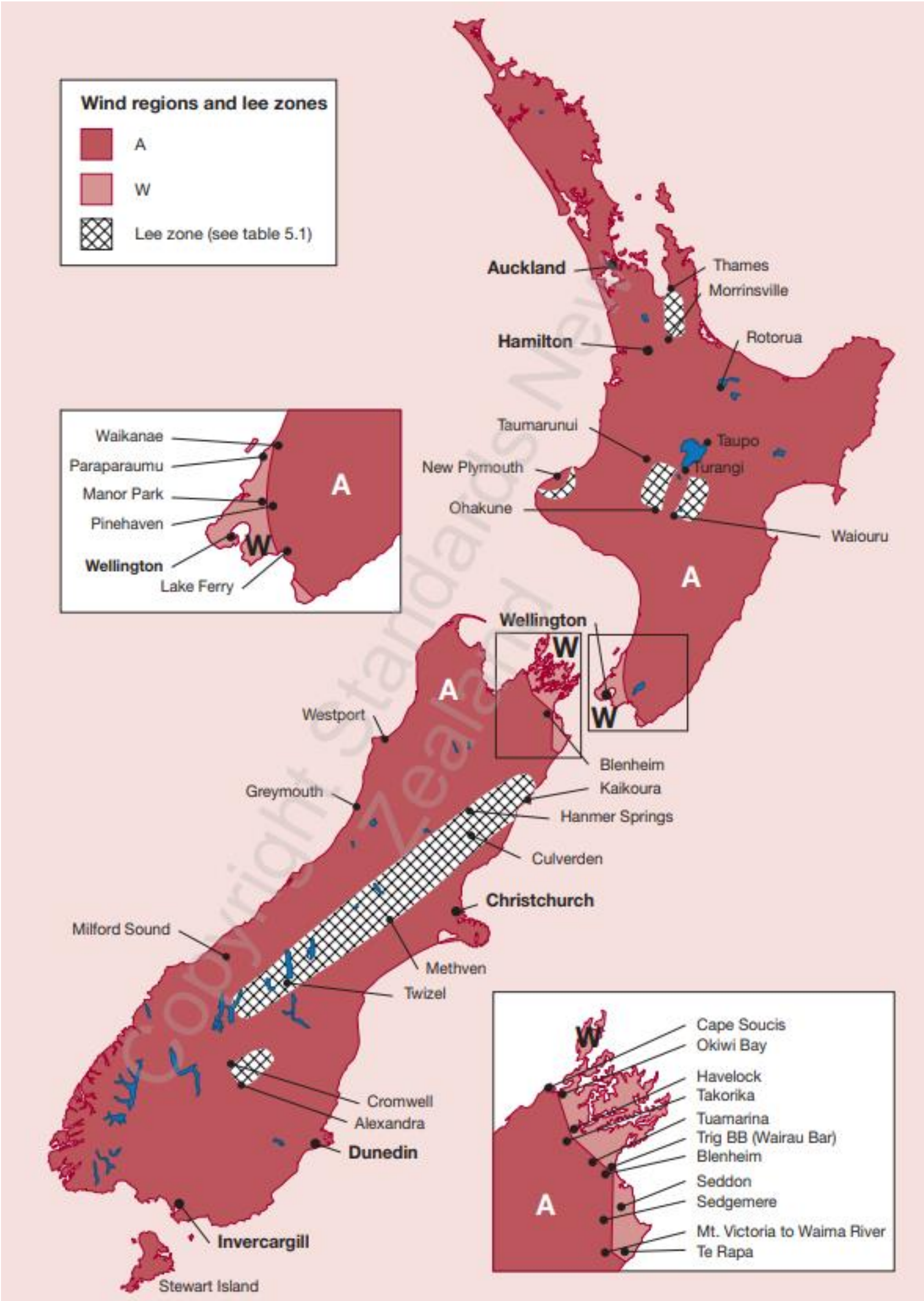

Fig.42 Wind Zones in New Zealand according to NZS 3604:2011 "Timber-Framed Buildings" (https://www.standards.govt.nz/shop/nzs-36042011)

New Zealand classifies wind zones into six distinct categories, each associated with specific wind speeds:

1. Low: Wind speeds below 32 meters per second.
2. Medium: Wind speeds below 37 meters per second.
3. High: Wind speeds below 44 meters per second.
4. Very High: Wind speeds below 50 meters per second.
5. Extra High: Wind speeds below 55 meters per second.
6. Specific Design: Wind speeds exceeding 55 meters per second.

Wind speeds in these zones are specified in the NZS 1170.2: 2020 standard, and the required wind design is calculated based on local factors such as building height, location, and exposure.

According to the double-wing foldable expandable container home, the Wind resistance is 120 km/h which is about 32.5 m/s or 116 km/h. In New Zealand, this level of resistance might be acceptable for low-wind or moderate-wind areas but would be insufficient for more exposed areas like Wind Zone 4 or Wind Zone 5, where building design must account for higher wind forces. New Zealand's higher wind zones (especially Zones 4 and 5) require homes to be able to resist much stronger wind speeds—potentially over 200-300 km/h, which is typical in areas affected by cyclones or severe storms.

As mentioned in the research methodology of this paper, this is one of the challenges of this model especially to implement in the areas of Hawke's Bay after Cyclone Gabrielle as Cyclone Gabrielle's peak sustained winds were around 150 km/h, which is approximately 41.7 m/s. The gusts reached up to 220 km/h, which is about 61.1 m/s.

6.3.2. Durability (clause B2 – durability)

This clause is used to ensure that the building components last without significant maintenance, ideally for the lifetime of the structure. The key requirements include:

Material Lifespan: Materials must be durable based on their use in various environments.

Corrosion Resistance: Requirements for steel and other materials in coastal or humid areas. Containers used in coastal areas like Hawke's Bay need added protection against corrosion.

In New Zealand, modular or prefabricated homes are generally expected to meet similar durability standards as traditional buildings, with a typical lifespan expectation of 50 years or more. This aligns with the New Zealand Building Code (NZBC), which sets durability requirements for structural components to last at least 50 years for permanent buildings.

According to the double wing foldable expandable container home, the life span is more than 30 years. In China, when the lifespan of a modular residential house is stated to be more than 30 years, it generally means that the house is designed, constructed, and maintained to remain structurally sound and safe for at least 30 years. This lifespan is determined based on materials, construction methods, and the durability of modular components. Even though the durability of the model has been mentioned as more than 30 years, there is no comment whether it covers 50 years durability. The 50-year durability requirement in New Zealand reflects a commitment to high structural resilience and aligns with the standards for permanent residential construction, aiming to provide safe, durable housing across diverse environmental conditions.

6.3.3. Fire safety (clauses C1-C6 – protection from fire)

With this clause, it ensures minimization the risk of fire spread within buildings and allows safe evacuation. Fire Resistance Rating (FRR) where Walls and other elements must meet a certain fire resistance rating, commonly 30 to 120 minutes, depending on building use and location.

The NZBC specifies fire resistance ratings (FRRs) for building elements, which are critical in assessing the ability of a building to resist fire. These ratings are typically given in the format 60/60/60, meaning:

- 60 minutes of fire resistance for structural integrity
- 60 minutes of fire separation to prevent the spread of fire between spaces

- 60 minutes of insulation to limit heat transfer

For high-risk buildings or areas (like commercial buildings, multi-unit housing, etc.), the NZBC might require higher FRR ratings, such as 120/120/120.
According to the double wing foldable expandable container home, the fireproof grade of the model is A. In China, a Grade A fireproof rating for a container home means that the structure and materials used in the construction of the home are highly resistant to fire and can withstand fire exposure for a prolonged period without catching fire or significantly contributing to its spread. In terms of New Zealand’s fire safety standards, particularly under the New Zealand Building Code (NZBC), the fireproof rating of a container home (Grade A in China) can be understood by referencing the fire resistance rating (FRR), which specifies how long a building or component can withstand fire without losing structural integrity, functionality, or posing a risk to occupants. A Grade A fireproof rating in China, indicating non-combustible materials with high resistance to fire, would align with New Zealand's fire resistance standards if the materials used meet the NZBC Clause C fire resistance criteria, such as the Fire Resistance Rating (FRR) of 60/60/60 or higher for high-risk buildings or residential areas.

6.3.4. Energy efficiency (clause H1 – energy efficiency)

This is to ensure that buildings maintain comfortable temperatures with minimal energy input, with standards varying across New Zealand’s six climate zones. Key Requirements:

- Thermal Insulation: Minimum R-values (insulation effectiveness) are required, which vary by climate zone (e.g., R 2.9 for walls in warmer zones, higher in colder zones).
- Building Envelope Requirements: Standards for floor, wall, ceiling, and roof insulation to reduce heat loss.

New Zealand has specific requirements for energy efficiency and thermal insulation as part of the Building Code (NZBC), especially under Clause H1 (Energy Efficiency).

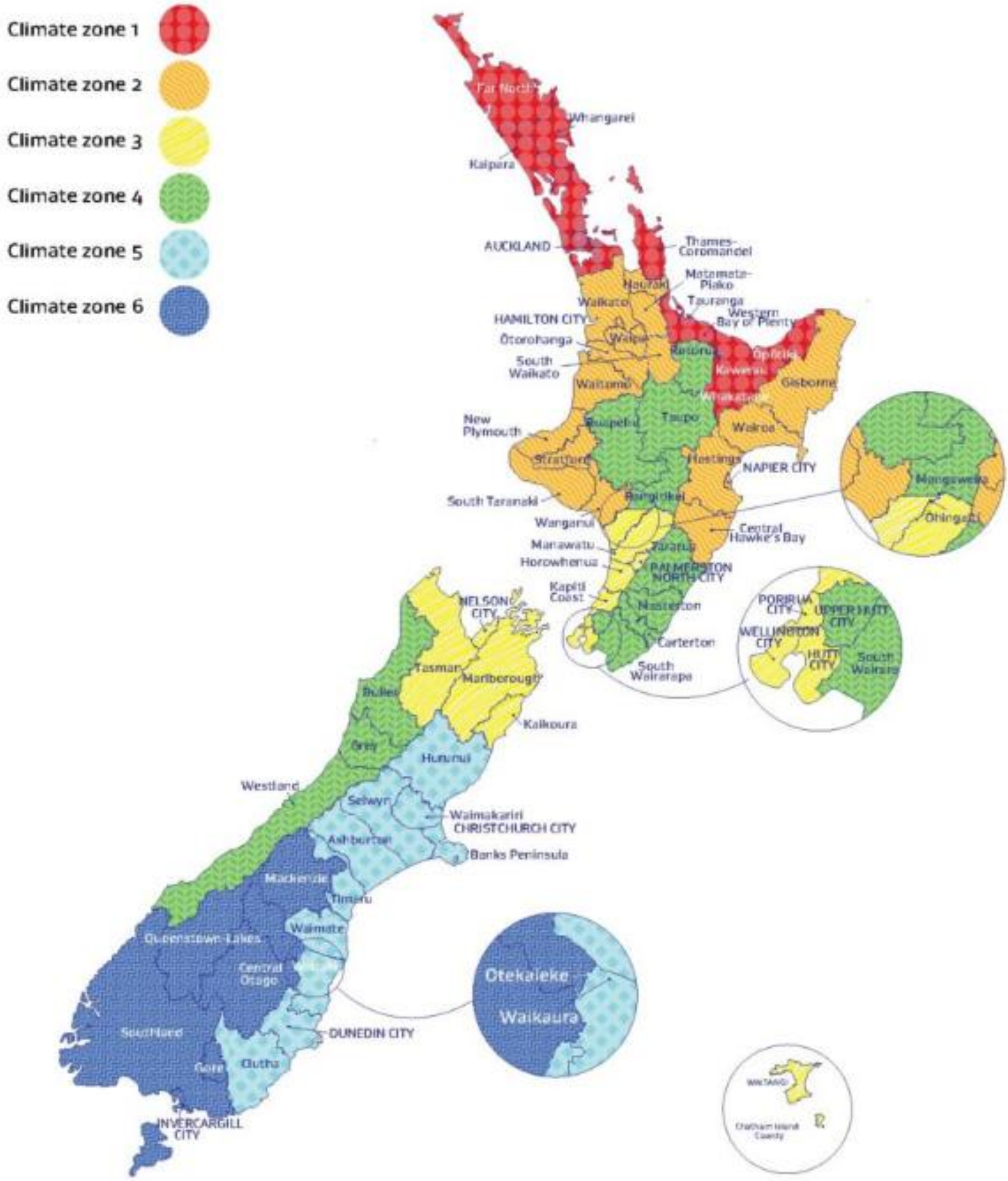

Fig.43 Energy efficiency zones in NZ (https://arcline.co.nz/new-nz-insulation-rules-2023/)

The insulation standards for buildings in New Zealand depend on the climate zone (since New Zealand has diverse climates, ranging from subtropical to temperate), but generally, the R-value requirements for residential insulation are as follows:

Roof Insulation: R-value of 2.9 to 3.6 for roofs in colder regions.

Wall Insulation: R-value of 2.0 to 2.9 for walls, depending on the region.

Floor Insulation: R-value of 1.3 to 2.0 for floors in colder regions.

These R-values are designed to ensure that buildings retain heat in colder months and prevent overheating in warmer months, contributing to energy efficiency and thermal comfort.

According to the double wing foldable expandable container home of China, the insulation material on the wall is 75mm sandwich board, color roll double-sided 0.35 (sandwich material is rock wool, EPS, optional) Standard sandwich material is12kg/m3 EPS.

To calculate the R-value (thermal resistance) for a sandwich panel with an EPS (Expanded Polystyrene) core material with the given information is as follows:

- Sandwich material: EPS (12 kg/m^3 density)
- Thickness: 75 mm (0.075 m)
- Thermal conductivity of EPS (λ): The typical thermal conductivity for EPS is around 0.035 W/m·K, but it can vary slightly based on the density. For EPS at a density of 12 kg/m^3, this value can be assumed to be around 0.035 W/m·K.

