

Prefabricated Technology in a Modular House

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Abstract

In view of the issue related to the demand of housing, the Philippine Government must find some alternative ways to lessen the expenses without altering the quality of the housing projects, the study paved the way to evaluate a comparison between the prefabricated housing components in modular house and the traditionally made housing components (CHB) in terms of cost, efficiency, effectiveness, and the time to spend during construction. It also attempts to search for the development and production of low cost housing, the end-users feedback and other institutions that used these materials and its impact to the market. One of the interesting insights in the study is that prefabricated components has a significance difference in terms of construction cost as compare to the traditional methods due to the materials, and fast and short time duration of construction.

Keywords: *Construction materials, indigenous materials, housing technology, modular housing, prefabricated materials*

1. Introduction

Having a house to call one's own is a dream and primary concern of every individual in the Philippines. Housing began before the Spanish take their first step in the Philippines shore. It was at that time when housing in the Philippines gets a big difference, difference in terms of looks, strength, size, cost and the length of time to spend during construction.

At present, the demand for housing unit is tremendously increasing, as the study conducted by the Housing and Urban Development Coordinating Council (HUDCC) it estimates a housing backlog of 9.4 million units for the year 2009-2014 [1, 4]. The problem is that the government cannot afford to spend billions of pesos for a massive construction of housing project.

With the increasing demand for housing, it is very important for the government to find some alternative and useful way to meet this expanding problem. According to [1], there are three options to meet this increasing demand. First is the used of indigenous building materials, second is the search for the improvement on the conventional method of construction as well as the design standard and lastly the used of innovative technology. Innovative technology refers to the used of newly discovered construction materials or methodology such as the Modular Housing System. One factor to show the government sincerity to solve the housing problem is the Republic Act 7729 also known as the Urban Development and Housing Act and the "Batasang Pambansa 230" also known as the processing and Approval of Subdivision Plans, which recognized and encouraged the used of innovative and system for economic and socialized housing projects [3].

Although the Philippines constitution and other government agencies encouraged the used of innovative technology such as prefabricated housing components , the demand for it is remain soft due to the reasons that many people in the Philippines has a poor knowledge about this components and used the conventional materials such as concrete hollow blocks (CHB), galvanized sheets, plywood, *etc.* The researcher also considers that Philippines and real Estate sector have not yet recovered from Asian financial crisis. Furthermore, the low cost housing sector has yet to resolve major issues such as larger number of outstanding mortgage and the absence of a viable and sustainable system for low cost housing finance. Sources say that the demand for the prefabricated building components will grow by at least ten percent until year 2014 [2, 5].

Modular house is the culmination of one type of building system. The building process starts with efficient modern factory assembly line techniques. The prefabricated components are brought to the site and erected using building block type construction. Work is never delayed by curing time or missing materials and can be completed for 30 to 45 working days. Further study shows that it can also lower the total cost of the project by 12 percent as compare to the traditionally build house using traditional materials such as CHB [6].

The study aims to introduce and to provide more knowledge about modular house to educate the market and to address the concern of every sector of the society especially the depressed areas of the society for a beautiful, stable and affordable shelter.

Now the technology is already here, this is the right time for us to use new concepts and idea where the end-users will benefits, it's up to them how they developed, improved, and used it.

It is with this view that the research study on the comparison between the modular house construction and the mass housing construction in terms in cost, efficiency, effectiveness and the time of construction is initiated.

2. Literature Review

Modular buildings and modular homes are sectional prefabricated buildings or houses, that consist of multiple sections called modules. "Modular" is a method of construction differing from other methods .The modules are six sided boxes constructed in a remote facility, then delivered to their intended site of use. Using a crane, the modules are set onto the building's foundation and joined together to make a single building. The modules can be placed side-by-side, end-to-end, or stacked, allowing a wide variety of configurations and styles in the building layout.

Modular buildings, also called prefabricated buildings, differ from mobile homes, which are also called manufactured homes, in two ways. First, modular homes do not have axles or a frame, meaning that they are typically transported to their site by means of flat-bed trucks. Secondly, modular buildings must conform to all local building codes for their proposed use, while mobile homes, made in the United States, are required to conform to federal codes governed by HUD. [7] There are some residential modular buildings that are built on a steel frame (referred to as on-frame modular) that do meet local building codes and are considered modular homes, rather than mobile homes.

