Containers Architecture

Reusing Shipping Containers in making creative Architectural Spaces

Ahmed Hosney Radwan

Assistant professor of Architecture - Architecture Department, Faculty of Fine Arts, Helwan University, Cairo, Egypt. Email: ahosney@gmail.com

Abstract— Reusing and recycling of materials is considered as an important value in sustainable design and architecture that prolonged among many historical ages, from reuse of stone, wood, marble columns, etc.… the previous decades witnessed the use of many materials in creating spaces that can host various functions, not only for economic or financial reasons but also for environmental reasons, in addition to the expenses of getting rid of these materials or reprocessing them by any mean. From re-use of paper, till reusing steel shipping containers, various attempts have been made to explore the possibilities, opportunities and examples of creating many functions, projects, or even large buildings been constructed in this way, the wide increase of these applications lead to the emerging of a type of architecture called afterwards containers Architecture. This paper is an attempt to explore this containers architecture, by studying different opportunities of reusing these steel boxes, that are usually supposed to be left unused or expensively reprocessed in a complicated manufacturing process that not only costs money but also consuming energy. This type of Architecture aims to create some architectural spaces that hosts different functions & human activities, not only on the scale of an individual building but also on a larger scale that can help in creating a quick or sometimes temporary solution for a building or a group of buildings that are structurally stable & safe, environment friendly, with very high capabilities of achieving aesthetic values that can be utilized by people. Going through this study, it will explore & analyze some projects and case studies from many points of views, Geometrically, Architecturally, structurally, financially, and of course environmentally.

Index Terms— Architectural spaces, Cargotecture, Containers Architecture, Containers homes, Shipping Containers, Reuse of materials, Recycling.

1 Introduction

Shipping container architecture could be defined as that type of architecture that is generally characterized by the re-use of steel shipping containers as a structural element and Architectural envelope that can host a specific function or a human activity. Often this type of architecture is termed cargotecture, a blend of conventional architecture and containers. The applicable of cargotecture has greatly expanded in the recent times in credit to their strong plating, inexpensiveness, and widespread obtainability. It was noticed recently that many people were building their houses using shipping containers for their low environ-mental impact in comparison to traditional houses made with brick and reinforced concrete structure, taking also in consideration the short time required to erect a building in this way, with future possibilities of moving these buildings to other locations or adding extra spaces or volumes.

Fig 1: Shipping Container

2 What is a shipping container?

A shipping container is a steel frame-usually cuboid- with a suitable strength to support large cargo transits and stowage. There are various types of containers, varying from refillable to universally standardized. For global trade, the term container is directly associated to a shopping container which can be loaded onto a great number of transportation options without requiring unpacking of its contents.[1]

Fig 2: Shipping Container Dimensions

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Though containers are made with intent to be consistently re-usable, a great number of them go into neglect when their owner companies possess containers far more than demand, or due to other economic reasons. This has led to a great number of neglected and forgotten containers in various ports around the world. Research has concluded that about twenty million containers are neglected around the globe at all times, with over one million having no purpose other than taking valuable space.

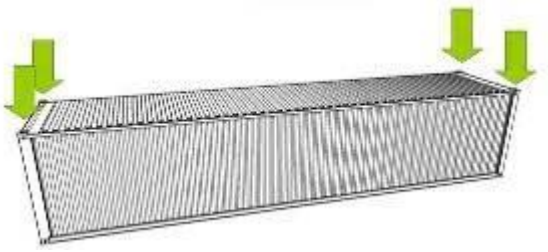

Fig 3: points of loading in a traditional Shipping Container

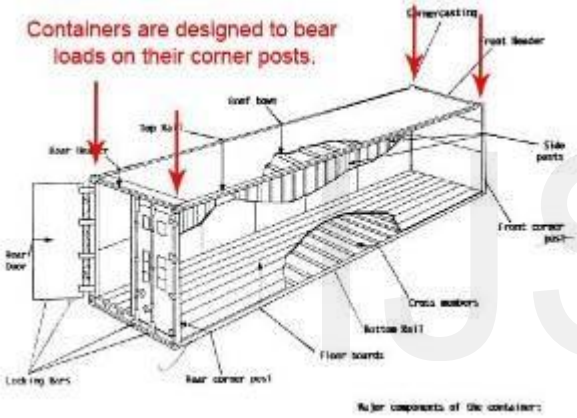

Fig 4: Bearing Loads on Corner Posts

3 FACTS

The following table shows the standard dimensions, volumes and weights of the shipping containers.