The R-value is calculated using the formula:

$$R = Thickness/\lambda$$

Where:

- Thickness is in meters
- λ is the thermal conductivity in W/m·K

For your EPS sandwich board:

$$R = 0.075/0.035 \approx 2.14 \text{ m2K/W}$$

Thus, the R-value for the EPS material in this sandwich panel is approximately 2.14 $m^2 \cdot K/W$. The R-value of 2.14 $m^2 \cdot K/W$ for the 75 mm EPS sandwich panel is moderate but may not fully meet New Zealand's Building Code requirements for wall insulation in all climate zones, especially in colder areas. If the R-value needs to be increased for specific climate zones or applications:

- Increase EPS thickness: Adding thickness can significantly boost the R-value.
- Alternative materials: Using materials with a higher R-value per unit thickness, like polyisocyanurate (PIR) or extruded polystyrene (XPS), may also help if feasible.

6.3.5. Standards supporting compliance - steel structures standard

NZS 3404 is the primary New Zealand standard for steel structures, particularly relevant for container homes involving steel frameworks. It specifies requirements for the design, fabrication, and erection of steel structures, ensuring they are safe, durable, and compliant with seismic and wind load requirements. The structural framework in the double wing expandable foldable container house including main beam, column, sub-frame, Box Lifting head, hinges, panels, etc are made of Galvanized cold formed steel Q235 with various thicknesses.

Q235 steel from China can potentially be used in New Zealand, but it must comply with New Zealand standards and codes. Q235 steel is a Chinese standard (GB/T 700), often equivalent to ASTM A36 or AS/NZS 3678 Grade 250 in terms of yield strength. However, any steel imported into New Zealand should comply with the relevant New Zealand standard, AS/NZS 3678 for structural steel. Material properties, such as chemical composition and mechanical strength, should be verified against this standard to confirm compliance. Q235 steel would need third-party verification, testing, or a detailed mill certificate confirming its mechanical properties, chemical composition, and performance to verify it meets New Zealand standards.

Any welding or fabrication done on Q235 steel complies with New Zealand’s AS/NZS 1554 standards for structural welding, as weldability and performance can vary between steel grades. Any use of structural steel in New Zealand must also meet the Building Code, specifically Clause B1 (Structure) and Clause B2 (Durability). The designer or engineer must confirm that the material, including Q235 steel, will perform as required over the structure's lifetime.

6.3.6. Standards supporting compliance - concrete structures standard

Concrete structures standard is relevant if containers are placed on concrete foundations. **NZS 3101** is indeed critical for concrete foundations in container home projects. This standard covers the design of concrete structures, focusing on aspects such as strength, durability, and stability, which are vital for foundations that will support container homes. For container homes, the foundation must withstand the load of the containers and provide stability against seismic and wind forces, especially in regions like Hawke's Bay with high seismic activity.

Using NZS 3101 will help ensure that concrete foundations are designed to perform well under stress, offering a secure base that enhances the safety and longevity of container homes. This will be an important aspect of demonstrating compliance with New Zealand building codes in your study.

The foundation of double wing foldable and expandable container homes are either on:

Concrete Slab: A concrete slab foundation is a popular choice. It involves pouring a concrete pad that provides a level and stable surface for the containers. It's essential to ensure the slab is level and properly reinforced to support the weight of the containers.

Concrete Piers: Concrete piers are another option, where the containers rest on a series of individual concrete footings. Piers can be a cost-effective choice and are suitable for areas with uneven terrain.

There should always be a check needed with the local building authorities and adhere to building codes and regulations regarding foundations for container homes. Regulations can vary from one location to another, and compliance is crucial to ensure safety and legality.

6.4. Site-specific compliance requirements for double-wing expandable container homes in Hawke’s Bay based on the New Zealand building code

Site-specific compliance is tailored to a particular location's unique environmental and regulatory requirements. This approach assesses how the structure will perform under specific conditions at the exact site where it will be installed. It ensures the system or structure will perform optimally given local hazards, soil conditions, climate factors, and council-specific requirements. For example, installing a container home in Hawke’s Bay, New Zealand, would require compliance with local building codes that account for high seismic activity, wind loads, and specific council requirements. This compliance would likely involve additional testing or adjustments, such as stronger anchoring systems, enhanced insulation, or specific structural reinforcements. Site-specific compliance is more precise, offering a customized safety and performance level suited to local conditions, thus providing greater assurance for resilience against site-specific hazards.

For Hawke's Bay, New Zealand, site-specific compliance considerations based on the New Zealand Building Code (NZBC) would address the region's unique environmental conditions and regulatory requirements. Here are the primary site-specific compliance factors needed to consider container homes in Hawke's Bay.

The site-specific compliance also includes the consideration of system compliance. System compliance is a baseline that ensures your container home meets the general building code standards. However, when considering site-specific compliance, you need to adapt and refine the system based on local conditions, making system compliance a crucial part of meeting the broader site-specific requirements. Essentially, system compliance provides the structure, but site-specific compliance fine-tunes it to fit the local environment, ensuring safety, durability, and performance in a given location.

For instance, if the container home system meets basic wind load standards for general use, but Hawke’s Bay is a high-wind area, the system must be modified to meet the higher local wind load requirements. This means that while the system is compliant with general standards, it must be adjusted to comply with the specific site conditions.

6.4.1. Seismic performance (structure - B1)

Since Hawke's Bay is in a seismically active zone, seismic performance is critical. Hawke's Bay is in Seismic Zone 3 in New Zealand. This zone indicates a moderate to high seismic risk, which is important to consider when assessing the compliance of structures in the region. Seismic Zone 3 generally requires buildings to be designed to withstand moderate to strong earthquake forces.

The model focused in this research has seismic resistance of Grade 10. As mentioned previously, Chinese buildings with Grade 10 are highly resistant to seismic activities which is comparable to IL3 buildings in New Zealand. However, the grading system is not active in New Zealand in terms of seismic resistance. The NZS 1170.5 standard provides guidelines on how to calculate seismic forces based on the building's location, height, weight, and the importance level. These forces are applied to the building in the design phase to ensure the building can withstand the expected ground motion.

According to the model specifications, the building size is a Length 5900m, Width 6300m, Height 2480m, Weight is 2500 KG, Importance level is 3 (assumed), the building location is Hawkes Bay, New Zealand and the Hazard factor of Zone 3 is 0.30, then the seismic load calculations as follows:

Seismic Design Coefficient (S)

The seismic design coefficient S is calculated as:

S = PGA * Site coefficient * Importance factor

Where:

- PGA (Peak Ground Acceleration) = 0.30 (value for Hawke's Bay)
- Site coefficient = 1 (for a typical site)
- Importance factor = 1.25 (for an Importance Level 3 building)

Thus,

S = 0.30 * 1 * 1.25 = 0.375

Seismic Load Calculation (Base Shear)

The weight of the building W is given as 2500 kg. To convert it to Newtons (N):

$$W = 2500kg * 9.81 m/s2 = 24,525 N$$

Where:

S = 0.375

W = 24,525 N

R = 2.5 (assumed Response Modification Factor)

Substituting the values:

$$F = 0.375 * 24525 / 2.5 = 3669.38 N$$

With the updated site hazard factor of 0.30, the seismic load or base shear for the building in Hawke's Bay is approximately 3.67 KN. While the 3.67 KN seismic load is not inherently problematic, its adequacy depends on whether the design and materials of your double-wing expandable container home can withstand this force without compromising the building’s safety and functionality. A structural engineer should verify whether this load aligns with the building’s strength and the requirements of the New Zealand Building Code for the intended location, Hawke’s Bay.

6.4.2. Wind loads (structure - B1)

Hawke's Bay can experience strong winds, especially near coastal areas. NZS 1170 (Structural Design Actions) provides guidelines for determining site-specific wind loads.

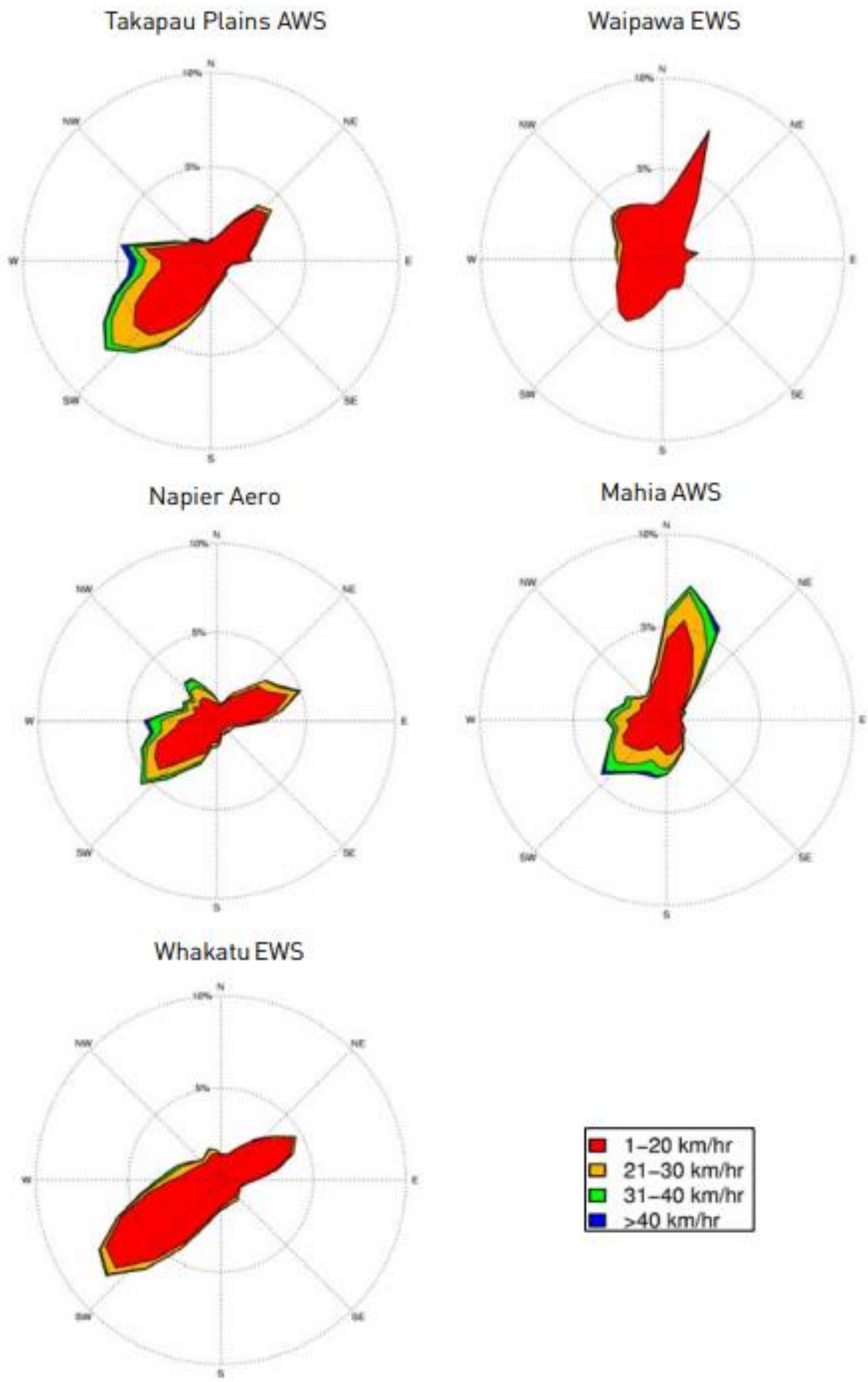

Fig.44 Mean annual wind frequencies (%) of surface wind directions from hourly observations at selected Hawke's Bay stations. The plots explain the directions from which the wind blows (https://www.hbrc.govt.nz/assets/Document-Library/Publications-Database/The-Climate-and-Weather-of-Hawkes-Bay.pdf)

The wind resistance of a double wing expandable and foldable container home is an average of 120 km/h. Mean annual wind frequencies (%) of surface wind directions from hourly observations at main Hawke's Bay stations according to NIWA science and technology series is an average of 40 km/hr. This would generally represent typical day-to-day weather conditions, and most buildings will be designed to withstand wind speeds higher than this average to ensure safety during more intense weather events.

However, Cyclone Gabrielle in Hawke's Bay reached up to 90 kilometers per hour, which is a significant increase from the typical mean wind speeds but still less than your container home's rated 120 km/h resistance, indicates that, during extreme weather events (like cyclones), wind speeds can be much higher than typical conditions. While 90 km/h is within the proposed container home's resistance capacity, it highlights the potential for stronger winds during severe weather events, especially when compared to the average annual wind speeds.

6.4.3. Fire safety (fire - C)

NZBC Clause C (Fire) covers fire safety standards, ensuring that buildings are designed to prevent fire spread, provide safe evacuation, and protect neighboring structures. For container homes, this might mean adding fire-rated materials, ensuring proper egress routes, and meeting specific requirements for insulation and cladding that are fire-resistant. Materials used in container modifications, such as internal partitions or insulation, need to meet fire compliance to prevent ignition and limit fire spread.

The double-wing foldable expandable container home has a fireproof rating of Grade A. In China, a Grade A fireproof rating signifies that the structure and materials used in the container home are highly fire-resistant, capable of withstanding prolonged fire exposure without igniting or significantly contributing to the spread of fire. In the context of New Zealand's fire safety standards, particularly under the New Zealand Building Code (NZBC), this Grade A fireproof rating can be interpreted through the Fire Resistance Rating (FRR), which outlines how long a building or component can resist fire while maintaining its structural integrity, functionality, and occupant safety. A Grade A fireproof rating in China, indicating non-combustible materials with high fire resistance, would be consistent with New Zealand's fire resistance requirements if the materials meet the NZBC Clause C criteria, such as achieving an FRR of 60/60/60 or higher for high-risk or residential buildings.

