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Research Article

Structuralism, Modular Construction, and "Grid" As Universal Instruments for Building Designs

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Abstract – Structuralism can be defined as an important concept of using "units" as elements of form and space-giving, where the whole form is made not only up of a "texture", a certain flexible grid, or an algorithm of shape-giving, but it depends also on the relationships created and how people use it. The hypothesis of this study is that "Modular Construction" can also have an aesthetically pleasing outlook and that modular housing can definitely have increasing importance in the future. Modular housing due to its cheap, and manufactural way of construction can be replicable in various locations. Structuralism and Modular Construction have been at the core of the Modernist movement. Although postmodernism marked the decline of modular construction adopting methods known for a more close sense of place, vernacular, and locality, which differs from the ubiquitous model of modernism, it is the universality of space and habitation seen since the times of Hippodamus Grid, Japanese Tattami systems, and rational universal space in housing known in Europe that make grid and modular design an excellent system in obtaining, rationality, functionality, flexibility, and energy efficiency, including quick construction and possibility for replication. In this regard, modular construction has a future, especially in times of crisis and economic instability.

Keywords – Modular Design, Grid, Structuralism, Modernist Ideas, Rethinking Modular Structures

I. INTRODUCTION

Structuralism can be defined as an important concept of using "units" as elements of form and space giving, where the whole form is made not only up of a "texture", a certain flexible grid, or an algorithm of shape giving, but it depends also on the relationships created and how people use it.
Herman Hertzberger wrote:
"By nature, Structuralism is concerned with the configuration of conditioned and polyvalent units of form (spatial, communicational, constructional or other units) at all urban scales. Only when the users have taken possession of the structures through contact, interpretation or filling in the details, the structures achieve their full status" [1].
Furthermore, the author describes roughly the structure and he states as follows:
Many Structuralists would describe a structure roughly in the following terms: it is a complete set of relationships, in which the elements can change, but in such a way that these remain dependent on the whole and retain their meaning. The whole is independent of its relationship to the elements. The relationships between the elements are more important than the elements themselves. The elements are interchangeable, but not the relationships" [2].

Le Corbusier created several early projects and built prototypes in a Structuralist model, some of them dating back to the 1920s. Although he was criticized by the members of Team 10 in the 1950s for certain aspects of his work (urban concept without a "sense of place" and the dark interior streets of the Unité d'Habitation), they nevertheless acknowledged him as a great model and creative personality in architecture and art.

This study hypothesizes that "Modular Construction" can also have an aesthetically pleasing outlook and that modular housing can definitely have increasing importance in the future. Modular housing due to its cheap, and manufactural way of construction can be replicable in various locations.

Modular construction is one of the methods that are near to the natural creation and growth of life, where the whole structure grows by single cells or units attached to it.

Furthermore, "Modular construction" is quite interesting as it offers opportunities for quick construction and fairly cheap construction costs. Although it was thought to be aesthetically not pleasant, this is more a "myth" that was created during the modernism period. According to Avi Friedman that has changed today [3].

Tom Lewith states that one of the limitations of Modular Housing is that a lot of companies do not get enough orders, as well as the image problem, "boring realities", such as volume and procurement, are obstacles to modular housing in the UK. "Efficiencies come from repeat orders, as with any factory. A lot of manufacturers (of modular housing) don't have the order numbers"

Furthermore, the fashion of living in a modular constructed building has always had a "stigma" of living in social housing. This is perhaps what ought to change today before "Modular Housing becomes in fashion once more and can be used in the reconstruction of cities, or the building of suburbs.

Friedman believes its potential is limitless, but says architects need more support from big house builders, developers, and policymakers to make it work. For the moment, however, "the industry is stacked against innovation" [4].

Some of the strong points of modular homes are:

Affordability
Flexibility
Speed of Construction

Some of the weaker points of modular construction are related to the costly interventions after the execution of the building that relates to thermal insulation, and internal changes to make the house more comfortable.