2.1. History of Modular House

The first record of modular building appeared in the South Australian Record in 1837, in an advertisement for the Manning Portabel Cottage. The structure was design

and built by carpenter Henry Manning, who built the components in London and shipped them to Australia. Hundreds of Manning's buildings were erected in Australia during the mid-1800s. His work was of such quality that one of his buildings, a Friends (Quaker) Meeting House, still stands in Adelaide [8].

The most famous early modular building was a prefabricated hospital built in 1855 during the Crimean War. Its name came not only from its early innovative use of modular construction, but from its inspiration: Florence Nightingale. Despairing over the poor conditions at the hospital where she served, she wrote a letter to the London Times, asking for help. Five months later, a modular hospital, designed by Isambard Kingdom Brunel, was shipped to the Crimea, where it reduced the death rate from 42% to 3.5% [8].

Another modular houses appeared in 1920s, the main idea was to have a mobile home with all technical installations and furniture and yet able to move [9]. The solution to that was home on wheels, more known nowadays as trailers shown in figure 1 The basic of a trailer is the same as portable module house; the difference is in stability, electricity connections and size. Although the difference nowadays between modular house and trailer house is quite impressive, the main principle remains the same – the house is basically ready for living. During years of technological development the trailer houses went its own evolution and were designed more for constant travelling. At that time, separately of trailer houses, developed an architectural way of modular houses, which could be bigger in dimensions more stable and could much the criteria of any rules for architectural design.



Figure 1. Modular House in 1920's

Huge popularity the industry of modular house building gained after World War 2 when veterans of war came home, but influenced of lack of money and job, they had to search for jobs in different locations and it was important to have their houses cheap and mobile.

The homes fabricated by the Sears Roebuck Company in 1940's were the first modular buildings to be popular in America shown in Figure 2. The kit homes were targeted at people moving west, especially those lured to California for the Gold Rush [10]. Once purchased, each house would arrive by rail in a kit complete with all necessities— from nails to paint—and a detailed list of instructions.



Figure 2. Modular House in 1940's

In 1960s the demands for comfort from clients side was growing and along it grew the design and functionality of modular houses as shown in Figure 3 [11].



Figure 3. Modular House in 1960's

At that time mobile modular house manufacturers got a full license and approval from architectural society for designing a safe modular house that is built according to all building regulations. Since then modular housing has been upgraded and split in different ways starting from design and functionality and continuing with different material and construction solutions.

Modular homes are also referred to as transportable homes, portable homes, pre-manufactured homes, manufactured homes, pre-built homes, granny flats, prefabricated homes, prefabs, prefab homes, cabins, holiday park cabins, tourist cabins and affordable housing.

These are all types of modular homes. However, they are not to be confused with a traditionally built house on a block of land that is moved after a period of years and transported to another location. These are purely houses that have been moved. Modular homes shown in figure 4 (or any other terminology used in the list above) are designed to be transported and have extra reinforcing to cope with possibly several moves over their lifetime [12].



Figure 4. Transporting of Modular House

2.2. Module House Classification

2.1.1. One Block Prefabricated House: The main characteristics of this type are full prefabrication [13]. The one block prefabricated house is produced not on site, it is fully pre-made with all furniture and technical installations. The main idea of this modular type is to deliver it on site in one piece and with just few modifications, house is ready for inhabitants. A type like this saves time on construction and it is portable with one time travel, it is also saving costs on building site arrangement. Usually time to fully finish mounting modular house is 2-3 month; this time is a lot shorter comparing to standard construction time that could last up to 1 year [13]. Construction worker team instead of constant driving around building sites can produce modular homes at factory that way saving their time and money for producing company and client. If comparing expenses for classical construction and prefabricated house, there is about 30% difference in material costs. Prefabricated house building can reduce expenses of materials ordering them directly from producing companies, avoiding premiums of construction designers. Also the materials are kept under roof without any weather damage. There are also several types of construction for this kind of modular house.

The most common construction is wooden frame shown in Figure 5, insulated in between and decorated with wooden cladding [13, 14]. This type gives less weight which is good for transportation, wooden construction is also cheaper. For this type of

construction there are unlimited choice of shape and design, as long as it stays within allowed dimensions for transportation.