6.4.4. Durability (durability - B2)

NZBC Clause B2 (Durability) requires that buildings last the intended lifespan with minimal maintenance. Hawke's Bay's coastal and humid climate could accelerate material degradation, especially corrosion in steel structures. Coatings, corrosion-resistant materials, or weatherproofing would be necessary to ensure the container home's durability under local environmental stresses.

The double-wing foldable expandable container home is designed to have a lifespan exceeding 30 years. In China, when a modular residential home is said to have a lifespan of over 30 years, it typically means that the structure has been designed, constructed, and maintained with materials and methods that ensure it will remain structurally sound and safe for at least three decades. This estimate takes into account the durability of the materials, the quality of construction techniques, and the modular components used in the home. These factors contribute to a home that can withstand typical wear and environmental conditions over a long period.

However, while the container home is designed for a lifespan of more than 30 years, the specifications do not clarify whether the home is engineered to meet the higher durability standards that are often required for housing in regions like New Zealand. Specifically, New Zealand has a durability standard of 50 years for residential buildings, which reflects a more stringent expectation for long-term structural resilience. This 50-year requirement is a reflection of the country's commitment to providing permanent housing that can withstand diverse environmental conditions—such as extreme weather, seismic activity, and corrosion over time—while maintaining safety, functionality, and structural integrity.

In New Zealand, housing designed for long-term use is expected to meet the 50-year durability standard as outlined in the New Zealand Building Code (NZBC). This includes considerations for material performance under various environmental conditions, such as exposure to moisture, temperature fluctuations, and potential corrosion, particularly in coastal or high-risk areas. The NZBC Clause B2 outlines these requirements for durability, ensuring that homes are resilient enough to last for decades while maintaining their safety and livability. If the container home is to be used in New Zealand, its durability would need to be assessed against these local standards, which may include verifying whether the materials and construction methods used can withstand the harsher conditions or environmental factors present in New Zealand for up to 50 years.

Thus, while the model's lifespan of over 30 years is an indication of its durability, additional testing or certification may be required to demonstrate compliance with New Zealand's 50-year durability standard, particularly if the container home is intended for permanent residential use in diverse environmental conditions.

6.4.5. Moisture and weather tightness (external moisture - E2)

NZBC Clause E2 (External Moisture) requires buildings to resist rain, condensation, and moisture ingress. Given the high rainfall and potential for extreme weather in Hawke’s Bay, waterproofing measures like roof and wall sealing, adequate drainage, and moisture barriers are essential. Containers should be designed to prevent leaks and water intrusion to maintain a dry and safe interior.

The double-wing expandable and foldable container homes have 9.999% waterproofing capacity. In China, when a product such as a container home or building material is described as having "9.999% waterproof," it generally means that the material or structure is highly resistant to water ingress, with a very low likelihood of water penetration under normal conditions. The figure of 9.999% suggests near-total waterproofing, indicating only a very tiny chance of failure or leakage.

NZBC Clause E2 - External Moisture covers the prevention of moisture entering a building from external sources (rain, wind-driven rain, etc.) and ensuring that the building envelope (roof, walls, windows, etc.) is designed and constructed to prevent water ingress. The performance criteria focus on ensuring that the building remains dry, and that water is safely directed away from the structure.

Watertightness and Durability would evaluate a structure’s watertightness using industry tests, where the building is subjected to controlled water exposure to assess whether any moisture enters the structure. The tests may involve spraying water or simulating rainfall conditions on the external surfaces and evaluating the interior for any signs of water leakage or damage.

Here are some of the main tests used to assess waterproofing and moisture resistance:

- Water Penetration Test (NZS 4211:2008) - This test measures how well a building material or assembly can resist water ingress under controlled conditions. In New Zealand, NZS 4211:2008 specifies the performance requirements for windows and doors, including resistance to water penetration.
- Water Tightness Test (BS EN 1027:2016 or AS 2047) - This is another test commonly used in New Zealand for windows and external doors, but can also apply to other building materials.
- Moisture and Condensation Control Testing - To assess the moisture resistance of materials like steel or insulation, moisture meters are used to measure the moisture content within materials.
- Wind-Driven Rain Test - This test simulates high winds and rain exposure, which can force water into building materials and joints. The structure or material is subjected to wind-driven rain under high-pressure conditions.
- Vapour Permeability Test (ASTM E96 or NZS 4211) - This test measures how easily water vapor can pass through a material, which is important for controlling condensation within walls, roofs, and ceilings.
- Corrosion Resistance Test (AS/NZS 2312) - The corrosion resistance of materials (e.g., steel) is tested under accelerated conditions (such as salt spray) to simulate exposure to harsh weather environments.
- Durability and Performance Testing - This can include accelerated aging tests where materials are subjected to conditions mimicking years of exposure to weather elements (e.g., UV exposure, rain, temperature fluctuations).

6.4.6. Thermal insulation and energy efficiency (energy efficiency - H1)

NZBC Clause H1 (energy efficiency) addresses insulation and heating efficiency, important for occupant comfort and sustainability. Insulation levels for container homes in Hawke's Bay should meet or exceed standards for energy efficiency, as the region experiences a range of temperatures. Considerations include appropriate insulation for walls, floors, and roofs, possibly exceeding typical levels due to the thermal conductivity of steel.

The double-wing foldable expandable container home in China uses a 75mm sandwich board with an EPS (Expanded Polystyrene) core for wall insulation. The R-value for this insulation material is approximately 2.14 $m^2 \cdot K/W$, which provides moderate thermal resistance. However, this R-value may not fully meet New Zealand's Building Code requirements for wall insulation in colder climates, where higher R-values are generally required. To improve insulation performance, options include increasing the EPS thickness or using alternative materials like polyisocyanurate (PIR) or extruded polystyrene (XPS), which offer higher R-values per unit thickness.

6.4.7. Access and accessibility (access - D1)

NZBC Clause D1 (Access Routes) ensures safe and easy access within and to the building. Especially for post-disaster housing, making the container home accessible for all users, including people with disabilities, may be necessary. Considerations might include ramps, doorway sizes, and bathroom layouts suitable for accessible design.

In New Zealand, for accessibility, the minimum clear width for doors on accessible routes is generally at least 760 mm (for a single-leaf door) with height between 198 cm and 210 cm to allow wheelchair access, but wider doors are often preferred. There is no upper limit for door width, though excessively wide doors might not be practical for regular residential use. There are no specific minimums for window size, but emergency egress windows (for escape during emergencies) must have a minimum clear opening of 0.33 m^2 and a minimum dimension (height or width) of 500 mm.

The door size of the double wing foldable and expandable container home is Width 160 cm, Height 220 cm and the window size is Width 80 cm, Height 180 cm, comply with New Zealand’s Building Code requirements for residential buildings in terms of accessibility and egress.

6.4.8. Foundations and soil conditions (structure - B1 and B2)

Hawke's Bay’s soil varies, and some areas may have soft or liquefiable soil, particularly near riverbanks or reclaimed areas. A geotechnical assessment might be necessary to determine the soil's load-bearing capacity. Foundations should be designed to account for potential liquefaction or settlement, especially for post-disaster applications where resilience to ground instability is crucial.

The Central Hawke’s Bay District Council issued a policy manual on August 15, 2019, called Guidelines for Geotechnical Site Investigation. It provides requirements for conducting geotechnical site investigations when applying for building or subdivision/land use consents. The purpose is to ensure applicants meet standards in the Building Act 2004 and Resource Management Act 1991, along with specific guidelines from the Ministry for the Environment and the Ministry of Business, Innovation and Employment. Failure to adhere to these guidelines may result in applications being returned for additional information.

Geotechnical investigations are required to provide adequate information to assure the council of site suitability for building and subdivision. These investigations should ideally be carried out by a Chartered Professional Geotechnical Engineer. Such reports are particularly critical in areas susceptible to hazards such as liquefaction, subsidence, fault lines, coastal hazards, flooding, and landslides. The policy outlines relevant legislation, including the Resource Management Act, which mandates thorough assessment of natural hazards in subdivision processes. It also references Section 71/72 of the Building Act 2004, which allows building authorities to consider natural hazards during consent processing. Additional guidelines for ground conditions and foundation requirements are cited from NZS 3604:2011 and Ministry guidance on liquefaction-prone land.

Specific types of building consent applications, such as those for new habitable buildings, relocated structures, large additions, and properties in hazard zones, require a geotechnical review. Exemptions apply to minor structures like pole sheds, standalone garages, and carports. The type of soil, potential hazards, and modifications to building platforms determine the scope and type of investigation needed, with requirements varying based on site conditions.

For subdivisions, especially those with identified hazards or location challenges (like slopes or proximity to watercourses), a detailed geotechnical report is mandatory. Such reports must evaluate soil type, bearing capacity, subsurface conditions, and any relevant site hazards. Larger subdivisions with five or more sites require in-depth testing for each plot to confirm suitability for future construction. The foundation for double-wing foldable and expandable container homes can be set up using either Concrete Slab or Concrete Piers. In all cases, it's essential to consult with local building authorities and follow the applicable building codes and regulations for container home foundations, as these requirements can vary by location.

6.4.9. Flooding and inundation risk (hazard management)

Some parts of Hawke's Bay are prone to flooding, which became evident during Cyclone Gabrielle. If located in a flood-prone area, the container home design may need to include raised foundations, drainage planning, or flood-resistant materials to minimize flood damage and facilitate faster recovery after a flood event.
The foundation of the model is resting on concrete slabs or piers. In Hawke's Bay, container home foundations on concrete slabs or piers can be adapted to withstand flooding by elevating the structure, reinforcing materials, and implementing water management strategies. Raising the foundation, either by lifting it on concrete piers or constructing a raised slab, helps ensure that the container sits above typical flood levels, which is essential in flood-prone areas. A concrete slab can be further strengthened by applying waterproof coatings and incorporating perimeter drainage systems like French drains or sump pumps to manage water flow, preventing water from pooling around the foundation. Flood vents or breakaway panels are additional options that allow floodwater to pass through safely without creating hydrostatic pressure, which could otherwise damage the structure. Anchoring the container home to the foundation with steel tie-downs provides stability, preventing displacement during significant flood events.

To protect against erosion, which can compromise foundation stability, materials like riprap or concrete collars can be added around the base, particularly important for homes on uneven terrain or slopes. Landscaping and site grading also play key roles; directing water flow away from the foundation helps mitigate the impact of heavy rain or flooding. Permeable surfaces, such as gravel or natural vegetation, around the home allow for gradual water absorption, reducing runoff that could otherwise pool near the structure. Using water-resistant, reinforced concrete ensures long-term durability, while regular inspections and maintenance—especially after heavy rains—

keep drainage systems effective and the foundation secure. Together, these measures provide a comprehensive approach to managing flood risk and enhancing the resilience of container homes in Hawke’s Bay.

6.5. Chapter summary

The evaluation reveals both strengths and areas for improvement in achieving mass compliance for the container home model in New Zealand. Structurally, the model's Grade 10 seismic resistance aligns well with New Zealand's IL2 and IL3 standards, but its wind resistance capacity of 120 km/h may not be sufficient for high-wind zones like those in Hawke's Bay. In terms of durability, the model's stated lifespan of 30 years falls short of New Zealand's 50-year standard, requiring enhancements to address long-term performance and corrosion risks in coastal areas. Fire safety is promising, with the Grade A fireproof rating suggesting a high level of resistance, but further validation is needed to confirm alignment with NZBC fire resistance requirements. For energy efficiency, the EPS sandwich panels provide moderate insulation (R-value of approximately 2.14 $m^2 \cdot K/W$), but this may require upgrades to meet the insulation standards of colder regions in New Zealand. Finally, the materials used, such as Q235 steel and concrete foundations, must comply with local standards like NZS 3404 and NZS 3101 to ensure safety, durability, and stability. These findings provide critical insights into the model’s current compliance levels and areas requiring adaptation to enhance its viability as a post-disaster housing solution in New Zealand.

This chapter outlined various site-specific compliance requirements essential for deploying double-wing expandable container homes in Hawke’s Bay, New Zealand. Starting with seismic performance, the chapter calculated seismic loads using regional hazard factors and NZS 1170.5 standards, highlighting the importance of designing structures to withstand moderate to strong earthquakes. Wind resistance was also assessed, noting that the container home’s wind tolerance is adequate for average conditions but must be reviewed for extreme events like Cyclone Gabrielle.

Fire safety considerations emphasized the adaptation of fire-resistant materials to meet NZBC Clause C requirements, while durability evaluations pointed to the need for enhanced corrosion protection and weatherproofing to meet New Zealand’s 50-year residential lifespan standard. Moisture resistance and waterproofing were analyzed, drawing on the model's near-total waterproof rating to ensure compliance with Clause E2 for external moisture. Thermal insulation and energy efficiency, governed by Clause H1, were discussed with recommendations to upgrade the insulation R-value to suit New Zealand's climate. Accessibility standards, as per Clause D1, were also evaluated, confirming the adequacy of the container home's door and window sizes for compliance.

Lastly, geotechnical and flood risk assessments underscored the importance of foundations tailored to local soil conditions and flooding risks. Raised concrete foundations, reinforced materials, and drainage strategies were identified as critical measures to enhance flood resilience. Through these analyses, the chapter points to many challenges for adapting these modular container homes to Hawke's Bay's unique conditions, because of the adequacy of the compliance with NZBC.