Specifications	10' Container	20' Container	40' Container
Inside Cubic Capacity	15.4 m3	33.2 m3	67 m3
Max Gross Weight	non payload	30,480 kg	30,480 kg
Tare Weight	1,500 kg	2,360 kg	3,980 kg

Dimensions	Length	Width	Height
10' External	3.10 m (10')	2.44 m (8')	2.59 m (8'6")
10' Internal	2.98 m	2.35 m	2.38 m
20' External	6.05 m (20')	2.44 m (8')	2.59 m (8'6")
20' Internal	5.90 m	2.35 m	2.38 m
40' External	12.19 m (40')	2.44 m (8')	2.59 m (8'6")
40' Internal	12.01 m	2.35 m	2.38 m
Door Size		2.34 m	2.28 m

Fig 5: Various Shipping Container Dimensions

4 EXPECTED LIFETIME OF A SHIPPING CONTAINER.

Based on the use intended for them, most containers are made to fulfil at least a one-decade lifespan, with three decades being the chief lifespan target. They are made to be extremely resilient and secure to facilitate safe cargo transit through a long distance. Most containers in use these days are expected to have finished a one-decade lifespan. Through application of reasonable maintenance, a lifespan far exceeding the anticipated figures can be expected.

5 USING SHIPPING CONTAINERS IN CREATING VARIOUS ARCHITECTURAL SPACES.

One of the main questions raised in Containers architecture is why a steel shipping container can be reused to create a livable space. Knowing that geometrically any space could be defined by different planes, horizontal and vertical, with a spatial relationship that organizes this space, defines it, and represents the human function that this space was created to be performed in, with the scale and dimensions, another value is added, thus leading to a better performance in this function, or another function that could be added or performed.so looking at any steel shipping container, the main and basic conditions of a space exists, with some modifications it can host various human activities of functions, thus creating not only functioning spaces but also interesting spaces for people to live, use and enjoy.

6 WHY COULD A SHIPPING CONTAINER BE USED AS A SPACE UNIT THAT CAN CREATE A BUILDING OR A GROUP OF BUILDINGS?

6.1. The composition of the shipping container:

Any shipping container is composed of 6 planes, floor, top, and four sides, made of steel, in regular corrugations that help in making these sides strong enough to tolerate loads, or pressures that may occur during the transportation process, in addition to steel posts and enforcements whether in the corners, or intersections of these planes(sides), or below the floor, or above the top. Accordingly, as a structure, its designed to resist forces as mentioned that exceeds the forces being developed in many architectural spaces like residences, offices, dorms, etc.

6.2. Storage Order:

Containers on a global scale are constructed with their frames intended for stacking in a standardized manner. It is not possible for containers to be stacked in any other manner other than the standardized norm. This is because the frames are meant to stack in a universal alignment with no other locks emplaced to facilitate an alien alignment.

- *Ahmed Hosney Radwan is currently an assistant professor of Architecture - Architecture Department, Faculty of Fine Arts, Helwan University, Cairo, Egypt.Email: ahosney@gmail.com*