Figure 5. Wooden Frame Construction

One block houses are also made with steel frame, the cladding and insulation can be the same as for wooden frame construction shown in Figure 6. This type of construction gives more weight, but it is easy to mount, this type increases the stability of house and it is also very variable on shapes and design [15]. This type allows using more glass on construction because of strength of frame.



Figure 6. Steel Frame Construction

Also depending on location and weather conditions there are possible variations of construction. If the weather is rough and windy than the precast concrete is used for the ground partition. This concrete slab requires for stronger foundation. The modular house later is connected to concrete slab which is used as floor as shown in Figure 7 [15, 16].



Figure 7. Concrete Foundation

Another type of construction is oceans container system. Basic container is adjusted to planning of ground floor shown in Figure 8, the windows and doors are cut out in necessary places [17]. Walls and floors are insulated. This type of construction is very limited for shape variances; it is triangular shape with flat roof.



Figure 8. Container House

2.1.2. Multiple Blocks of Prefabricated House: This type of modular housing remains the same principle as one block prefabricated houses shown in Figure 9. The difference is in layout of blocks. There can be more than one block connected together, that way ensuring more space for open planning. One block can be one room, the wet rooms can be made separately in other block [17, 18].



Figure 9. Multiple Prefabricated Blocks

As shown in Figure 10, the system allows building blocks one to another that way making multi-storey prefabricated house. Managing blocks of this kind can reach unlimited design variances, it can fit any environment and the time process of building is shortened due to prefabrication [18]. The blocks are delivered with several trucks and with crane they are connected together.

All technical installations are set up before. The stability of those blocks are ensured, each item is made according to load bearing regulations. When connected, blocks obey their own static rules. If blocks are arranged with overhangs, the extra reinforcement is made. Usually the layout of blocks is designed before in factory, therefore all necessary construction reinforcement is provided.

The construction of blocks usually is made of steel frame, but there are also wooden constructions and container systems. Once the modules of a portable home are assembled, there is a double wall effect. Where the modules meet, as each module is a mini building in its own way, when connected together, the internal walls are effectively doubled.

This type is gaining popularity among motel business, the construction time is short, costs are lower than traditional building and the design doesn't play important role.



Figure 10. Multiple Container Blocks

2.1.3. Modular House Assembled on Site: This type of module house is a prefabricated home built in an offsite factory, which is then delivered by truck to the home site, and assembled by a construction crew [18, 19]. The sort of this kind home can share some similarities to prefabricated block houses. The materials and way its built could be very similar. The difference between this type and prefabricated block house is that there are more varieties of shape, the size could grow bigger and the main issue is mounting. This type of construction may be subject to weather conditions – at the moment of mounting. Also the time spent on site assembling this house lasts longer than one block house finishing. As shown in Figure 11, the module house assembled on site doesn't need to be specially reinforced for transporting.



Figure 11. Modular House Assembling

As long as it is delivered to site in pieces shown in Figure 12, the elements do not suffer from different statistical forces that may influence block house [18]. To assemble such a house the crane is required. Building elements are connected piece by piece by construction workers.



Figure 12. Modular House Delivery

All connection holes are later insulated and prevented from thermal bridges. This type of mounting must obey all building regulations. As shown in Figure 13, the building site is arranged by standards because there are several processes taking place on site and most of those processes concerns work safety [19].



Figure 13. Modular House Assembled on Site

3. Modular Manufacturing Process

3.1.1. The Factory Modular manufacturers vary in their production capabilities, technologies and assembly methods. They range from true automated moving production lines that shift the modules thru several different stations where specialized crews perform specific tasks, to static production lines where various crews come to the module and perform their respective tasks. Regardless of production line type, the steps involved are very similar. Today most modular manufacturers employ wood frame construction as opposed to steel or concrete. The very beginning step for most manufacturers in the building phase within the factory is the lumber check shown in Figure 14 [20].



Figure 14. Lumber Check on Factory

Lumber must be moisture checked, and pre cut for the floor and ceiling joists. This is an integral step that manufacturers tout as evidence of superior product quality. It is done to ensure that the structure does not experience shrinkage or warping since lumber that is too dry can become twisted and brittle; if it is too wet it warps. Thus by monitoring this via meter reading, manufacturers can refuse wood that doesn't fit within moisture and grade parameters. Some companies go a step further and use kiln dried lumber that is stored in heated warehouses. Once the lumber is checked, approved and cut, the floor platforms are built on raised steel jigs to ensure they are plumb and level

While elevated on these risers, any rough plumbing or required duct work is laid out shown in Figure 15 [18, 20]. Some manufacturers utilize 2x10 beams for cross-bridging to increase floor strength. After the decking comes the sub-floors and walls while the module is set on the floor or the production line.