CHAPTER 7

KEY CHALLENGES FOR DOUBLE WIND EXPANDABLE FOLDABLE CONTAINER HOMES

7.1. Chapter introduction

Double-wing foldable and expandable container homes present an innovative and efficient housing solution, particularly for rapid deployment in disaster-affected areas. Their compact design, transportability, and ease of assembly offer significant advantages, such as cost-effectiveness and adaptability. However, implementing these homes in New Zealand faces several challenges due to the country's stringent building codes, diverse climate zones, and unique environmental risks, including seismic activity, high wind speeds, and flooding. This study explores the key challenges and compliance requirements associated with deploying these homes, using Hawke's Bay as a case study.

7.2. Research methods

This study employs a comprehensive approach to evaluate the implementation challenges of double-wing foldable and expandable container homes in New Zealand, particularly in Hawke's Bay. Data collection began with a thorough review of manufacturer documentation provided by Hebei JiaCheng Integrated Housing Co., Ltd. This included floor plans, compliance test reports, product brochures, and certifications. These documents were analysed to understand the design specifications, material properties, and performance claims of the container homes. However, key details, such as connection drawings and precise material grades, were found to be incomplete or not aligned with New Zealand's requirements.

Additionally, consultation with a structural engineer played a critical role in assessing the container home's structural integrity against New Zealand standards. The engineer evaluated the seismic, wind, and foundation design aspects using the manufacturer's information and identified gaps that needed further clarification or local testing. This included a focus on compliance with New Zealand's stringent standards, such as NZS 1170.5 for seismic resilience and the Producer Statement (PS1 and PS4) requirements for structural stability and construction accuracy.

A literature review of New Zealand's Building Code (NZBC) provided the regulatory framework for assessing container homes. Key clauses, including Clause B1 (Structure), Clause C (Fire Safety), Clause E2 (External Moisture), and Clause H1

(Energy Efficiency), were examined to identify compliance gaps and areas needing design modification. This review also highlighted the challenges posed by New Zealand's diverse climate zones, environmental hazards, and high durability standards.

Finally, hazard-specific assessments were conducted to evaluate the container home's resilience to local risks, such as earthquakes, high wind speeds, and flooding. These assessments considered site-specific factors in Hawke's Bay, including seismic zone classification, historical wind speeds, and soil conditions prone to liquefaction and flooding. The findings emphasized the importance of localized design adaptations to ensure safety and functionality under New Zealand's unique environmental conditions.

This multi-method approach ensures a holistic evaluation of the container homes' feasibility and compliance with local building standards, providing a robust foundation for the research.

7.3. Key challenges in implementing double-wing foldable and expandable container homes in New Zealand

Double-wing foldable and expandable container homes offer several compelling advantages, making them an attractive solution in New Zealand's housing landscape, particularly for regions needing rapid recovery options, like areas affected by natural disasters. These homes can be deployed quickly and transported easily, often reaching sites that are difficult for conventional construction. The foldable and expandable design also means they can be compact during transport, reducing logistics costs and simplifying delivery to remote or disaster-affected areas. Once on site, these homes can expand into larger living spaces, offering flexibility in layout and functionality. Additionally, they are usually made from durable materials like steel, which contribute to their strength and resilience against environmental wear, extending the potential lifespan of the structure. Cost-effective, versatile, and easy to assemble, these homes are well-suited for temporary or transitional housing and can be adapted for various uses.

Despite these advantages, there are significant challenges to implementing double-wing foldable and expandable container homes in New Zealand. First, New Zealand’s stringent building codes demand high standards for structural integrity, particularly in areas prone to seismic activity, which is a major factor in the design of all structures in the country. For example, container homes need to meet specific requirements to withstand earthquake and wind loads, which may require additional structural reinforcements or design adjustments. The country’s diverse climate zones present further challenges, as insulation and thermal performance requirements differ from one region to another. For instance, the cold winters of the South Island necessitate higher insulation standards, which may exceed the typical specifications of container homes and could require modifications to the design or materials used. Compliance with energy efficiency standards, fire safety, and accessibility also adds layers of complexity, as container homes may need specialized insulation, fireproof materials, and accessible design features to align with New Zealand's building code. Additionally, local authorities in high-risk areas like Hawke’s Bay often have specific regulations for flood-resistant foundations, meaning container homes in these zones must incorporate elevated foundations, drainage, or other flood mitigation measures.

the key challenges in implementing Hebei Jia Cheng’s double-wing foldable and expandable container homes in New Zealand is as follows:

7.3.1. Seismic adaptation and compliance

New Zealand's high seismic standards require designs capable of withstanding moderate to strong earthquakes, especially in seismic zones like Hawke's Bay (Zone 3). The Chinese seismic grading (Grade 10) may not align directly with New Zealand’s NZS 1170.5 standard, which involves complex calculations considering local hazard factors, structural importance, and specific force distributions. Literally, we have assumed here that Grade 10 container houses of China are comparable to the IL3 buildings of New Zealand. Adapting the container home to fully meet these standards may require additional structural reinforcement and validation.

According to the assumed calculation, with the updated site hazard factor of 0.30, the seismic load or base shear for the building in Hawke's Bay is approximately 3.67 KN. While this seismic load is not inherently problematic, its adequacy depends on whether the design and materials of your double-wing expandable container home can withstand this force without compromising the building's safety and functionality. It is essential to have a structural engineer verify that this load is compatible with the building's structural integrity and meets the requirements of the New Zealand Building Code for the Hawke's Bay area.

The key challenge here is proving the earthquake resistance grade as 10, due to the lack of supporting documents from the Chinese manufacturer. Although the manufacturer possesses the relevant certification, it is in Chinese, and to obtain approval, it must first be translated into English and provided to the structural engineer. Despite the existence of certifications, New Zealand regulations require the design and testing to be conducted locally to ensure authenticity, as the certificates may have been assessed and verified only in China.

7.3.2. Wind load resistance

While rated for 120 km/h wind speeds, Cyclone Gabrielle in Hawke's Bay reached wind speeds of up to 90 km/h, which, although significantly higher than the typical mean wind speeds, is still below the container home's rated resistance of 120 km/h. This suggests that during extreme weather events, such as cyclones, wind speeds can far exceed typical conditions. While 90 km/h falls within the proposed container home's wind resistance capacity, it underscores the potential for even stronger winds during severe weather events, especially when compared to the average annual wind speeds.

However, many more wind hazards happened in New Zealand's history, thus the container home must withstand extreme wind events above 120km/hr. The NZS 1170 standard would likely require modifications to improve wind resistance, particularly for coastal or high-wind zones, possibly through enhanced anchoring, bracing, or the use of wind-resistant materials.

The key challenge here is the lack of English documentation to prove that the double-wing expandable and foldable container home has a wind resistance of 120 km/h on average. The manufacturer does possess a certification in Chinese, but it has not been translated into English, making it difficult to use for local verification in New Zealand. While the container home is rated to withstand wind speeds up to 120 km/h, the lack of an English version of the certification hinders the process of confirming this resistance following New Zealand regulations. The translation of the certification is essential to demonstrate compliance with local standards for extreme weather events.

7.3.3. Fire safety compliance

The Chinese Grade A fireproof rating may not directly align with New Zealand's Fire Resistance Rating (FRR), which requires specific ratings for walls, partitions, and other materials. Adapting to NZBC Clause C (Fire Safety) may involve verifying or upgrading fire-rated insulation, cladding, and materials to meet the FRR requirements, ensuring safe evacuation and limited fire spread. In the context of New Zealand's fire safety standards, particularly under the New Zealand Building Code (NZBC), this Grade A fireproof rating can be interpreted through the Fire Resistance Rating (FRR), which outlines how long a building or component can resist fire while maintaining its structural integrity, functionality, and occupant safety, however this is challenge for the model.

Like proving the seismic resistance and wind resistance, the key challenge for fire resistance is not only the lack of English documentation to prove the container home's fire resistance capabilities but also the requirement for local testing in New Zealand. Although the manufacturer has a certification in Chinese, which can be translated into English, New Zealand regulations mandate that the design undergoes local testing to ensure its authenticity and compliance with local fire safety standards. The translated certification alone is not sufficient to meet the regulatory requirements, and local testing is essential for approval.

7.3.4. Durability and longevity

NZBC mandates a 50-year durability standard for residential buildings, while the container home's projected 30-year lifespan might not suffice. Additional protective coatings, corrosion-resistant materials, or design modifications would be necessary to extend durability, especially for steel components in Hawke's Bay's humid and coastal environment.

The key challenge in proving the durability of the container home because of the difficulty in collecting the relevant certifications from the manufacturer. While the manufacturer provides some details on their company website, this is the only evidence available. However, New Zealand regulations require proper local testing to verify the durability of the materials and design. The information on the manufacturer's website is insufficient to meet the regulatory standards, and local testing is needed for compliance.

7.3.5. Moisture and weather tightness

High rainfall and extreme weather in New Zealand necessitate stringent waterproofing and drainage requirements to prevent moisture ingress. NZBC Clause E2 compliance would require rigorous testing and possible enhancements, like increased waterproofing measures, drainage systems, or vapor barriers, to withstand wind-driven rain and potential flooding.

The double-wing, expandable and foldable container homes are described as having 9.999% waterproofing capacity. In China, when a product, such as a container home or building material, is described as "9.999% waterproof," it typically indicates that the material or structure is highly resistant to water ingress, with an extremely low likelihood of water penetration under normal conditions. The figure of 9.999% suggests near-total waterproofing, implying only a minimal chance of failure or leakage. However, local testing in New Zealand may still be required to verify the performance of the waterproofing under local conditions because of the lack of certification to prove the same here.

7.3.6. Thermal insulation and energy efficiency

New Zealand's energy efficiency standards may demand higher insulation levels than those provided by the standard 75mm EPS panels used in China. Meeting NZBC Clause H1 may require insulation upgrades to achieve adequate R-values for walls, floors, and ceilings, ensuring thermal comfort in colder climates and energy efficiency.

The double-wing foldable expandable container home in China uses a 75mm sandwich board with an EPS (Expanded Polystyrene) core for wall insulation. The R-value of this insulation material is approximately 2.14 $m^2 \cdot K/W$, providing moderate thermal resistance. However, this R-value may not fully comply with New Zealand's Building Code requirements, particularly in colder climates where higher R-values are typically needed for sufficient thermal performance. To enhance insulation, options include increasing the EPS thickness or using alternative materials such as polyisocyanurate (PIR) or extruded polystyrene (XPS), which offer higher R-values per unit thickness and better insulation efficiency.

7.3.7. Foundation design and soil conditions

A significant challenge for the double-wing foldable expandable container homes in areas like Hawke's Bay is the varying soil conditions and the risk of liquefaction, which could affect the stability of the foundation. Given that some regions are prone to flooding and soil liquefaction, it is crucial to develop site-specific foundation solutions that can mitigate these risks.

A geotechnical assessment is necessary to determine the most suitable foundation types, such as reinforced slabs or piers, that can ensure the container home's stability in unstable or liquefiable soils. Without this detailed assessment and tailored foundation design, the safety and durability of the structure could be compromised, particularly in flood-prone or seismic areas where the ground may shift or lose strength.

7.3.8. Flooding and inundation risk management

Cyclone Gabrielle underscored the flood risks in regions like Hawke’s Bay, necessitating elevated and flood-resistant foundations.

The challenge in flood-prone areas of Hawke’s Bay lies in ensuring that the double-wing foldable expandable container homes can withstand potential flooding, especially given the region's vulnerability demonstrated during Cyclone Gabrielle. While the container home foundation rests on concrete slabs or piers, additional modifications are needed to adapt these foundations to flood risks. Raising the structure above typical flood levels is crucial, requiring elevation via piers or raised slabs. Additionally, flood-resistant measures like waterproof coatings, drainage systems, flood vents, and breakaway panels must be integrated into the design to manage water flow and prevent damage. Anchoring the home securely with steel tie-downs is necessary to avoid displacement during significant floods. Furthermore, erosion control, site grading, and the use of water-resistant materials are essential to preserve foundation stability.

The challenge lies in ensuring that all these adaptations are properly designed and implemented to meet the specific needs of flood-prone areas while complying with New Zealand building regulations, all while maintaining the home's structural integrity and resilience. Regular inspections and maintenance are also required to ensure that these flood mitigation measures remain effective over time.

7.4. Compliance assessment for double-wing expandable container homes as post-disaster housing in New Zealand

In my research, I have explored the compliance requirements for the double-wing expandable container home model, which is proposed as a potential post-disaster housing solution for Hawke's Bay, New Zealand, following Cyclone Gabrielle. To assess the structural integrity and compliance of this model with New Zealand's building standards, I consulted with a structural engineer, providing documents from the manufacturer, Hebei JiaCheng Integrated Housing Co., Ltd., including Floor plan of the model, The company brochure of Hebei JiaCheng Integrated Housing Co., LTD, the compliance test document (Report No: JC20240924001R-1) issued by JAT Physical & Chemical Lab for Hebei Jiacheng Integrated Housing Co., Ltd., concerning a "Container House (Prefab House), Product specifications, Interior customization brochure, the certificate of quality management system, the certificate of verification of conformity.

The structural engineer highlighted several key aspects required for certification under New Zealand's building code, specifically for the Producer Statement PS1 and PS4. The PS1 certifies that the design is structurally sound, while the PS4 confirms that the completed construction aligns with the approved design.

7.4.1. PS1 compliance requirements

Structural Stability Systems and Load Paths: To proceed with the PS1 certification, an in-depth understanding of the structural stability and load distribution systems of the container home is required. This includes how lateral loads (wind and seismic) are transferred through the building, particularly the role of the main central unit in providing stability. A clear description of how loads are transferred through the diaphragm action of the roof and walls is crucial.

Internal Wall Partition Contribution: The role of internal walls in the overall stability system of the final structure also needs to be clarified. In particular, it must be established whether these partitions are integral to stability or if they serve only as dividers.