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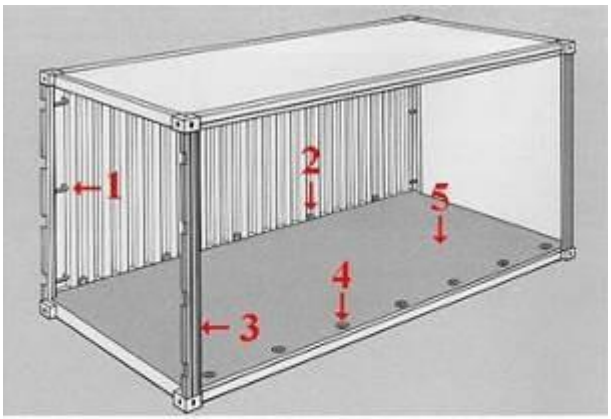
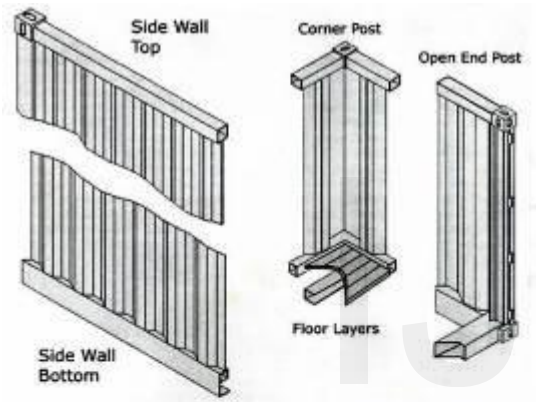


Cargo securing components in the container.
(Hapag-Lloyd AG, Hamburg)

1 - Lashing bars (corner posts)
2 - Lashing bars (side rail)
3 - Corner posts
4 - Lashing rings
5 - Wooden floor



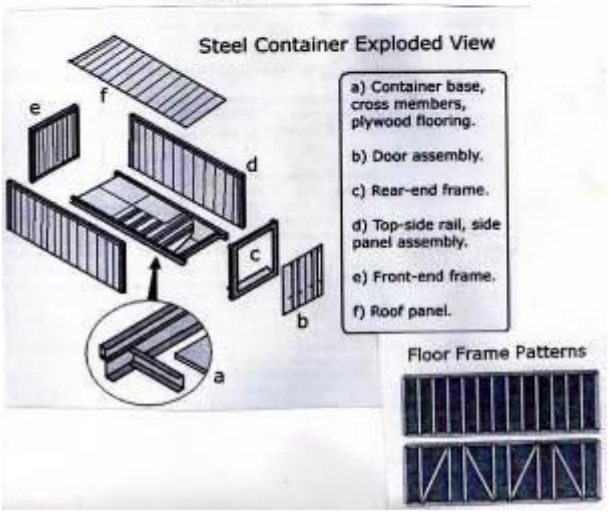


Fig 6: Steel Container Exploded View showing its structural composition

Fig 7: Containers on top of each other

Fig 8: Shipping Order of containers in regular horizontal and vertical lines

7 THE BUILDING FUNCTIONS THAT SHIPPING CONTAINERS CAN HOST.

As a result of its structural composition, a shipping container, in addition to its uniform, regular cuboid shape, & its modular size(s), many functions inside a building or even complete buildings could be easily constructed by reusing these containers, several examples existed all over the world for buildings that was constructed this way. Generally, they could be re-used to construct these kinds of buildings/functions:

- housing, Emergency crisis shelter, Emergency natural disaster shelter, School buildings, residential and commercial structures, studios, shops, mobile museums, bank branches, pharmacies, Sleeping rooms, malls and public restrooms.

Talking more specifically on real life projects, they have been used all over the world in creating various projects, and in various countries, with different scales and functions, the following are case studies been explored and analyzed starting from a very simple residence till large scale developments.

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7.1. Small Size Residence [2]

Small Shipping Container Cabin

- The cabin was constructed in 2008.
- It is composed of two twenty feet standardized containers, one container is placed on top of other in an intertwined manner.
- criss-cross stacking can be done as another solution of formulating a non-traditional box shape.
- Adding some modifications and reinforcement required for supporting the weight, particularly the added supports and beams.
- Upper containers as well as lower containers need reinforcing, borders of globalized containers are made to facilitate placement of another container straying from its corners, which means the upper container is balanced.
- by applying a specific color theme its atheistically pleasing to the human eye
- Modifications have been made to connect the 2 containers vertically thus creating a staircase that connects the 2 levels, While criss-cross stacking created a shaded area on both sides of the lower container beside two terraces on both sides of the upper container.
- The possibility of adding a third container on top of the second one, in the case of needing an extra space.