Once these elements are set, the roof trusses go on and there is further framing, piping, electrical and data wiring and sheet rocking (usually 5/8") shown in Figure 16 [20]. The sheetrock application is different from a site built structure in that it is applied prior to the exterior being enclosed.



Figure 15. Duct Work is Laid Out

This is possible because carpenters do not have to worry about protecting the inside from the elements. What this allows for is a wall fully insulated from the inside out. With traditional home-building methods, the corners of the structure rarely get insulation as they are sealed from the outside prior to the sheetrock installation and are largely inaccessible.



Figure 16. Framing, Piping, Electrical and Data Wiring and Sheet Rocking of Roof Truss

In design, manufacturers leave a small space between what will become marriage walls (walls where two modules are joined) to allow for a margin of error that will be backfilled with foam when set. Next, several finish components are performed including kitchens, baths, lighting, ducting, windows and occasionally flooring and exterior siding. Doors and windows are assembled with foam around the edges and good quality flashing, weather-stripping and chafing strips, ensuring proper insulation. Once built, the modules must be tested and most manufacturers do this on site.

These tests include airtight testing, plumbing inspections (running the bathtubs/Jacuzzi's *etc...* to ensure piping is leak free), and tests on radiant heat and any other specialized systems in place that are specified. After this step, the interior walls of the modules are typically primed and the modules are prepared for transportation as shown in Figure 17 [21].



Figure 17. Transporting of Modules

Most times sheetrock is cut with extra slack to prevent cracking where walls meet door openings or hallways shown in Figure 18, then once on site, the excess is trimmed away [21].



Figure 18. Sheetrock is Cut with Extra Slack

When combining modular with panelized or site-built construction (to achieve a wide span or a cathedral ceiling) temporary walls or framing is built in to add extra structural support and arched plywood is applied to the tops of the modules where the heavy plastic will be placed to create a bowed frame that rain or snow will readily run off.



Figure 19. Roofs Covered with Plastic Material

Floors are covered, doors are locked and a plastic wrap covers the sides. Roofs are always covered with a thicker, heavier plastic material shown in Figure 19 [13, 22].



Figure 20. Wrapped Modules

It is common for manufacturers to utilize their additional interior or exterior storage capacity in the event that customers are not ready to receive their product or a manufacturer feels it more efficient to stage delivery only when a certain inventory builds up. As shown in Figure 20, modules being stored outside, although shrink wrapped, are routinely checked for any potential leaks or cracks in the wrapping as anything from severe weather conditions to birds can potentially impact the integrity of the protective wrapping and allow water to damage the interior and create the potential for mold. Once the time is right, the modules can be lifted onto flatbed trucks for delivery to their destination. The modules are carefully secured to the truck at the factory to protect against the rigors of the transportation process, which has been compared by multiple parties to “earthquake-like conditions” shown in Figure 21. There are a few horror stories involving modules slipping off trucks during transit or being involved in accidents, but these sort of occurrences appear to be infrequent. An interesting testament to the structural integrity of the modules came from a story about a single family home module that fell off a truck and rolled over multiple times. The module was found to be in solid structural condition except for damage to some interior fixtures. The customer requested that it be used in their home as they felt content with the structural integrity and therefore thought it would be wasteful to destroy it [22].