According to the definition: A modular home is a structure designed and built for residential use, and constructed in one or more three-dimensional modules in a factory to the prevailing state or local building code found in the jurisdiction where the home is to be built, and transported to the home site for final assembly and completion on a permanent foundation.

Surveys have shown that some home buyers and some lending institutions resist the consideration of modular homes as equivalent in value to site-built homes.

Furthermore, modular homes are becoming increasingly common in Japanese urban areas, due to improvements in design and quality, speed and compactness of onsite assembly, as well as due to lowering costs and ease of repair after earthquakes. Recent innovations allow modular buildings to be indistinguishable from site-built structures [3].

II. MODULARITY AND MASS HOUSING

After the second world war with "baby boomers" and the new housing of post-war destroyed Europe energized the concept of modular construction. This became more evident in Team 10 and its members most of whom experimented at some point in their career with "Modular Construction"

If we look also at the bold experiments of "Le Corbusier" such as Maison Domino and "Unite d'Habitation" are early experiments that consist of the ideas of mass production of housing or units, domino type or unit type that can be replicated ad infinitum. On a larger scale, this is completed with the picture of "Plan Voisin" or Hilbeserimer "Vertical City" plan.

The very first conclusion of this chapter is that modularity is a typical modernist approach that focused on solving problems of mass housing and architecture in general by means of functionality, rationalization, cheap construction, and quick building approach.

This can be found in the works of Le Corbusier, Candilis, Josic, Woods, Metabolism and Archigram but also rather utopic designers such as Yona Friedman. More so is visible in Aldo Van Eyck and Japanese architects such as Kenzo Tange who also coined the term "Structuralism".
Other architects that have experimented with modularity/structuralism are the French Architect Guy Dessauges and furthermore "Plug in City" a mega-scale modular concept by Archigram.
Very specific project was the mmodular housing is that of Moshe Safdie, Habitat 67, built for the 1967 Expo in Montreal but also the 1972 Nagakin Capsule Tower, by Kisho Kurokawa as an early experiment of the Metabolist Movement

Fig 1. Habitat 67 [5]

Fig. 2. Nagakin Capsule Tower by Jordy Meow (Jordy Meow/Wikipedia) [6]

The side effect of the extravagant capsule towers can be seen as a segregated caste of creative artists, or a marginalized minority in the sense of taste for living as compared to the larger middle-class group.

The biggest struggle of modular construction is how to build for the middle class. Yet it is possible to reinvent housing and create opportunities for the majority of society that are based on modular construction [7].

Fig.3. Container City II by Cmglee [7]

Postmodernism as the "End of Grand Narratives" as Leotard would call it, combined with a tremendous diminishing of new housing needs and a fall in demography at least in the West, slowed down tremendously the new construction which possibly led to the postmodernist movement and authors such as Aldo Rossi, Christian Norbert Schultz and furthermore who called for a more "related to the historical city"
The architecture related to the ground and materials of the actual site, automatically would "kill" ideas such as modular concrete or steel construction seemingly unfit for the actual landscape.
Postmodernism was the biggest hit to the decline of modular construction, seemingly repetitive, boring, limitless, and ubiquitous, the very essence of what modernism stranded for.

III. GRID AS A BASIS FOR MODULAR HOUSING

Walter Gropius thought of the modular principle, with the idea that industry would help in the construction of new settlements. Rationalism was an integral part of modernist architecture with principles of saving resources and mechanization. The buildings take the form of interlocking cubic structures of various heights. Towards the street the semi-detached houses are distinguished by generously glazed studios; vertical strip windows on the sides letting light penetrate into the staircases. Only the director's house had an asymmetrical arrangement of windows. The light-colored houses have generously sized terraces and balconies, and

colorful accents appear on the windows, on the lower parts of the balconies, and on the gutters [8].