Fig 9: 2 Containers on top of each other

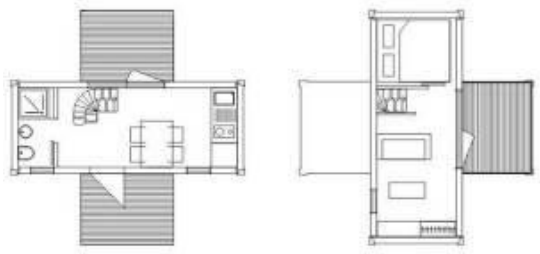

Fig 10: floor plans showing the internal and external spaces been created using the 2 containers on top of each other.

Fig 11: crisscross configuration of 2 containers on top of each other.

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7.2. Shipping Container Guest House [3]

- This cabin was designed in Texas by the prominent architect Jim Poteet. This design uses a single container, which can function as a garden retreat, studio, and even a playhouse for children and adults. This house contains glass doors and windows and the container is 8x40 ft. This cabin has one toilet, shower and sink available. There also are cooling and heating systems emplaced. The roof features an assortment of various plants.
- The house is made entirely out of containers, and due to the boxy nature of the container, the decorating possibilities are limited. Two large sections of steel were removed for the sliding doorway and window and the container was given a blue paint.
- Patio is featured in the roof and front, minimizing the chances of rainwater smashing against the glass. The interior of the cabin is made with wood to reflect a feeling of comfort and calm.
- The mix of materials and colors give it a unique standing in the conventional mass of guesthouses. The designing creativity for this house belongs to the Poteet Architects, it is important to note that this is not their sole container-based design.

Fig 12: Making some modifications in the vertical planes to create doors and windows.

Fig 13: the guest house could be also a temporary residence.

Fig 14: using wood for the internal planes to change the industrial look of the container.

Fig 15: Terrace for containers.

Fig 16: the guest house green roof

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Fig 17: the integration of the guest house with the sur-rounding environment.

7.3. Mid-Size Residences 4

- Applying the same way, not only to a single or double shipping containers, many containers could be utilized to create a larger scale, with different configurations to host families of bigger size, with a bigger number of spaces, whether internally or externally.

The DeWitt and Kasravi Sea Container Home

- This home consists of four containers; the designing creativity belongs to Modulus.
- It is based in California, but the actual framework was completed in another location. The containers were only reassembled in the house location.
- The top floor features 9 skylights, giving large volume of natural light into house.

Fig 18: various configurations of staking the containers can lead to various models of residential units.

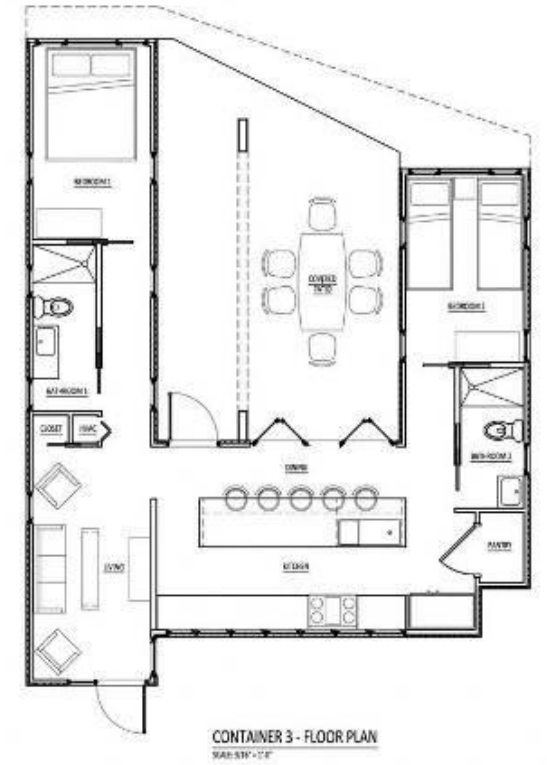

Fig 19: floor plan showing the internal and external spaces.

Fig 20: floor plan showing the internal and external spaces.

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Fig 22: floor plan showing how it looks like if 3 containers are closed between each other.