Fabrication Drawings and Structural Components: Detailed fabrication drawings of the container home in its final configuration are needed, including specifics on the sandwich panels for the internal and external walls, as well as the roof. The engineer also requested connection details for the main and secondary frame elements, as well as how the sheeting/cladding is fixed. The manufacturer's brochure mentions the use of hinges for connections, and the engineer requested additional details to verify the performance of these connections under seismic wind loads.

Anchoring and Holding Down Arrangements: The foundation system must include holding down arrangements, especially given that the container home is likely to be anchored to a concrete slab-on-grade rather than timber bearers or piles. The engineer asked for detailed requirements on the anchoring system to ensure the structure remains secure during extreme weather events.

7.4.2. PS4 compliance requirements

For the PS4 certification, which confirms that the construction matches the approved design, the following documentation is required:

Material Grades: Certification confirming that the material grades used in the construction of the container home align with those specified in the design, ensuring their suitability for load bearing and durability.

Connection Details: Full documentation confirming that all connections for the structural elements have been executed as per the design. This may include test certificates, photographs of the connections, and screw layouts for the sheeting and cladding systems.

Final Holding Down Inspection: A final inspection of the holding down system will be required once the units are installed on-site in New Zealand. This inspection will be part of the site work and cannot be provided by the manufacturer.

7.4.3. Challenges and limitations

A significant challenge I encountered in advancing this project was obtaining all the necessary technical details from the manufacturer to meet New Zealand’s stringent compliance requirements. While the manufacturer provided some useful documentation, such as compliance test reports and floor plans, critical information, such as detailed connection drawings and material specifications, was lacking. This made it difficult to fully assess the compliance of the container home with New Zealand’s structural requirements.

The structural engineer also emphasized that while their focus is on structural compliance (PS1 and PS4), additional expertise is needed from other professionals to ensure that the container home meets all regulatory standards. These include:

- Planners, who will assess the project's environmental impact, zoning, and urban planning requirements.
- Architects, who will ensure the design is functional, aesthetically pleasing, and meet building code standards for space usage, accessibility, and energy efficiency.
- Fire Engineers, who will need to evaluate fire safety systems, material flammability, and emergency evacuation routes to ensure the safety of occupants in the event of a fire.

Thus, while structural compliance is a critical first step, the overall success of the container home model in New Zealand’s post-disaster housing market will also depend on securing input from a wider range of professionals to address non-structural aspects like fire safety, planning approvals, and design integration.

7.5. Research conclusion

The study of double-wing foldable container homes as a post-disaster housing solution for New Zealand reveals a promising, yet complex, pathway for addressing urgent housing needs in the wake of natural disasters. These container homes offer notable advantages in terms of cost-efficiency, rapid deployment, and structural integrity. Their modular, prefabricated design allows them to be easily transported to disaster sites and quickly assembled, which could accelerate the recovery process for communities in areas like Hawke's Bay affected by Cyclone Gabrielle. By offering a flexible, scalable alternative to conventional construction, container homes present a viable option to meet New Zealand's demand for resilient, temporary shelters.

However, implementing this solution in New Zealand also comes with specific constraints. Firstly, New Zealand's stringent building codes and compliance standards, aimed at ensuring seismic and weather resilience, introduce regulatory hurdles for deploying prefabricated housing units designed overseas. These homes must meet high standards for durability, insulation, and weather resistance, which can be challenging to achieve given the unique climate and environmental conditions across New Zealand's regions. For example, the structural adaptability of double-wing foldable models may not meet the necessary wind resistance and insulation requirements without significant modifications, particularly in areas prone to high winds and fluctuating temperatures.

In summary, while double-wing foldable container homes present a promising and innovative approach to post-disaster housing in New Zealand, their effective deployment will require addressing several significant constraints. These include adapting designs to New Zealand's climatic conditions, overcoming regulatory challenges, and ensuring a consistent supply chain to meet local needs. Without such adaptations, the widespread adoption of container homes may remain limited, particularly for medium- to long-term recovery housing. Addressing these barriers could enhance the practicality and resilience of container homes as a strategic component of New Zealand's disaster response and recovery framework, providing both immediate relief and potentially more robust housing options for future events.

7.6. Research recommendations

Adapting Designs for Local Climate: Given the varied climate across New Zealand, container homes should be adapted to include improved insulation and weatherproofing. Wind resilience, earthquake resistance, energy efficiency, durability, fire resistance in particular, must be addressed since the double-wing foldable model may have structural vulnerabilities in hazardous conditions, which are common in disaster-affected areas.

Navigating Regulatory Hurdles: Regulatory approvals, including PS1 (Producer Statement – Design) and PS4 (Construction Review), present delays in deploying container homes. Collaborating with local councils and regulatory bodies to establish standardized guidelines for prefabricated modular homes can help streamline this process, reducing bureaucratic delays that can hinder disaster recovery efforts.

Enhanced Local Production and Sourcing: Establishing partnerships with local manufacturers could mitigate dependency on overseas suppliers, making container homes more adaptable to local standards. This approach would also support local economies and potentially reduce costs associated with importing materials and prefabricated units.

Improving Community and Stakeholder Engagement: Effective deployment of container homes should involve early consultations with affected communities and stakeholders. Incorporating feedback from local communities can help ensure that these homes align with social and cultural needs, enhancing their acceptance as temporary or semi-permanent housing solutions.

Developing Customizable Modules: Given that each disaster-affected area may have unique needs, designing container homes with modular add-ons or customizable interiors could make them more adaptable. Features such as enhanced insulation, renewable energy integration, and adaptable layouts would better align with New Zealand’s housing requirements.

7.7. Areas of future research

Climate-Specific Modifications for Container Homes: Investigate materials, insulation methods, and structural modifications that would improve container homes' resistance to New Zealand’s diverse weather conditions, including heavy rainfall, humidity, and strong winds. This research would be crucial for developing climate-resilient prefabricated housing.

Various Testing: Conduct studies such as wind resistance, seismic resistance, durability, energy efficiency, waterproofing, fire resistance etc, for double-wing foldable models, as adverse weather conditions are frequent in New Zealand's disaster-prone areas. This would inform potential reinforcements or design changes that could make container homes more resilient in such environments.

Sustainability and Local Material Integration: Analyze the environmental impact of using container homes in disaster recovery, with a focus on sourcing materials locally. Research could explore the feasibility of integrating local materials, such as sustainably harvested wood or eco-friendly insulation, to improve environmental suitability while supporting local industries.

Long-term Health and Social Implications: Container homes are often designed as temporary shelters, but New Zealand's housing shortage may extend their use. Studies on the psychological and social impacts of prolonged living in container-based housing would provide insights into potential modifications to enhance comfort and reduce the risk of mental health challenges associated with long-term occupancy.

Cost Analysis and Economic Feasibility: A comprehensive cost-benefit analysis comparing container homes to traditional construction models under various disaster scenarios would help determine their viability. This research should factor in the lifecycle costs of container homes, including maintenance, insulation upgrades, and any retrofitting needed to comply with New Zealand's standards.

Appendices

Appendix A: Certificate of Verification of Conformity

Appendix B: Certificate of Quality Management System

Appendix C: Test Reports

Appendix D: Hebei JiaCheng Brochure

Appendix A

VERIFICATION OF CONFORMITY

S/N: 007561

No.: **ICR/VC/HE240115**

Name and address of Applicant
Hebei Jiacheng Integrated Housing Co., Ltd
West District of Economic Development Zone, Fucheng County, Hengshui City, Hebei Province, China

Name and address of manufacturer:
Hebei Jiacheng Integrated Housing Co., Ltd
West District of Economic Development Zone, Fucheng County, Hengshui City, Hebei Province, China

Product name: Folding container house

Product types: Folding house, mobile house, double wing expansion box, packing box room

Product trademark: n/a

Verification was carried within following scope:

Information on the Declaration of Conformity:

Result:	**Legislation:**	**Standard:**
✓	CPR	EN 1090-1:2009+A1:2011

The assessment process has been carried out in accordance with individual rules and conditions agreed with the applicant.
Evaluation has been carried out in accordance with:

Test report(s): CE-HR20240122-HBJC-1
Tests conducted by: Hebei Jiacheng Integrated Housing Co., Ltd

Issue date: 22.01.2024
Expiration date: 21.01.2029

Remarks:

- VoC was issued on voluntary basis and does not imply meeting all essential requirements listed in Declaration of Conformity.

ICR Co. Ltd.
www.icrqa.com
www.icrpolska.com
cert@icrqa.com

CEO, ICR Co., Ltd.

Edition: 5.1.0.B of 01.03.2023

Appendix B

CERTIFICATE OF QUALITY MANAGEMENT SYSTEM

Certificate No. **115423Q0414R0S**

This is to certify that

Hebei Jiacheng Integrated Housing Co., Ltd

Unified social credit code：91131128MA7F3LF10X

Registered address：West Zone, Fucheng County Economic Development Zone, Hengshui City, Hebei Province

Official address：No. 1, Shunda Street, West District, Fucheng County Economic Development Zone, Hengshui City, Hebei Province

Production/business address：No. 1, Shunda Street, West District, Fucheng County Economic Development Zone, Hengshui City, Hebei Province

The Quality Management System established conforms to the standard following

GB/T19001-2016/ISO9001:2015

The range of certification following

Manufacturing of containers (integrated houses)

Date of first issuance：August 04th,2023   Date of this issuance：August 04th,2023   Valid until：August 03rd,2026

Not included in the system coverage of multiple places shall not use the certification certificate and certification logo;
When the scope of certification involves the administrative license, qualification license and mandatory certification requirements required by laws and regulations, this certificate and the qualification requirements are valid for joint use;
The certified organization shall be subject to regular supervision and audit as required and pass the audit,The certificate shall remain valid.

Issuer:

LIAONING ZHUOXIN CERTIFICATION SERVICE CO., LTD.

1368,Floor 13,Dongji Building, No.1 Qishan Middle Road,Huanggu District, Shenyang,Liaoning Province,P.R.China
Tel:024-81076225   E-mail:zhuoxinrenzheng@126.com   Http://www.zhuoxinc.cn
The audit results and certificate information can be found at www.cnca.gov.cn of the national certification Or the company's official website or scan the QR code

Appendix C

Report No: JC20240924001R-1 Date: 2024-09-24 Page 1 of 11

Test Report

Applicant	:	Hebei Jiacheng Integrated Housing Co., Ltd.
Address	:	West Development Zone, Fucheng County, Hengshui City, Hebei Province

The following sample(s) was /were submitted and identified on behalf of the clients as:

Sample Name	:	Container House (Prefab House)
Trade Name	:	N/A
Sample Model	:	CC Series, SR Series, PC Series, GE Series, SC Series, LS Series, PT Series, AC Series, ZFC Series, FC Series, FPC Series, MC Series, M Series, E Series, V Series, S Series
Sample Received Date	:	2024-09-14
Testing Period	:	2024-09-14 to 2024-09-24
Test Requested	:	Selected test (s) in the selected parts as requested by client with the RoHS 2 Directive 2011/65/EU Annex II (EU) 2015/863 as last amended by Directive (EU) 2017/2102.
Test Method	:	Please refer to next page(s).
Test Result	:	PASS. Please refer to next page(s).

Signed for and on behalf of

Dongguan Jun'an Testing & Certification Co., Ltd. APPROVED

Tim You/ Approved Signatory

Dongguan Jun'an Testing & Certification Co., Ltd.
Add: Room 303, Building 1, No.316, Renzhou Road, Shatian Town, Dongguan City, Guangdong Province, China.
Tel: 0769-81710286 E-mail: wangzhao@junantest.com Website: www.junantest.com

Test Content:

Test Item(s)	Test Method	Reference	Unit	Limit	MDL
Cadmium(Cd)	IEC 62321-5:2013	ICP-OES	mg/kg	100	2
Lead(Pb)	IEC 62321-5:2013	ICP-OES	mg/kg	1000	2
Mercury(Hg)	IEC 62321-4:2013+AMD1:2017	ICP-OES	mg/kg	1000	2
Hexavalent Chromium(CrVI) (Metal)	IEC 62321-7-1:2015	UV-Vis	$\mu g/cm^2$	0.13	0.1
Hexavalent Chromium(CrVI) (Nonmetal)	IEC 62321-7-2:2017	UV-Vis	mg/kg	1000	8
PBBs (Next form)	IEC 62321-6:2015	GC-MS	mg/kg	1000	5
PBDEs (Next form)	IEC 62321-6:2015	GC-MS	mg/kg	1000	5
Dibutyl Phthalate(DBP)	IEC 62321-8:2017	GC-MS	mg/kg	1000	30
Butyl benzyl phthalate (BBP)	IEC 62321-8:2017	GC-MS	mg/kg	1000	30
Di-(2-ethylhexyl) Phthalate(DEHP)	IEC 62321-8:2017	GC-MS	mg/kg	1000	30
Diisobutyl phthalate (DIBP)	IEC 62321-8:2017	GC-MS	mg/kg	1000	30

PBBs		PBDEs	
Monobromobiphenyl	Hexabromobiphenyl	Monobromodiphenyl ether	Hexabromodiphenyl ether
Dibromobiphenyl	Heptabromobiphenyl	Dibromodiphenyl ether	Heptabromodiphenyl ether
Tribromobiphenyl	Octabromobiphenyl	Tribromodiphenyl ether	Octabromodiphenyl ether
Tetrabromobiphenyl	Nonabromobiphenyl	Tetrabromodiphenyl ether	Nonabromodiphenyl ether
Pentabromobiphenyl	Decabromobiphenyl	Pentabromodiphenyl ether	Decabromodiphenyl ether

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Sample Description:

No.	Description
1	• H-Beams, C-Channels, Z-Channels
2	• Angle Steel
3	• Steel Pipes
4	• Channel Steel
5	• Bolts, Nuts, Washers
6	• Steel Plates
7	• Wall Panels
8	• Roof Panels
9	• Doors and Windows
10	• Embedded Parts
11	• Anchor Bolts
12	• Welding Materials
13	• Insulation Materials
14	• Vapor Barriers
15	• Interior Wall Panels
16	• Flooring Materials
17	• Ceiling Materials
18	• Locks, Hinges
19	• Window Hardware
20	• Electrical Cables
21	• Distribution Box
22	• Switches, Sockets, Lighting Fixtures
23	• Water Supply Pipes
24	• Drainage Pipes