Figure 21. Modules are Carefully Secured to the Truck

3.1.2. Transportation. Typically it is not feasible to ship modules extremely far due to road size/load restrictions. The average manufacturer typically quotes 250-400 miles as the maximum distance that it is desirable to transport modules. Some companies, like Epoch Homes in New Hampshire, are looking into how to efficiently transport beyond this distance, in special circumstances such as aiding in the reconstruction of New Orleans, but this is atypical [23]. [24]. Modular appears to have pushed some fairly interesting boundaries in terms of alternate transport by utilizing both sea barge and helicopter delivery to islands or particularly remote locations. Despite the obvious difficulty inherent in such complicated transport it may often be a more cost effective alternative than utilizing a site built method. Exotic transport aside, most modular deliveries are made over the highway and governed by a somewhat complicated web of international and inter-state regulations. It is not rare for a transporter to have to deal with three or more different government agencies to get through a single state. Opinions vary on the complexity of the approval process. Modular manufacturers are increasingly responding to developer's desire to be provided with more seamless service and are handling the transportation component of the process. Modules less than twelve feet wide are mostly allowed to travel with no restrictions. When the size increases to between twelve and fifteen feet wide there is an accompanying increase in the restrictions and often a requirement for police escort. Once a module reaches the fifteen to sixteen foot width it is almost universally declared a wide-load that requires police escorts and can often be required to travel overnight as to not impede local traffic.

3.1.3. The Set. It is the developer's responsibility to have the foundation ready and the tie-ins for electric, plumbing, and sewer in place so that the modules can be connected to the necessary infrastructure. Such infrastructure work occurs, weather permitting, concurrently with the manufacturing process so that essentially, once the foundation is set one can ship the modules, connect them and obtain occupancy permits. The modules arrive built with walls, floors, trusses, ceilings, wiring and interior fixtures to the extent the developer wants them. Once on site, the modules are stacked by a crane (usually between an 80 to a 160 ton crane depending on the size of the modules and the distance from the crane that it must travel) at an average pace of approximately four to six modules per crane per day shown in Figure 22 [25]. The modules are bolted together along both the floor and the ceiling joists and the marriage walls are connected with a series of steel fasteners and strapping. They are quickly weather proofed by sealing them with building wrap that blocks moisture and pollutants yet allows the structure to breathe and water vapor to escape. Care needs to be taken to monitor weather conditions around the scheduling of the set. While tarps may be used to protect the unwrapped modules from rain or snow during a set if necessary, this is a less than perfect solution and it is better to schedule around inclement weather if possible. Once set and connected, the structure is then ready for subcontractors to begin the process of performing the interior and exterior finishes and all required utility connections.



Figure 22. Modules are Stuck by Crane

3.1.4. Inspection and Quality Control. One primary difference between site-built and modular methods is inspections. With modular, throughout the manufacturing and installation process, there are multiple parties monitoring the process. While a large multifamily project still requires local architects and engineers to submit stamped permit drawings in their particular state, the physical inspection of the modules as they are built are not handled by local building inspectors but independent third party inspection companies who are licensed to review the work as it is being performed in the factory to ensure code compliance. As each module is inspected and approved it receives a seal certifying that everything within the module conforms to the plan and the building code. Local building inspectors are only “supposed” to review the additional work that occurs once the module is set such as utility connections and the buttoning up and connections of modules. This is occasionally tested however, by local inspectors who overreach their authority. The third party inspection process applies in most jurisdictions but one must locally verify the applicability. Additionally, the design process involves both a factory architect and an architect employed by the developer and licensed in the state where the development is to occur. This dual design/review process can often eliminate any future change orders or surprises in the field. Quality control is not just code compliance, however, and quality assurance employees and shop foremen inspect the modules throughout the construction process. A major difference between the site-built and the modular process is proximity of quality control personnel to the work being inspected [24, 25]. Quality controls are still subject to human error. Since the factory building method is a fast moving process, many industry insiders recommend the practice of having the manufacturer make two or three modules and then sending the local architect and general contractor to the factory to inspect so that any issues, specifically those pertaining to MEP systems, can be cleared up early on. Some common infractions that do arise either during manufacturing, or once on-site, are minor issues: foil insulation is facing the wrong way inside an interior wall, hairline cracks in the plaster, sixty foot long modules may be slightly off in length.

4. Interview

4.1. Methods

The researchers conducted the interview by asking a series of prewritten questions. Thirty-three (33) Civil engineers who worked in the VAZbuilt /VAZcrete Construction

had a digital copy of the questionnaires so that they could read the questions as the researchers interviewed them. The researchers took notes during the interview. After the interview, the researchers summarized what they said.

4.2. Paraphrased Interview

Based on the gathered information, it is difficult to single out either modular or of traditional mass housing construction and choose one as better than the other. It greatly depends on what clients are trying to accomplish. There are not a whole lot of differences between the two. If speed is what matters most, modular is the best way to go because it is quite a bit faster. If flexibility of design is the most important aspect of the project, stick-built construction can offer more versatility.