Fig 23: floor plan showing how it looks like if 3 containers are opened between each other.

Fig 24: various configurations of staking the containers can lead to various models of residential units

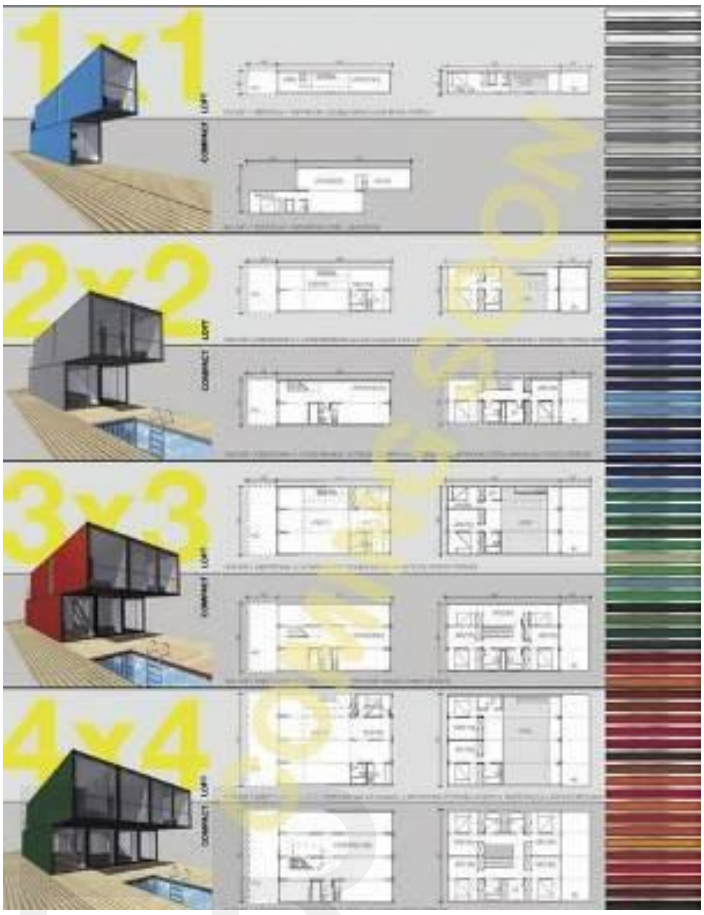

Fig 21: various configurations of staking the containers can lead to various models of residential units

7.4. Keetwonen in Amsterdam, The Netherlands [5]

The largest container locality in the world is located in Netherlands. This city was created by Tempo housing, and called Keetwonen. This city went on to gain huge prominence in the country, particularly in students groups. The city has become the second largest dormitory in the city of Amsterdam. The success of Keetwonen displaced any previous anxiety that container households would be either too noisy, small, or cold. The containers proved to be highly cost-efficient, roomful and insulated against noise and effects of weather, beating out other student housing schemes present in the city.

Keetwonen also manages to offer utilities that were missing in other student housing societies; each house came complete with its own kitchen, bathroom, gallery, study and bedroom. Each house featured upsized glass windows to facilitate daylight entering the house and ventilation system. This project was based on the requirements of students, a personal space for study without the necessity to share showers and bathrooms with individuals to whom you are unfamiliar. The city offers plenty of opportunities to facilitate student convenience, for instance, the interior area features a cordoned area to facilitate bike parking.

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Fig 25: Keetwonen is the biggest container city in the world.

Fig 26: Keetwonen is the biggest container city in the world.

The Keetwonen was constructed in 2005, though it may appear that residents are living inside metal boxes, the interiors is actually quite affluent on the standards of students. Each house consists of its own gallery, kitchen, and bathroom. There even is access to fast broadband internet. This housing was meant as a temporary location for student housing, however, relocation plans have been extended as further as 2016 and students and individuals who purchased their containers can relocated their house to a new personal spot.

Fig 27: floor plan for a typical room.

Fig 28: the designer worked on creating dynamic external spaces.

Fig 29: using a distinctive color helped in creating an eye-catching mass of rooms.