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Tel: 0769-81710286 E-mail: wangzhao@junantest.com Website: www.junantest.com

25	• Valves, Faucets
26	• Anti-Corrosion Coating
27	• Scaling Materials
28	• Fireproof Materials
29	• Installation Tools
30	• Temporary Supports and Scaffolding

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Test Result:

Test Item(s)	**No.1**	**No.2**	**No.3**	**No.4**	**No.5**
Cadmium (Cd)	N.D.	N.D.	N.D.	N.D.	N.D.
Lead (Pb)	N.D.	N.D.	N.D.	N.D.	N.D.
Mercury (Hg)	N.D.	N.D.	N.D.	N.D.	N.D.
Hexavalent Chrormium (CrVI)	N.D.	N.D.	N.D.	N.D.	N.D.
PBBs	N.D.	N.D.	N.D.	N.D.	N.D.
PBDEs	N.D.	N.D.	N.D.	N.D.	N.D.
Dibutyl Phthalate (DBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Butyl benzyl phthalate (BBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Di-(2-ethylhexyl) Phthalate(DEHP)	N.D.	N.D.	N.D.	N.D.	N.D.
Diisobutyl phthalate (DIBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Test Item(s)	**No.6**	**No.7**	**No.8**	**No.9**	**No.10**
Cadmium(Cd)	N.D.	N.D.	N.D.	N.D.	N.D.
Lead(Pb)	N.D.	N.D.	N.D.	N.D.	N.D.
Mercury(Hg)	N.D.	N.D.	N.D.	N.D.	N.D.
Hexavalent Chrormium (CrVI)	N.D.	N.D.	N.D.	N.D.	N.D.
PBBs	N.D.	N.D.	N.D.	N.D.	N.D.
PBDEs	N.D.	N.D.	N.D.	N.D.	N.D.
Dibutyl Phthalate (DBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Butyl benzyl phthalate (BBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Di-(2-ethylhexyl) Phthalate (DEHP)	N.D.	N.D.	N.D.	N.D.	N.D.
Diisobutyl phthalate (DIBP)	N.D.	N.D.	N.D.	N.D.	N.D.

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Test Item(s)	No.11	No.12	No.13	No.14	No.15
Cadmium (Cd)	N.D.	N.D.	N.D.	N.D.	N.D.
Lead (Pb)	N.D.	N.D.	N.D.	N.D.	N.D.
Mercury (Hg)	N.D.	N.D.	N.D.	N.D.	N.D.
Hexavalent Chrormium (CrVI)	N.D.	N.D.	N.D.	N.D.	N.D.
PBBs	N.D.	N.D.	N.D.	N.D.	N.D.
PBDEs	N.D.	N.D.	N.D.	N.D.	N.D.
Dibutyl Phthalate (DBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Butyl benzyl phthalate (BBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Di-(2-ethylhexyl) Phthalate(DEHP)	N.D.	N.D.	N.D.	N.D.	N.D.
Diisobutyl phthalate (DIBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Test Item(s)	**No.16**	**No.17**	**No.18**	**No.19**	**No.20**
Cadmium(Cd)	N.D.	N.D.	N.D.	N.D.	N.D.
Lead(Pb)	N.D.	N.D.	N.D.	N.D.	N.D.
Mercury(Hg)	N.D.	N.D.	N.D.	N.D.	N.D.
Hexavalent Chrormium (CrVI)	N.D.	N.D.	N.D.	N.D.	N.D.
PBBs	N.D.	N.D.	N.D.	N.D.	N.D.
PBDEs	N.D.	N.D.	N.D.	N.D.	N.D.
Dibutyl Phthalate (DBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Butyl benzyl phthalate (BBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Di-(2-ethylhexyl) Phthalate (DEHP)	N.D.	N.D.	N.D.	N.D.	N.D.
Diisobutyl phthalate (DIBP)	N.D.	N.D.	N.D.	N.D.	N.D.

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Test Item(s)	No.21	No.22	No.23	No.24	No.25
Cadmium (Cd)	N.D.	N.D.	N.D.	N.D.	N.D.
Lead (Pb)	N.D.	N.D.	N.D.	N.D.	N.D.
Mercury (Hg)	N.D.	N.D.	N.D.	N.D.	N.D.
Hexavalent Chrormium (CrVI)	N.D.	N.D.	N.D.	N.D.	N.D.
PBBs	N.D.	N.D.	N.D.	N.D.	N.D.
PBDEs	N.D.	N.D.	N.D.	N.D.	N.D.
Dibutyl Phthalate (DBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Butyl benzyl phthalate (BBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Di-(2-ethylhexyl) Phthalate(DEHP)	N.D.	N.D.	N.D.	N.D.	N.D.
Diisobutyl phthalate (DIBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Test Item(s)	**No.26**	**No.27**	**No.28**	**No.29**	**No.30**
Cadmium(Cd)	N.D.	N.D.	N.D.	N.D.	N.D.
Lead(Pb)	N.D.	N.D.	N.D.	N.D.	N.D.
Mercury(Hg)	N.D.	N.D.	N.D.	N.D.	N.D.
Hexavalent Chrormium (CrVI)	N.D.	N.D.	N.D.	N.D.	N.D.
PBBs	N.D.	N.D.	N.D.	N.D.	N.D.
PBDEs	N.D.	N.D.	N.D.	N.D.	N.D.
Dibutyl Phthalate (DBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Butyl benzyl phthalate (BBP)	N.D.	N.D.	N.D.	N.D.	N.D.
Di-(2-ethylhexyl) Phthalate (DEHP)	N.D.	N.D.	N.D.	N.D.	N.D.
Diisobutyl phthalate (DIBP)	N.D.	N.D.	N.D.	N.D.	N.D.

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Note:

1. mg/kg= ppm
2. N.D.= Not Detected(<MDL)
3. MDL = Method Detection Limit
4. -- = No Testing
5. When Cr (VI) in a sample is detected below the 0.10 μg/cm^2 LOQ (limit of quantification), the sample is considered to be negative for Cr (VI). Since Cr (VI) may not be uniformly distributed in the coating even within the same sample batch, a "grey zone" between 0.10 μg/cm^2 and 0.13 μg/cm^2 has been established as "inconclusive" to reduce inconsistent results due to unavoidable coating variations. In this case, additional testing may be necessary to confirm the presence of Cr (VI). When Cr (VI) is detected above 0.13 μg/cm^2, the sample is considered to be positive for the presence of Cr (VI) in the coating layer. Unavoidable coating variations may influence the determination Information on storage conditions and production date of the tested sample is unavailable and thus Cr (VI) results represent status of the sample at the time of testing.

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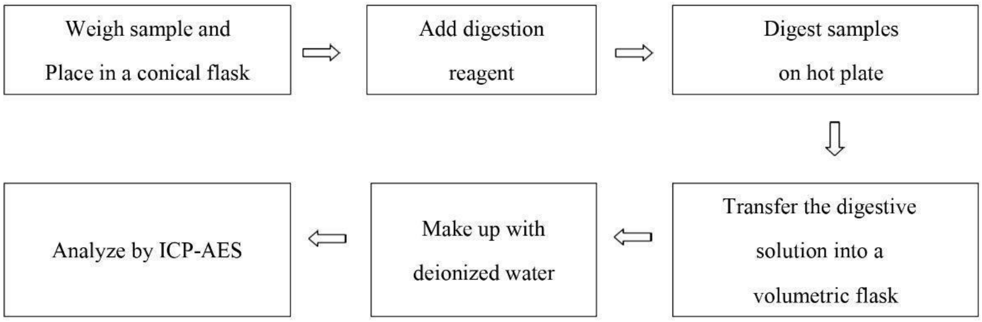
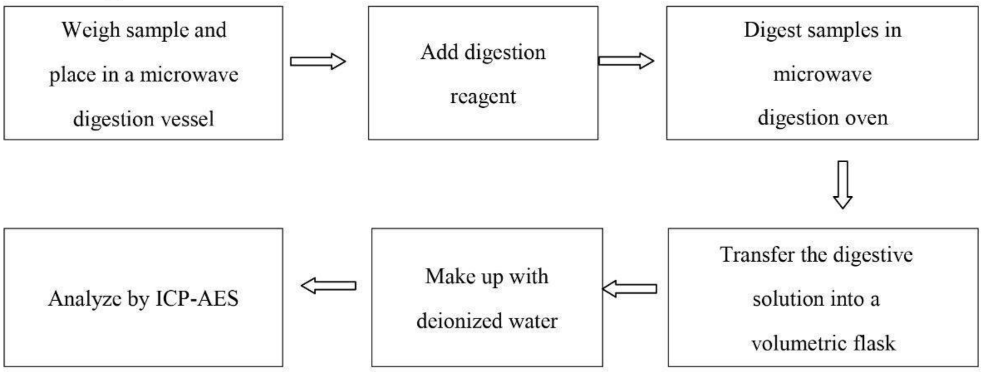
Test Process:

1. Test for Cd/Pb Content



2. Test for Hg Content



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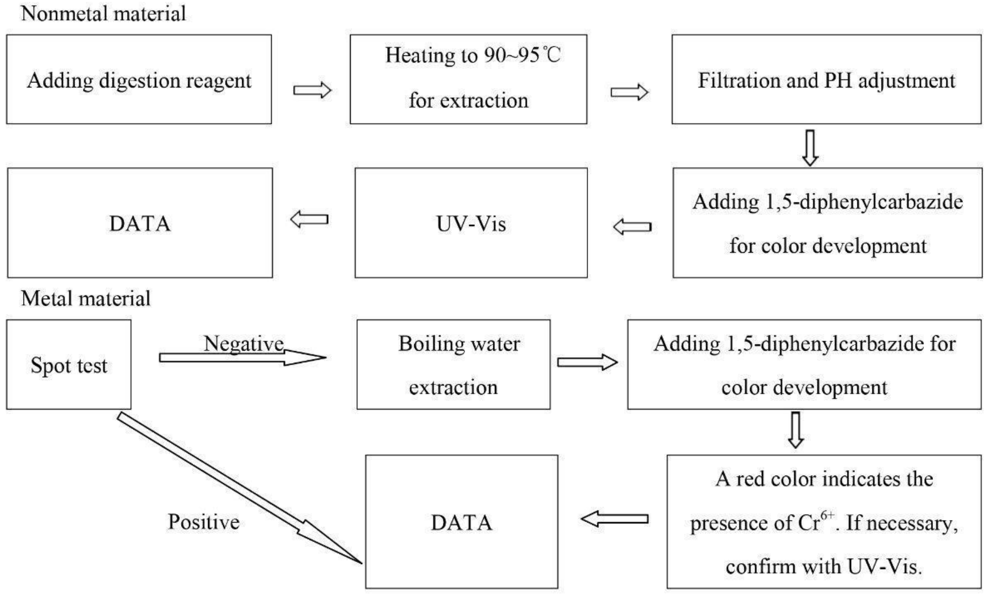
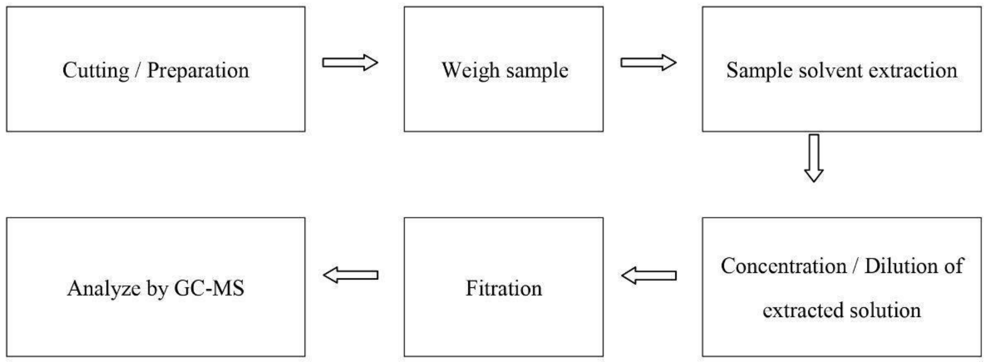
3. Test for Chromium (VI) Content



4. Test for DBP, BBP, DEHP, DIBP, PBB, PBDE Content



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Sample Photo:

*** End of Report ***

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Appendix D

HEBEI JIACHENG BROCHURE

河北嘉诚集成房屋有限公司，中国装配式建筑专业服务商。
秉承引领全球便捷、绿色房屋，创造品质生活的企业愿景
提供安全、环保、智慧、舒适的组合建筑空间
期待与您携手、
铸就世界新高度！

Hebei Jiacheng Integrated Housing Co., Ltd. is a professional service provider fo prabricated buildings in China.
Adhering to the corporate vision of leading global convenient and green houses and creating quality life.
Provide safe, environment-friendly, intelligent and comfortable combined building space
Looking forward to working with you,
Create a new height in the world!