Modular construction will cost more up front every time. However, the owner can get a quicker return on investment because the property is able to be rented quicker. There are some cases in which owner could save money by using modular construction. For instance, unionized labor up north is expensive. If owner was to have the project built in a modular factory with non union labor, the owner could ship the modules to their site and place them for less than owner could build on site.

Modular is easily the fastest method of construction. It provides a quicker return on investment because the property is available for renter occupancy sooner than if mass housing construction is traditionally made housing component (CHB) used. Right before the World's Fair in Camella Homes, modular apartments were built and made to rent out nightly to people coming from all over the world. They chose modular because they needed it done fast.

Another example for choosing modular as the best method would be if owners are trying to finish an apartment complex next to a university before the semester begins. Because modular construction is faster, owner can rent the property quicker and start paying off the construction loan resulting in paying less interest on the life of the loan.

Modular construction generates a lot less waste than traditional stick-built construction. There are things that are standard in modular construction such as tight building envelopes, water saving fixtures, and energy saving appliances. Though all of these things can be done in regular mass housing construction, it is more challenging to get the same results. The advantage to modular construction is that the bottom plate, top plate, sheetrock, and rafters are all glued to each other, in addition to being nailed, to almost completely eliminate air infiltration.

If speed is everything, pick modular. If flexibility of design is everything, pick stick-built. It is common to use hybrid construction in which some complex pieces of the project are built on site while other more simple components are brought in and set as modules. If knowing the price of the project up front is important, modular is a good choice. When using modular construction, the owner has a very good estimate of what the project will cost before the job starts. The quality of modular is more consistent, but the same quality can be accomplished by a skilled framer using stick-built construction.

Modular construction is much "greener" than stick-built construction. Because all of the construction is done inside a climate controlled area, no moisture is able to get into materials. A common problem in stick-built construction is getting moisture stuck in a wall that was built with material that got wet prior to use inside. This often creates environments where mold can easily grow inside the wall, which has been blamed for being one of the leading causes of respiratory diseases in young children. The air quality inside a modular building is very good.

Generally, banks view both methods the same. However, in a lot of small counties, city ordinances have banned modular construction because of the misconception that all modular construction looks like a mobile home. Owner may run into issues where a bank will not loan you money for a modular project because of city ordinances

5. Structural Properties of Prefabricated Components

5.1. Cheecolite Prefabricated Technology

5.1.1. Air cured. The specimens have been demolded at 24 hours and stood in a laboratory air with a relatively low humidity until the time at test. No means of moist curing the specimens was carried out and therefore the results obtained are the minimum value expected for what property.

5.1.2. Warm cured. The specimens have been demolded at 24 hours having been kept moist during that time and then stored under water at 19 degrees Celsius until the time of test. The specimens were then tested in a saturated condition.

5.1.3. Compressive strength. The strength achieve in construction will therefore depend upon the curing method adopted. As guided, however, cheecolite cured in a temperature of 35 degrees Celsius and 85 percent relative humidity with protection from direct sunlight could be expected to achieve strength of 10 percent higher. The compressive strength of a grade 20 concrete in 20N/mm^2 .

5.1.4. Strength gain. The strength gain of a concrete is dependent upon sufficient free water being available within the material to allow the hydration of the cement to continue. The strength gain is indicative of that which would be expected in a moist, tropical climate. For a grade 20 concrete made with ordinary Portland cement and cured under favorable conditions, about 70 percent of the strength attained in one year is reached at 288 days; 80 percent of that strength is reached in two months, and about 95 percent in six months. Two thirds of the strength attained in 288 days is normally achieved after 7 days.

5.1.5. Flexural strength (modulus of rupture). A grade of 20 concrete would be expected to achieve a modulus of rupture of 33 N/mm^2 at 28 days. For a dense concrete, the modulus of rupture is approximately one quarter of its compressive strength.

5.1.6. Shear strength. The ultimate shear stress of materials should not exceed 2 percent of the characteristic compressive strength without special shear reinforcement being provided. The ultimate shear stress of a grade 20 concrete varies between 2-4 percent of the characteristics compressive strength

5.1.7. Modulus of elasticity. The static modulus of elasticity of grade 20 concrete is 25000N/mm^2 .

6. Other Properties of Prefabricated Components

6.1. Sound Insulation

The index is related to the mass per unit area of wall construction. The index value can be therefore improved by constructing the wall of denser material or increasing the wall thickness. Table 1 shows that the introduction of a cavity wall construction has greatly improved its sound insulation.