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7.5. Cite A Docks

- Architect: Cattani Architects
- Location: La Havre, France
- Date: 2010
- This structure is a dormitory located in Le Havre, France.
- One hundred dorms were construction through transforming old containers into a four-story building.
- Each apartment has 24 square meters and includes a bathroom and a kitchen, which is just about everything a student could need.
- Observing the building façade, it sponsors a highly metallic and dull theme, which fails to complement the students' learning energy.
- According to the developers, the metallic framework facilitates greater identification of various rooms and broadens them by using foreign extensions, which are modified, into balconies.
- The sloping architecture provides the entire structure a mixed feeling of being both filled and hollow. Granting a more scenic view.
- This existence of this structure is in credit to modified used containers. The modications provided changes the containers into complete houses spanning 24 sq. meters individually, and amounting over hundred houses in a 4-floored structure.
- One of the chief designers for this structure provided a reflection on her through process. The team had to work against the popular sentiment against stacking. The housing demands have changed drastically and therefore this structure had to be designed in a way that ensures greater feeling of personal housing independences.
- Containers came out as the best solution, older models would be renovated, and interior space would be refurbished. The designing on containers allowed for them to be stacked on each other and foreign objects, such as walkways would be erected to facilitate movement.
- Container based framework makes it easier to identifies the boundaries of each house and makes them aesthetically pleasing through the placement of terraces. The sloping effect makes the structure even more aesthetically pleasing through portraying the structure as neither too crowded nor empty.
- Structure, comprised of one hundred houses, is spread over 4 floor plan. The first floor was elevated to ensure identical privacy for the ground floor residents as the residents from upper floors receive.
- Each house faces a garden located within the structure premises, plenty of windows and glass walls facilitate consistent penetration of natural light into each house.
- In order to facilitate greater noise and temperature isolation, the containers at dividing locations those lacking adjacent containers were coated with forty centimeters of reinforced concrete, alongside rubber coating to ensure minimal vibrations.
- The external facade is designed by the combination of the old "boxes" that has kept the undulating, repainted in metallic gray. Inside, the designers chose white walls and wooden furniture. Each studio has a bathroom and a kitchen.

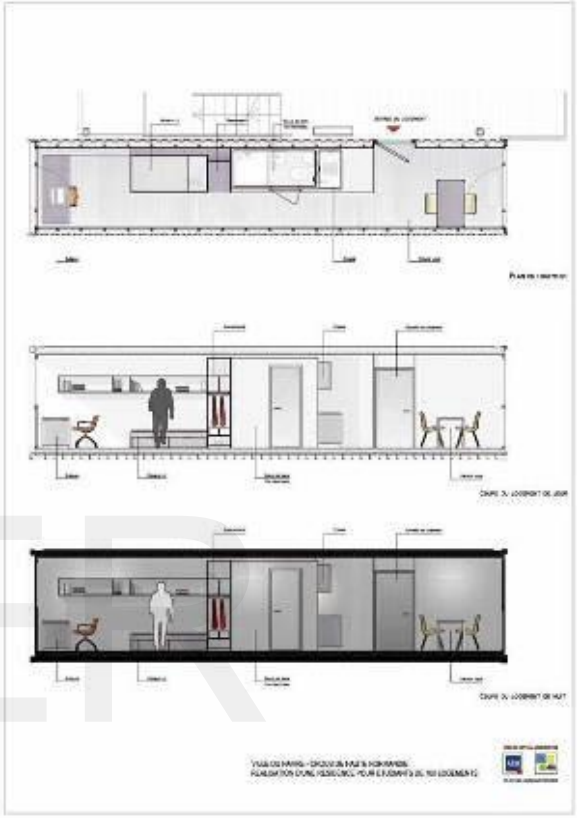

Fig 30: plans and sections through the room – shipping container.

Fig 31: the designer worked on creating dynamic external spaces.