300亩
产业占地面积

2 亿
总投资2亿元

COMPANY PROFILE
企业简介

河北嘉诚集成房屋有限公司总部位于河北省衡水市阜城县经济开发区，旗下子公司:北京华宇日盛钢结构有限公司、山西华宇日盛钢结构有限公司，山西华东装配式房屋有限公司。是一家集专业设计、制造、施工于一体的大型现代化模块化房屋企业。河北嘉诚拥有独立的压型车间、自动焊接车间，自动彩板生产车间、总装车间等整套生产设施，逐步建立起以河北为中心，辐射全国的销售服务中心。提供安全、环保、智慧、舒适的组合建筑空间,

Hebei Jiacheng Integrated Housing Co. , Ltd. is headquartered in the economic development zone of Fucheng County.Hengshui City,Hebei province, Its subsidiaries include Beijing Huayu Risheng Steel Structure Co. , Ltd. Shanxi Huayu Risheng Steel Structure Co. , Ltd. , shanxi Huadong prefabricated Housing Co., Ltd. It Is a large modern modular housing enterprise integrating professional design, manufacturing and construction. Hebei Jiacheng has a complete set of production facilities such as independent molding workshop,automatic welding workshop, automatic color plate production workshop and general assembly workshop,and has gradually established a sales service center centered on Hebei and radiating the whole country.Provide safe,environment-friendly, intelligent and comfortable combined building space.

〉〉〉装配式建筑专业服务商

COMPANY STRENGTH

企业实力

公司拥有业内领先的专业研发设计中心、先进的制造能力、强大的产能以满足客户需求，拥有独立的压型车间、自动焊接车间，自动彩板生产车间、总装车间等整套生产设施，具有各种生产、安装经验，配备相应特殊设备，稳定的技术工人队伍，可以同时满足多个地区的安装施工需求。

The company has an industry-leading professional R & D and design center, advanced manufacturing capacity and strong production capacity to meet the needs of customers.It has a complete set of production facilities such as independent molding workshop, automatic welding workshop, automatic color plate production workshop and final assembly workshop.It has various production and installation experience, equipped with corresponding special equipment and a stable team of skilled workers,which can meet the installation and construction needs of multiple regions at the same time.

PREFABRICATED BUILDING SERIES

全球化销售网络

建立起以河北为中心，辐射全国的销售服务中心。
根据国家提出的“一带一路”，特别设立国际中心，产品远销欧洲、非洲、东南亚、北美洲、南美洲和中东等地区。

Establish a sales service center centered on Hebei and radiating the whole country.
According to the "one belt, one road" proposed by the state, the International Centre is specially established, and its products are exported to Europe, Africa,Southeast Asia, North America, South America and the Middle East.

Patent certificate 专利证书

河北嘉诚装配式建筑的专利证书......

Hebei Jiacheng fabricated building patent certificate......

CERTIFICATION 荣誉资质

AAA级信用等级证书、诚信经营示范单位、质量服务诚信单位、重合同守信用企业、级资信等级、重合同守信用单位、诚信企业家。

AAA credif rating certificate,integrity management demonstration unit,quality service integrity unit,contract abiding and trustworthy enterprise,first-class credit rating,contract abiding and trustworthy unit,and integrity entrepreneur

河北嘉诚装配式建筑选用材料的检测报告……

Test report on selected materials of Hebei Jiacheng prefabricated building……

高端折叠瓦楞房
High-end folding corrugated house

高端折叠瓦楞房是在折叠式打包箱的基础上做出的升级，所有的材料都采用的是更加坚固耐用的制造材料，外层瓦楞铁皮厚度升级为0.5mm，内部铁皮厚度升级为0.3mm，整体墙体厚度增加到75mm，折叠处的28个合页均升级为高强度合页衔接，这样不仅仅是增加了产品的使用年限和各项耐久度，还提升了产品整体的美观性和舒适性。根据在市场上对客户做出的调查，本款产品主要采用可租可售的方式投放入市场，为客户解决工期结束后房屋安置问题，也大大减少了前期资金的投入。

The high-end folding corrugated room is an upgrade on the basis of the folding packaging box. All materials are made of more durable manufacturing materials. The thickness of the outer corrugated iron sheet is upgraded to 0.5mm, the thickness of the inner iron sheet is upgraded to 0.3mm, and the thickness of the overall wall is increased to 75 mm. The 28 meeting pages have been upgraded to high-strength hinge street connection, which not only increases the service life and durability of the product, but also improves the overall aesthetics and comfort of the product. According to the survey of households in the market, this product is mainly put into the market in a rentable and sellable way to solve the problem of housing resettlement for customers after the end of the construction period, and also greatly reduces the investment of early funds.

双翼拓展房

Double-wing expansion room

双翼拓展房也叫双翼折叠房，使用镀锌高强度方管、镀锌角铁等轻钢材料做框架，防腐双面彩钢复合板作为墙体，框架之间使用高强度合页进行衔接起来，经过合理设计，能够快速扩展房屋空间的房子，扩展后的房屋空间比展开前扩大将近3倍。可制作20尺、40尺的扩展房，同样也可以根据客户需求来定制。

The double-wing expansion house is also called the double-wing folding house. It uses galvanized high-strength square pipe, galvanized angle iron and other light steel materials as the frame, and the anti-corrosion double-sided color steel composite plate is used as the wall. The frame question uses high-strength hinges for street connection. After reasonable design, It has expanded nearly three times. Expanded houses of 20 feet and 40 feet can be made, which can also be customized according to customer needs.

FOLDING ROOM SERIES
折叠房系列

本公司主营高端折叠式打包箱，产品特点:面包顶，加宽流水槽，可达到有组织定向排水的效果，解决了传统折叠房漏雨的弊端。采用结构性严密拼接，充分达到防风防尘的效果，外形美观。漏电保护器、工业插头等设备齐全，均符合CE认证，做到了室内整齐美观。

折叠式打包式箱房由顶框组件、底框组件、角柱和若干块可互换墙板组成，采用模块化设计理念和生产技术，把一个箱房模块化成标准的零部件，到受用地再现场组装或吊装落位即可。该产品以箱体为基本单元，箱体结构采用特殊冷弯镀锌型钢构件，围护保温材料全部采用不燃材料，水暖电气、装饰装潢以及配套功能全部在工厂预制完成，不需要二次施工，现场组装或者整体吊装落位即可入住。可单独使用，也可通过水平及竖直方向的不同组合形成宽敞的使用空间和叠层。

打包式箱房结构简单、安全，对基础要求低，具有现场安装快捷、移动搬迁便利、周转次数多、使用寿命长等特点，该产品拆装无损耗，无建筑垃圾，可作为办公、住宿、餐厅、卫浴、娱乐以及组成大空间使用，可满足建筑工程营地、市政临时用房、野外作业营房、紧急安置房、学校、医院、旅游驿站隔离房、方舱医院、各类商业用房的需求。

The companyis mainly engaged in high-end folding packing boxes product features: Bread top, widened water trough, which can achieve the effect of organized and directional drainage, and solve the disadvantages of rain leakage in traditional folding houses. The structure is tightly spliced to fully achieve the effect of wind and dust prevention, and the appearance is beautiful.Leakage protectors, industrial plugs and other equipment are complete,all in line with CE certification so that the indoor is neat and beautiful.

The folding and packing box house is composed of top frame assembly, bottom frame assembly, corner column and several interchangeable wallboards. Modular design concept and production technology are adopted to modularize a box house into standard parts, which can be assembled or hoisted to the site. The product takes the box as the basic unit, the box structure adopts special cold-formed galvanized steel components, the enclosure and thermal insulation materials are all made of non combustible materials, and the plumbing, electrical,decoration and supporting functions are all prefabricated in the factory,without secondary construction, on-site assembly or overall hoisting. It can be used alone, or spacious use space and lamination can be formed through different combinations of horizontal and vertical directions.

The packaged box house has simple and safe structure and low requirements for foundation.It has the characteristics of fast on-site installation, convenient movement and relocation, many turnover times and long service life. The product has no loss in disassembly and assembly and no construction waste. It can be used as office, accommodation, restaurant, bathroom, entertainment and large space. It can meet the needs of construction engineering camp, municipal temporary house, field operation camp, emergency resettlement house, school, hospital The demand for isolation room of tourist post station, shelter hospital and various commercial rooms.

折叠房的便捷 打包箱的配置

CONFIGURATION CONVENIENT PACKING BOX IN FOLDING ROOM

折叠房采用模块化的设计技术，可根据客户喜好进行设计制作，尺寸可以随意制造，可折叠运输，节约空间及运输费用。

折叠房子的折叠处都采用了特殊的合页连接，可以折叠上千次，且几乎无损耗，更好的解决了连接处漏风、漏雨问题，采用塑胶垫密封。防火等级A级，抗震、抗风、抗漏雨，可反复折叠，循环利用，符合应急居住标准。

The folding room adopts modular design technology, which can be designed and manufactured according to customers' preferences. The size can be manufactured at will, which can be folded and transported to save space and transportation costs.

The folding part of the folding house adopts special hinge connection, which can be folded for thousands of times with almost no loss, which better solves the problem of air and rain leakage at the connection, and is sealed with plastic gasket.The fire protection grade is a, anti-seismic, wind and rain resistant, can be folded repeatedly and recycied, and meets the emergency living standard.

优势 ADVANTAGE

制作简单、美观、牢固、焊接位少

It is simple, beautiful, firm and has few welding positions

现场安装 FIELD INSTALLATION

无需地坪、拆装便捷、2–3人即可操作

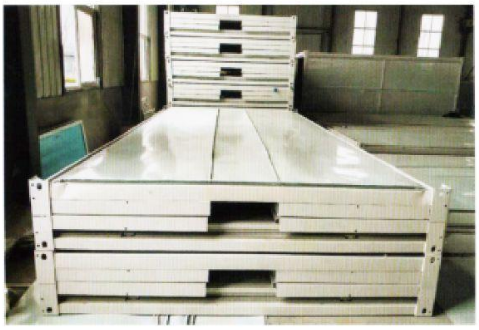
安装只需3–5分钟，打开自成一体。

it needs no floor, convenient disassembly and assembly, and can be operated by 2–3 people. The installation takes only 3–5 minutes, and the opening is self–contained.

运输成本 TRANSPORTATION COST

6.8m小车即可装7套，17.5m平板车可装17-28套。

7 sets can be installed for 6.8m trolley and 17-26 sets can be installed for 17.5m flat car.



储存成本STORAGE COST

一套地方可双层叠放储存。

A set of places can be stacked and stored in two layers.

使用成本USE COST

对比传统彩板房节约2/3临建费，对比其他类集装箱房屋，成本节约70%。

Compared with the traditional color board house, it saves 2 / 3 of the temporary construction fee and 70% of the cost compared with other types of container houses.

使用周期 SERVICE CYCLE

反复折叠上千次，使用寿命可达20年以上。

Repeated folding for thousands of times, the service life can reach more than 20 years.

面包顶优势BREAD TOP ADVANTAGE

加宽流水槽、有组织定向排水。

Widened gutter and organized directional drainage.

PLAT PACKED CONTAINER HOUSE SERIES
装配式厢房系列

箱式房屋是一种可工业化生产可移动的组合箱式房屋。它具有即取即用、随时随地移动、随时随地回收、循环使用、安全、环保、美观、经济、快捷、高效等优点。它可以拼接，运输时直接吊装即可。

装配式箱房是一款基于钢框架和轻质墙板结构体系的模块化建筑产品。该产品采用专有的第三代打包箱技术，由顶框、底框、角柱和可互换的墙板组成，可打包装、安装便捷，便于陆地或海上运输，可作为办公、住宿、餐厅、卫浴以及组合大空间使用，可满足建筑工地营房、野外作业营房、市政安置用房及各类商业用房的需求，目前广泛应用于欧洲、非洲、东南亚、北美洲、南美洲和中东等地区。

Box house is a kind of movable combined box house that can be industrialized, It has the advantages of ready to use,anytime and anywhere mobile,anytime and anywhere recycling,recycling,safety,environmental protection, beautiful, economic, fast and efficient.It can be spliced and directly hoisted during transportation.

Prefabricated box house is a modular building product based on steel frame and light wall panel structure system. This product adopts the proprietary third–generation packing box technology, which is composed of top frame, bottom frame, corner column and interchangeable wallboard. It can be packed and installed conveniently, which is convenient for land or sea transportation. It can be used as office, accommodation, restaurant, bathroom and combined large space, and can meet the needs of construction site barracks, field operation barracks, municipal resettlement houses and various commercial houses. At present, it is widely used in Europe, Africa, Southeast Asia North America, South America and the Middle East.

- 高效便捷 Efficient and convenient
- 高安全性 High security
- 高保值性 High hedging
- 高舒适性 High comfort
- 高耐用性 High comfort

装配式厢房特点及结构
Features And Structure Of Prefabricated Container House

装配式箱房采用独有的第三代装配技术，高度集成、拆装快捷。

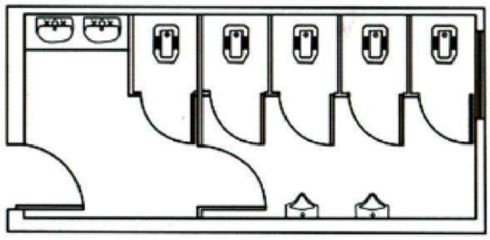
产品可拆卸压缩，压缩后，1个标准20尺集装箱可容纳四套产品，可大幅节省运输费用。

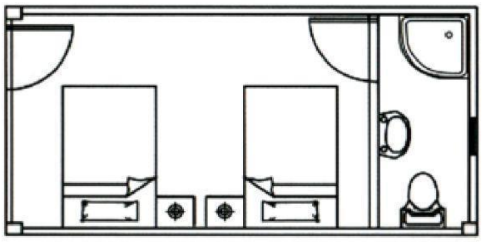
The prefabricated box room adopts the unique third–generation assembly technology, which is highly integrated and fast disassembly.

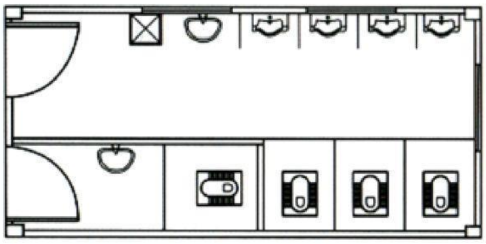
The product can be disassembled and compressed. After compression, one standard 20 foot container can accommodate four sets of products, which can greatly save transportation costs.