Table 1. Sound Insulation

Material	Thickness (mm)	Superficial density (kg/m)	Sound reduction index (db)	R _w
Cheecolite ref 1500	100	133	39	41
19 mm chipboard on timber frame	100	11	24	27
Thermalite blocks	100	125	39	42
Dense concrete	100	330	47	50

6.2. Durability

6.2.1. Frost Resistance. Materials with normal moisture content are highly resistant to frost action. This is because any moisture in the material when frozen can expand into the voids of the material without rupturing the matrix. When there is danger of frost, it would not be recommended to use cheecolite below ground level without a waterproof protection.

6.2.2. Sulphate Resistance. Materials with normal moisture content are highly resistant to frost action. This is because any moisture in the material when frozen can expand into the voids of the material without rupturing the matrix. When there is danger of frost, it would not be recommended to use cheecolite below ground level without a waterproof protection.

6.2.3. Carbonation. Due to the cellular nature of cheecolite, carbonation of the cement gets proceeds a little more quickly than in the case of dense concrete. This can permit reinforcement to corrode at an earlier stage, but the intrinsic strength of the cheecolite is not impaired.

6.2.4. Corrosion. Cheecolite, before advanced carbonation takes place, provides adequate protection to steel reinforcement from corrosive attack.

6.2.5. Deterioration. Cheecolite does not require any surface treatment as a protection to atmospheric conditions and exhibits little tendency to crazing, surface cracking or spalling.

6.2.6. Sunlight. Cheecolite is unaffected by exposure to strong sunlight and will have no signs of distress due to the heating/cooling, night/day experienced in tropical climates.

6.3. Finishes

6.3.1. External Walls. Finishes are not required as a protection for the material but are often provided for their aesthetic value. They are also useful for designing minor surface blemishes and soy patching which may be necessary due to damage during handling and erection.

6.3.2. Internal Walls. For internal finishes, emulsion paint would normally be adequate but the surfaces may be plastered if required.

6.3.3. Roof Surfaces. Bituminous flat is normally used on that roofs with mineral provided for falls of 10 degrees. A finish of light colored chipping is recommended for smaller falls. Spot bonding of the first layer is advisable to prevent thermal movement rupturing the felt.

6.3.4. Roof Soffits. The soffits of proofs in many cases can be left untreated. When painted, emulsion paints are adequate but fungicidal paints are preferred. Oil paints which are impermeable to water vapor should not be used.

7. Advantages

7.1. Design

7.1.1. Structurally Sound. Each wall panel has a ribbed type design on all sides to function as a structural column, resist vertical compression, and a beam type element on top to resist lateral loads. This means that each panel possesses structural properties that make the wall very independent and the use of any concrete column is eliminated.

7.1.2. Architecturally Elegant. Aesthetic expression, size proportion, shape and smooth clean surface texture are designed to easily harmonize with other building materials. Surface imperfections due to plastering and repair of other flaws are eliminated.

7.1.3. Fire Resistant. Wooden materials such as window/door jambs are avoided since the main design of window/door jambs are made up of concrete homogeneously poured together as part of the wall and now making the prefabricated wall panel in a pure non-combustible concrete materials.

7.1.4. Durability. The concrete made used is sufficiently resistant against corrosion and cracking. In this walls are properly reinforced by grade 40 temperature bars or welded wire fabrics as reinforcement for temperature shrinkage

7.2. Construction

7.2.1. Fast Wall Construction. The wall component of a single detached house unit can be erected in less than 4 hours. This is more hastened by the use of lifting equipment available and thus, placement and erection of the wall on its desired locations will be more accurate. This makes the work more comfortable, easy and offers

a very wide margin of time savings and therefore, construction time in subdivision development substantially shorten.

7.2.2. Minimized Carpentry Work. Production of conventional wooden door and window jambs which is being fit together with the CHB walls is eliminated. Now, with the prefabricated panel, all the jambs can be made in one concrete pouring making the jambs part of the wall.