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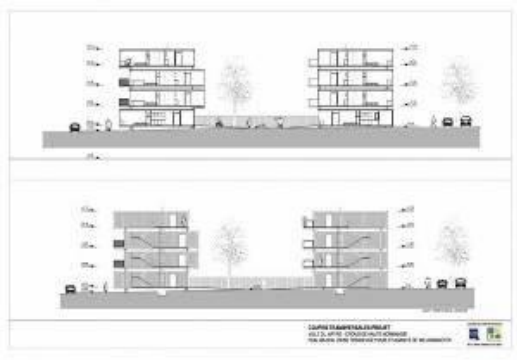

Fig 33: Sections through the shipping containers.

Fig 32: containers staking in various directions created a distinctive urban configuration.

Fig 35: the inside of the container

Fig 36: a steel skeleton was constructed to host the containers.

Fig 34: stacking the containers.

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7.6. Cultural centers.

Platoon Kunsthalle, berlin, Germany.

- An iconic reality of the container based architecture.
- This structure functions as an art center and exhibition hall
- The firm responsible for designing this structure is Graft Lab Architecture. The entire structure is made from containers.
- This structure was designed with intent to exhibit the modern feeling, a place where inspiration and imagination can meet.
- The interior of this structure features exhibition areas, studios, pubs and even a restaurant. The interior has plenty of clear space to facilitate larger groups visiting the exhibitions.
- This structure was designed with intent to serve as a place where creative individuals could work and thrive.
- Opened on 2012

Fig 39: creating a transparent elevation by removing the doors and replacing them with glass panels.

Fig 37: internal view showing the spans that can be created.

Fig 38: main elevation with sculpture displays.

Fig 41: vertical staking of containers lead to a reasonable height that is suitable for art works display.

Fig 40: stability of structure.

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7.7. Crou in Le Havre, France [6]

Fig 42: The pyramid-like arrangement of shipping containers.

Fig 43: Front View.

- The architects from Olgga created a building design comprising only one hundred containers.
- A single container equal one house, a vast improvement over the tiny dormitory rooms available in most educational institutions.
- This structure was designed by French architects.
- One hundred containers were used for the construction of this dormitory structure.
- The progject was nicknamed CROU, alongside being called an environmentally-friendly project.

Containers are rapidly gaining prominence. They stand out as elegant, modern and beautiful. Alongside these aesthetic traits, containers-made houses are also inexpensive, sturdy and environmentally-friendly.

Fig 44: 'Crou' student housing made from 100 recycled shipping containers.

- This structure was developed to facilitate greatest space utilization. Plenty of space in each individual room is given to students, far more economical than the cramped dormitories. In this structure, each container is a separate house for anew student. The CROU spans 2,851 sq. meters in an architectural design previously unseen. The structure is given a pyramid shape, but only a single side of the pyramid is connected through foreign connected stairscase, leading into an entrance for each house. Since this structure is based entirely on containers, there was little anti-environment aspects associated to its construction, furthermore the containers are given a new life through this renovation, otherwise they would become rusted and useless for stowage in a landfill.

Fig 45: One of the room typologies.

Nicknamed as the CROU. This project will encompass over thirty thousand sq. ft. of area. This project is expected to cost almost five million. All of the one hundred houses in this structure will be completely isolated in terms of noise and temperature factors.

Fig 46: Another room typologies.

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7.8. Puma City

- Puma City is an 11,000-square-foot store, crafted with 24 red shipping containers, located a mere stone's throw from Boston's Fenway Park.
- Puma City is a three level indoor-outdoor structure, constructed out of twenty-four containers.
- The structure fulfils the purpose of a stowage, living area and moveable headquarter for companies.
- The structure is designed to be easily taken apart, shipped and reassembled anywhere in the world.

Fig 47: Puma City – external and internal views.

7.9. London Container City I, II:

Based in London, the Container City is built as a unique and simple workplace made out of only containers. The design is made to look modern, stylish, and innovative. Inexpensiveness and environmentally friendly structure are the defining traits of this container-based city. The primary purpose of this city is to serve as a modern workplace in a modern setting.

The construction location is the Trinity Buoy Wharf, with constructions beginning in 2000 and 2002 respectively. This city has won multiple prizes in London for its innovativeness and modern designing. The cities have been used by a great number of organizations pertaining to various industries, ranging from local governmental officers, banks, software development companies, healthcare, educational institutions amongst the numbers.