As a spatial form, the grid has been used since antiquity in urban planning, architecture, design, etc. Ancient Egypt was an important instrument of land division. Grid was used during the Italian renaissance by Alberti and Bramante not only in the plan but also in the facade. From the utilitarian point of view, the grid is a very smart thing since it divides space at the utilitarian level, including the spatial unit (room, thus the grid accommodates function).

The grid concept produces exceedingly homogeneous, universally useful, and constructively simple places, but it must be adapted for proper habitation. Depending on the size of the original cell, there are numerous alternatives available: partitioning the units with thin walls, joining them together, and adding an additional cell for the technical rooms. Universal space in a home is space that can accommodate any fundamental activity. This idea can serve as the foundation for universal housing because each space's use can be easily changed. According to its theory, a grid made up of homogeneous units must result in just one kind of space that may be used in any way. There are six fundamental daily activities, according to B. Leupen: sleeping, gathering with others, eating, cooking, taking a bath, and working [9], [10], [11].

Each of them requires a very certain space that is determined by their technical requirements as well as size. Circulation space is another crucial area that does not contain any activity but is vital to connect them together. While considering the idea of universality, it is crucial to specify the parameters of its application: some highly specialized places that require equipment, such as kitchens and bathrooms, typically have their sizes reduced to a bare minimum, making them automatically non-universal. At the same time, bathrooms cannot be considered places where people spend significant amounts of time or gather. It is a very functional room that requires specialized installations and equipment, is related to the home's technical systems, but seldom plays a significant part in comprehending universality. The universality of space is also impacted by hallways and corridors since the application of any function to a space directly depends on its access and the availability of passageways. Economics allows for two alternative methods of evaluating a home: the overall area and the dwelling area alone, excluding circulation and utility areas. The living space is given considerably more importance since it displays the actual space that inhabitants may utilize for their daily activities. Due to this, circulation areas are frequently left out of the floor plan and access is provided through the rooms, which lessens the use of such a place.

If a house has more than one occupant, it cannot be utilized only for purposes like sleeping and working.

Even if circulation space is not ubiquitous, granting equitable access expands the range of uses for the rooms. It is possible to attain universality in usage by designing environments that are comparable in terms of their spatial features, size, and accessibility. Each of them produces the same outcome. Any room or home may be occupied in various ways, making them universal.

The constructive grid enables the uniform creation of all cells in the housing structure and spatial arrangement without regard to size or shape hierarchy. The structure itself is a tridimensional grid made by repeatedly repeating one unit.

The grid pattern has had an impact on a variety of human endeavors as a spatial form, including graphic design, archaeology, and cartography as well as urban planning, architecture, and modern art. The grid divides the area into regular, rectangular pieces that are good for development and is simple to plan out and understand. This is a way of creating spatial divisions rather than a shape. It also offers the most straightforward and adaptable option. At the urban scale, it establishes the architectural composition within the urban block or unit, arranges the building's components, and organizes the city pattern with its streets and blocks.

As the Greek city of Miletus was rebuilt, the grid pattern became widely used in the West. With relation to the existing orientation lines, the new city layout was squarely grid-set and strictly orthogonal. In a clear simplification of social space, its 10,000 residents were distributed among three residential districts, each of whose blocks were encircled by public amenities and a central marketplace. Residential units were of the same size and shape within each city district. Each unit could be divided equally into four halves and had four sides that were accessible from the street.

Each resident had a similar property, and the city provided central, specialized venues for gatherings and celebrations that were also the outcome of the union of the grid cells. This city structure was a

manifestation of the democratic concept. One of the most adaptable urban planning strategies was the Hippodamus grid: cells varied in size depending on their role, principal streets had various widths, and square shapes were determined by social and landscape needs. The proportion of the grid, its position, and the location of the main structures were fixed and consistent from city to city during the latter Roman era when grid-based towns maintained largely utilitarian areas.