7.2.3. Assured Quality Control of Construction. The quality of workmanship for the walls is attained in the production plant where the concrete casting, curing and handling are done. Any problem regarding surface imperfections and other defects are then corrected and avoided. Thus, all the prefabricated walls to be used on site are properly controlled, cured and has reached its correct allowable strength before installing the wall into its final assembly.

7.2.4. Organized Construction Procedure. The resulting construction site is cleaner and more space is available because less false works and formworks are used. In this manner, the placement of the prefabricated wall panel has more room for precision. All other subsequent assembly of trusses and roof system can be implemented section by section without worrying in over lapping of activities. Any errors and incorrect alignment can be detected because the subsequent assembly cannot proceed if this happens; the highest quality of workmanship is attained.

7.2.5. Maintenance-free Construction Material. The present wall panel is being fabricated with pure reinforced concrete material making it free from any probable voids or surface imperfections. Plastering and finishing works are eliminated. Definitely, the wall panels require no maintenance in a long life term of the structure. Both exterior and interior faces are smooth and will be free from dust collection to stick on the surfaces making it hazard free.

7.3. Economic

7.3.1. Material Cost Savings. Concrete which is measured in terms of cement, sand and gravel and being the material used in the precast concrete wall fabrication is significantly reduced because of lesser volume requirement demanded by this design of walls. Concrete volume requirement for one house unit is reduced by a much five cubic meters compared with conventional CHB construction. Although a slight additional amount of steel reinforcement is necessary. As shown in Table 1 and Table 2, the projected material cost is 5.98 percent and a labor cost is 9.69 percent lesser compared with the conventional CHB construction.

7.3.2. Minimized Concrete Wastage. Significant cost savings are generated during panel production in the plant because concrete pouring can be organized and done by skilled personnel's and mechanical equipment, this proper placing of concrete can be controlled and monitored. The factors affecting the workers inefficiencies in the field which means wastage in manual concrete pouring practice are avoided.

7.3.3. Labor Economy. Definitely lesser labor requirement is demanded since the main bulk of the construction work which is the erection of walls is done by lifting

equipment and assisted by new erection personnel only. Labor for concrete plastering, CHB piling are avoided, erecting conventional scaffolding, formworks are cut-off significantly, and labor for jamb assembly is eliminated.

7.3.4. Environment contribution. Tremendous reduction of concrete material consumption and lesser demand of lumber will contribute so much to the preservation of environmental resources of lesser quarrying required and utilization of forest product is substantially reduced.

7.3.5. In Terms of Construction Methodology. Prefabricated building components are easy to assemble and can be finished in 12 to 30 working days depending upon the area of the house to be erected. 8 to 15 manpower is enough to finish the whole structure, work is never delayed because there is no need poor's curing of the materials because before it is installed, it already passed the standard psi required for building houses.

8. Cost Analysis

Considering a single unit with 48 square meters floor are. The cost evaluation analysis being considered is centered on the item of works. The researcher included the construction of walls, footings, beams and all the skeleton structural support. Table 2 and Table 3 show the comparison between the conventional CHB construction and the precast concrete wall construction.

Table 2. Direct Material Cost

Material	Cost (Php)	% Reduction
Conventional CHB	33 082.03	3.98
Prefab Concrete wall	31101.88	

Table 3. Labor Cost

Material	Cost (Php)	% Reduction
Conventional CHB	4370	9.69
Prefab Concrete wall	3947	

9. Conclusion

Modular construction is superior to traditional mass construction in most cases. There are a few limits to modular construction but they are usually not encountered in a multi-family building project. Modular construction is completed in about half the time it takes using traditional mass construction, meaning the property can be rented faster and added revenue can be created that would not be possible using stick-built construction. Modular construction is also better quality. Because the workers in the factory use lasers to cut the wood and jigs to place the pieces together, the quality is very consistent. The workers are also very efficient because they do the same job repeatedly, which increases their skills and reduces errors. Very little waste is created and no materials are damaged by moisture, which creates a home with very good indoor air quality that is far superior to the average stick-built home.

If knowing the price of a project upfront is important, modular construction can offer far more precision. This is especially helpful when building rental properties because an accurate estimate for return on investment can be easily calculated. Knowing the price

upfront also benefits investors in that they can know exactly how long it will take to get a return.

For someone looking to build a multi-family property, modular construction offers higher quality than traditional mass construction for the same amount of money. Modular construction should be strongly considered if having consistent quality is of high value

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