The first Container city is also known as the Riverside building, which is comprised of a total seventy-three containers, based on five floors, the construction work on this building was finished near the end of 2005.

The entire prospect of the Container city is based on its excellent idea of reusing previously used containers, thus granting them new life. The containers are inexpensive in comparison to other conventional building material. The reuse of containers meant that there was little need for bricks or environmentally damaging material.

Both cities are perhaps the most prominent container based structures in the world. The second city is based on its unique ziggurat designing approach, its vivid paint job acting as a source of joy and motivation to its residents.

The Container city was built only as a singular city, the second day and its multiple extensions are a part of an overall extension of the project, highlighting its great global prominence. The second Container city building was finished two years after the completion of the original project.

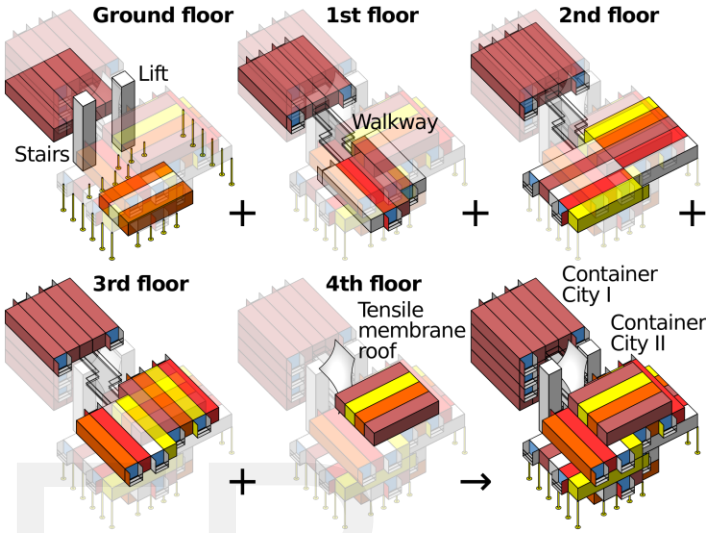

Fig 48: London shipping containers city.

8 CONCLUSIONS

Although having a very systematic and regular shape, shipping containers could be reused to create not only functional spaces, but also various configurations of architectural programs or functions, that vary from a very simple residential unit, to a small office building extending to a shopping mall, or a cultural center, that hosts bigger number of users. Many attempts have been done globally to create interesting architectural space(s), that can be constructed in a relatively short interval of time, with a reasonable cost. Possibilities are extended also to compose livable urban spaces, that can be easily constructed and relevantly in a low budget within a short time, in addition to the flexibility and possibility of been reconstructed in other locations or sites. Containers architecture is not a rigid type of construction of buildings or spaces configuration, although it's based on the modularity of volumes, yet many examples showed a wide range of varieties in spaces externally and internally.

Shipping Containers Architecture Benefits could be briefed in the following points:

- Renovation of previously utilized containers that have fallen into disuse from ports located worldwide.
- Containers are highly inexpensive compared to conventional building material, ranging from between $1,500 to $3,000 United States dollars per individual container.
- Containers are considerably sturdier compared to

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wooden or brick structures, they also late for multiple decades with little decay.
- Containers are all standardized with identical designs, thus all containers can be stacked upon or placed side by side without requiring additional resources or planning.
- Renovation of containers take little time, there have been reports of a container being successfully renovated for personal living in little as 72 hours.
- Durable against extreme temperature and pests.
- Easily broken down for movement and reassembled with the same structure intact, requiring little expense for transit of house between locations.
- Highly durable frame lasts for decades without requiring too expensive or specific maintenance.
- Always a possibility for further extensions, a house can be expanded with more containers to make it larger, with personalized placement of new rooms and utilities.

9 FURTHER RESEARCHES THAT CAN BE DONE BASED ON THIS RESEARCH

- Several researches can study the possibilities of using Containers Architecture in constructing low cost housing projects, whether in Egypt or in developing countries that need a quick solution to maintain a shelter for the homeless people.
- Studying the possibilities of high rise buildings using shipping containers.
- Wider emphasis on urban configurations using shipping containers.

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