Fig. 4 A. The city of Miletus, based on a rigid orthogonal grid [12]; B. Bird eye view of Miletus [13]

The universality of use of Palladio's villa Rotonda is achieved by clustering four equal units around the main hall, which is established as a result of the square's partition into four parts. The building's spatial arrangement has no biases for any one location or direction, and the axis of symmetry is formed by two crossing corridors. At the same time, each unit is split into two smaller ones that are proportionately 1:2 to one another. The four smaller and larger rooms are accessible from the center hall, and they are all connected to one another via a system of apertures. Two main circulation axes are superimposed to create the grid of the finished house plan. In a traditional Japanese home, a similar scenario may be seen: the basic grid is tatami.

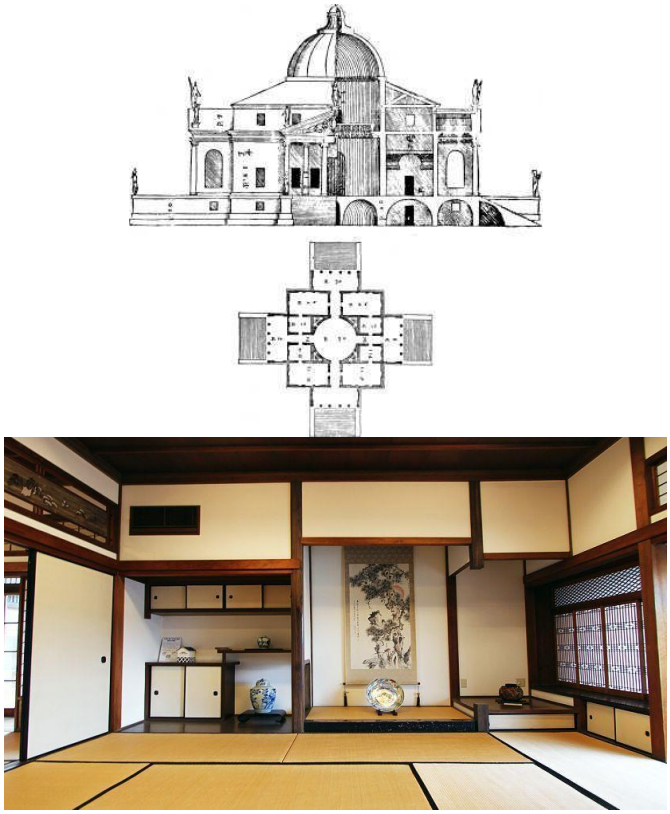
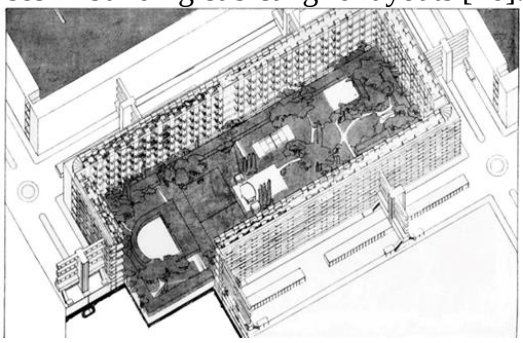


Fig. 5. A. Palladio's Villa Rotonda [14]. B. Traditional Japanese home (tatami) [15].

Tatami is a sort of mat with a 1:2 side ratio that is used as flooring in traditional Japanese homes. Tatami could be used to arrange the rooms in a variety of ways, which also molded the structure of the house.

In his "Modular," Le Corbusier designed a grid with varied cells based on human dimensions. He explored the notion of "alveolar volume" - the living unit with dimensions 2.26x2.26x2.26m, termed "a container of men, cellular volume, which permits a large variety in composition". The alveolar volume could only support a single use, such as a bed, table, kitchen, etc. The works of American conceptualist and minimalist Sol LeWitt are examples of abstract exercises in building cubical grid layouts [16].