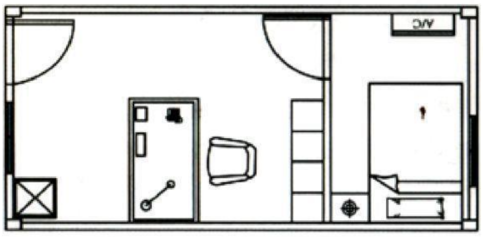
装配式箱房图纸

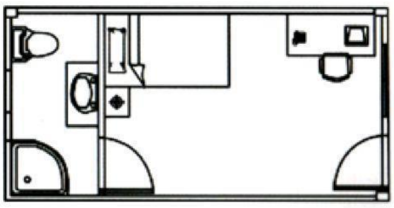
DRAWINGS FLAT PACKED CONTAINER







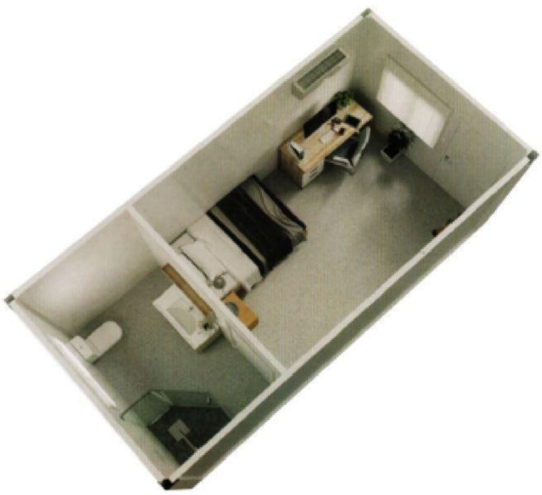




独立卫生间

BOX ROOM

WITH ARATE TOILET



- 地基对地质要求较低，在地质条件差的地方依然能满足结构设计安全性的要求；
- 色彩造型多样，动感轻盈，建筑与自然环境相融合；
- 采用环保材料，防潮透气，健康舒适，保温隔热降低空调能耗；
- 轻钢龙骨可100%回收利用，改建和拆迁容易；
- 建筑自重轻，韧性大，由于采用“笼式”结构整体结构性好，在地震荷载下受到的损害微乎其微；
- 轻钢构件构件及相应配套技术可实现工厂化制作，工期短；干法作业，无建筑垃圾，符合环保建筑的要求；
- 建筑防潮墙措施一体化，无盲点，墙体附有单向呼吸纸。

The foundation has low geological requirements and can still meet the requirements of structural design safety in places with poor geological conditions;
Various colors and shapes, dynamic and light, and the integration of architecture and natural environment;
Adopt environmental protection materials, moisture-proof and breathable, healthy and comfortable, thermal insulation and reduce air conditioning energy consumption;
The light steel keel can be 100% recycled, and it is easy to reconstruct and demolish;
The building has light weight and high toughness. Due to the "cage" structure, the overall structure is good, and the damage under seismic load is minimal;
Light steel components and corresponding supporting technologies can be manufactured in factory with short construction period; Dry operation, no construction waste, meeting the requirements of environmental protection buildings;
Building damp proof wall measures are integrated without blind spots, and the wall is attached with one-way breathing paper.

安装快速
Fast installation

傻瓜式安装、可快速安装和拆卸、也可组装后整箱移动搬迁、方便快捷，拆卸可回收，无建筑垃圾产生、环保耐用。

Fool type installation, quick installation and disassembly, and full container movement and relocation after assembly, convenient and fast, recyclable disassembly, no construction waste, environmental protection and durability.

配套完善
Complete supporting facilities

模块化设计，可搭配不同造型的配件，屋顶、走廊、楼梯、玻璃幕墙、阳台、厨卫等可应需求灵活配套组合并可根据需求对外观、内部进行装饰。

Modular design can be matched with accessories of different shapes. Roofs, corridors,stairs,glass curtain walls,balconies, kitchens and bathrooms can be flexibly combined according to needs, and the appearance and interior can be decorated according to needs.

安全耐用
Safe and durable

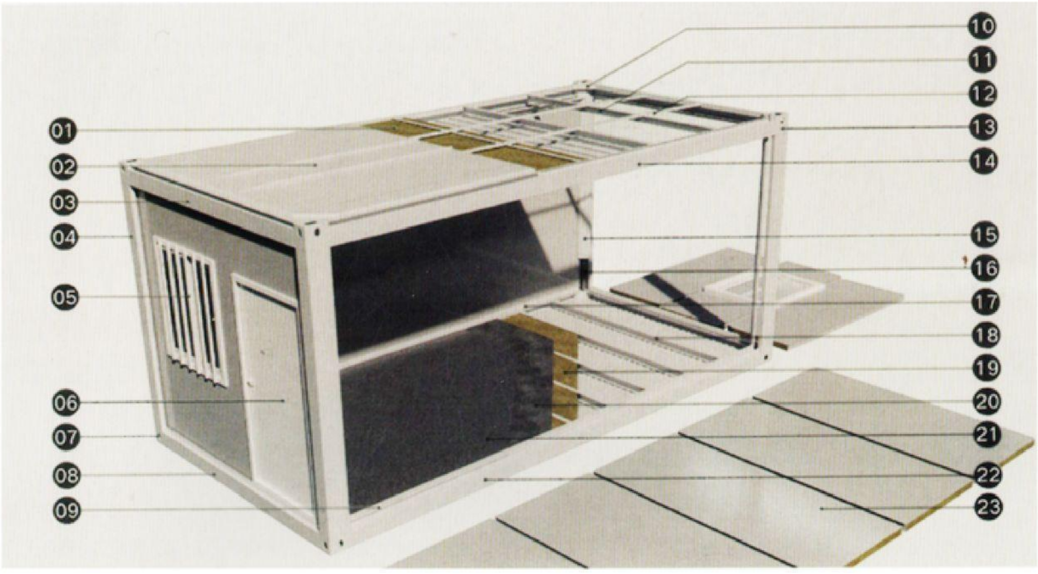
结构进行加固和保温处理、顶部采用专利防水设计，安全耐用、防风抗震，使用寿命达20年以上，抗震烈度8度，抗风11级。

The structure is reinforced and insulated. and the top adopts patented waterproof! design. which is safe and durable, windproof and earthquake resistant. The service life is more than 20 years, with seismic intensity of 8 and wind resistance of 11.

组装灵活
Flexible assembly

可单箱使用，可组合成敞开式大空间，并能叠加至3层。

It can be used in a single box,can be combined into an open large space, and can be stacked to 3 floors.



01.顶保温棉
Top insulation cotton
02.顶蒙皮
Top skin
03.顶横梁
Top beam
04.立柱
Column
05.防盗窗
The anti-theft window
06.防火门
fire-proof door
07.底角件
Bottom corner piece
08.底横梁
Bottom beam

09.反水槽
Backwater tank
10.W型件
W-shaped parts
11.顶次梁
Secondary beam top
12.顶支撑
Top support
13.顶角件
Top corner piece
14.顶侧梁
Top side member
15.立柱包件
Column package
16.内置落水管
Built in downpipe

17.踢脚线
Skirting line
18.底次梁
Bottom secondary beam
19.底保温棉
Bottom insulation cotton
20.水泥板
Cement board
21.塑胶地板
Plastic floor
22.底侧梁
bottom side rail
23.墙面板
Wall panel

结构方式
Structure

组装式打包箱
Assembled packing box

1. 安装底部

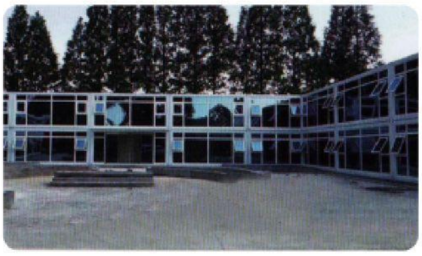
2. 安装角柱

5. 安装完成

4. 安装墙板

3. 安装顶部

折叠式打包箱
Folding packing box



PREFABRICATED BUILDING SERIES

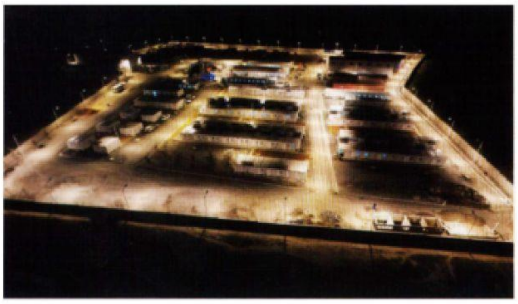
装配式建筑系列

装配式建筑是指把传统建造方式中的大量现场作业工作转移到工厂进行，在工厂加工制作好建筑用构件和配件(如楼板、墙板、楼梯、阳台等)，运输到建筑施工现场，通过可靠的连接方式在现场装配安装而成的建筑。

装配式建筑主要包括预制装配式混凝土结构、钢结构、现代木结构建筑等，因为采用标准化设计、工化生产、装配化施工、信息化管理、智能化应用，是现代工业化生产方式的代表。

Prefabricated building refers to a building that transfers a large number of on-site operations in the traditional construction method to the factory, processes and manufactures building components and accessories (such as floor slab, walboard, staircase, balcony, etc)in the factory, transports them to the construction site, and assembles and installs them on site through reliable connection.

The application of modern steel structure and assembly management is the representative of industrialized construction, which mainly includes the application of prefabricated concrete structure and intelligent production.



装配式建筑特点及结构

CHARACTERISTICS AND STRUCTURE OF PREFABRICATED BUILDINGS

大量的建筑部品由车间生产加工完成,构件种类主要有:外墙板,内墙板,叠合板,阳台,空调板,楼梯预制梁，预制柱等。

现场大量的装配作业，比原始现浇作业大大减少。

采用建筑、装修一体化设计、施工，理想状态是装修可随主体施工同步进行。

设计的标准化和管理的信息化,构件越标准,生产效率越高,相应的构件成本就会下降,配合工厂的数字化管理整个装配式建筑的性价比会越来越高。

符合绿色建筑的要求。

节能环保，装配式建筑具有较大节省资源的优势。

A large number of building components are produced and processed in the workshop.The types of components mainly include: exterior wall panels, interior wall panels, laminated plates, balconies,air conditioning panels,stairs,precast beams, precast columns,etc.

A large number of assembly operations on site are greatly reduced compared with the original cast-in-situ operations.

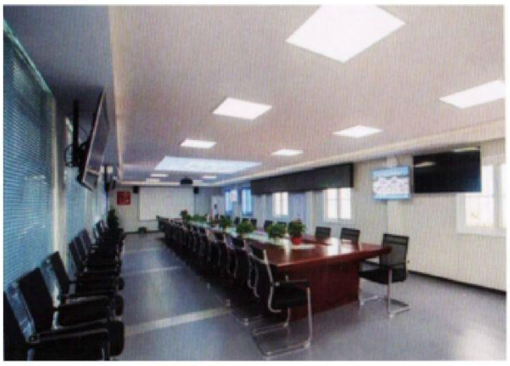
Adopt the integrated design and construction of architecture and decoration. Ideally, the decoration can be carried out simultaneously with the main construction.

With the standardization of design and informatization of management, the more standard the components are, the higher the production efficiency will be, and the corresponding component cost will decrease. With the digital management of the factory, the cost performance of the whole prefabricated building will be higher and higher.

Meet the requirements of green building.

Energy saving and environmental protection. Prefabricated buildings have the advantage of saving resources.


中国建筑



泰兴一建

Taixing Yijian Construction Group Co., Ltd

单位名称：泰兴一建
项目地点：江苏镇江
项目承建：河北嘉诚集成房屋有限公司
项目规模：300间
Unit name: Taixing Yijian Construction Group Co., Ltd
Project location: Zhenjiang, Jiangsu
Project construction :
Hebei Jiacheng Integrated Housing Co., Ltd
Project scale: 300 rooms

中铁十四局

China Railway 14th Bureau

单位名称：中建十四局
项目地点：河北邢台
项目承建：河北嘉诚集成房屋有限公司
项目规模：320间
Unit name: China Railway 14th Bureau
Project location: Xingtai, Hebei
Project construction :
Hebei Jiacheng Integrated Housing Co., Ltd
Project scale: 320 rooms

中建六局

China Construction Sixth Engineering Bureau

单位名称：中建六局
项目地点：山西介休
项目承建：河北嘉诚集成房屋有限公司
项目规模：500间
Unit name: China Construction Sixth Engineering Bureau
Project location: Shanxi Jiexiu
Project construction:
Hebei Jiacheng Integrated Housing Co., Ltd
Project scale: 500 rooms

山西二建 Shanxi Erjian

单位名称：山西二建
项目地点：山西太原
项目承建：河北嘉诚集成房屋有限公司
项目规模：270间
Unit name: Shanxi Erjian
Project location: Taiyuan, Shanxi
Project construction:
Hebei Jiacheng Integrated Housing Co., Ltd
Project scale: 270 rooms

中建一局

China Construction First Engineering Bureau

单位名称：中建一局
项目地点：河北衡水
项目承建：河北嘉诚集成房屋有限公司
项目规模：230间
Unit name: China Construction First Engineering Bureau
Project location: Hengshui, Hebei
Project construction:
Hebei Jiacheng Integrated Housing Co., Ltd
Project scale: 230 rooms

广西路桥

Guangxi Road and Bridge

单位名称：广西路桥
项目地点：山西大同
项目承建：河北嘉诚集成房屋有限公司
项目规模：180间
Unit name: Guangxi Road and Bridge
Project location: Datong, Shanxi
Project construction :
Hebei Jiacheng Integrated Housing Co., Ltd
Project scale: 180 rooms

支援灾区 抗击疫情 嘉诚在行动

JIACHENG IS IN ACTION TO SUPPORT THE DISASTER AREA IN FIGHTING THE EPIDEMIC

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