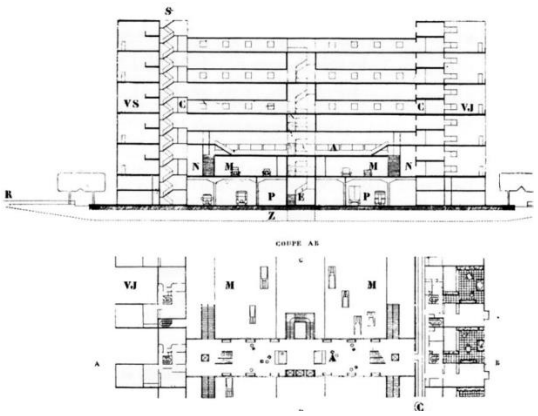


Fig. 6. A. The “alveolar” blocks (Le Corbusier 1925); B. Cross section and plan of “rue usine” [17].

Beginning in the 1960s, he created a number of pieces known as "Modular structures"—three-dimensional grids built on the repetition of cubic modules. He uses simple shapes and uncluttered compositions in his works, allowing the viewer to see how different interpretations of a single basic cube may be made using only pure geometry. Sol LeWitt described his concept as "a machine that makes art" in his essay "Paragraphs on Conceptual Art". The introduction of virtually any material is made feasible by the idea's precedence over its reality. "Each piece of art, which became material, there are numerous immaterial versions," claimed LeWitt.

IV. RESULTS

The evolution and potential applications of the grid spatial system are demonstrated through the analysis of several projects from various architectural scales and historical periods. The structure can be applied to different levels: at the urban level grid is defining the street system and the system of parcels; at the level of the neighbourhood – the arrangement of buildings and their open spaces; within the building – the division into living units; in the flat – the spatial elements (rooms). The grid's implementation is simple and has some favourable economic and environmental effects. It enables the production of a commercial line of prefabricated building components that, when combined, can result in a variety of habitation styles. The program of domestic activities needs spaces that vary in size, so the creation of unified spaces has one drawback. The smallest area is the toilet, or storage, measuring about 1.5 square meters. The largest space (minimum needed) is a living area measuring 16 square meters. As can be seen from the case studies, using the unified grid results in large or undersized spaces. The answer in this situation is to create a more complex matrix with a variety of units or to provide a way for cells to be divided or attached. The size of the grid unit that is appropriate for housing is a second crucial factor. There are several fundamental cells in some projects, including 2.26x2.26x2.26m, 3x3x3m, 2.5x5x3m, 4x4x3m, 5.5x5.5x3m, 10x10x3m, and 23x23m. Meanwhile, the sizes of the cells vary 5 sq. m, 9 sq. m, 10 sq. m, 16 sq. m, 30 sq. m, 100 sq. m, and 529 sq. m. Scale expansion is accompanied by an increase in size. Additionally, a contrast to the minimum size requirement for a room (16 sq. m) enables one to comprehend the space's adaptability to any activity. Lower row numbers indicate cells with the potential to join together, while higher numbers indicate cells with the potential to split. Although the current work focuses primarily on the study of homes and their interiors, the modular grid can also be found at the urban level. The fundamental activities that take place in a city vary depending on its size and may include residential, commercial, social, recreational, and utility areas. The concept of a universal urban unit must also be considered as a process of urban development, which has a timeline that can be expressed in years. The grid system should be developed from the basic unit repetition to the more complex, individualized pattern combined with the set of universal spaces. Potential applications include homes and offices with constantly changing floor plans.

V. CONCLUSIONS

Structuralism and Modular Construction have been at the core of the Modernist movement.

Although postmodernism marked the decline of modular construction adopting methods known for a more close sense of place, vernacular, and locality, which is different from the ubiquitous model of modernism, it is the universality of space and habitation seen since the times of Hippodamus Grid, Japanese Tattami systems, and rational universal space in housing known in Europe that make grid and modular design an excellent system in obtaining, rationality, functionality, flexibility, and energy efficiency, including quick construction and possibility for replication.

In this regard, modular construction has a bright future, especially in times of crisis and economic instability.

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