Design Innovation for Prefabricated Housing Components for SMEs

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ABSTRACT

Labor shortages in Thailand have been a chronic and prolonged problem, affecting many industries particularly the construction industry. Currently, prefabrication technique is being adopted by most large private property developers to produce precast concrete panels thereby lowering the demand for construction workers and minimizing construction schedules. The utilization of fully-automated production facilities has proven to be highly efficient and feasible. The high production capacity has enabled the developers to expand beyond Bangkok to other large cities in Thailand. Regional expansion coupled with the labor shortage has amplified the competitiveness faced by small and medium enterprises (SMEs) in carrying out small-scale projects such as housing and construction. The findings show that SMEs rely mainly on the conventional construction methods and processes to compete, irrespective of the new development of modern and effective construction methods. In this research, it is initially assumed that SMEs cannot, and should not compete by focusing solely on the efficiency and production product cost, although product differentiation, added values and the design innovation are the means for market survival. Moreover, SMEs must pay attention not only to the production, but particularly on the design innovation in response to the customers' needs.

From an extensive field research, literature review and interviews, the findings show that precast concrete panel construction is not the best system for SMEs due to its high investment cost, and a high logistic cost since the involved processes are quite complex and complicated.

This research proposes a light-gauge steel prefabrication system as an alternative for housing by means of standardized components that can be assembled on-site to meet the customers' needs. Light-gauge steel framing can offer several advantages over the precast concrete panels due to its unique characteristics such as its adaptability and ease of expansion, thereby removing the monotonous appearance of precast concrete housing.

KEYWORDS: *prefabrication, prefabricated house, light-weight structure, expandable house, innovative housing, mass- customization*

INTRODUCTION

Labor shortages in Thailand have become a chronic problem affecting all Thai industries especially the labor-intensive construction industry which is one of the most significant economics drivers of a country. In 2011, a survey conducted by Bank of Thailand confirmed that Thai construction industry was one of the five sectors facing critical labor shortages. These are further magnified by an increase in the daily minimum wage to 300 Baht across the country by the Yingluck Government which became effective on January 1st, 2013. To overcome such problem, most large property developers have adopted the prefabrication method by using the precast concrete panels to lower the construction demand for workers and to minimize time for on-site construction. Fully automated production facilities have proven to be highly efficient and viable for large property developers who make use of the high production capacity to expand beyond Bangkok. The regional expansion together with labor shortage has intensified the aggressive market conditions. Literature reviews and past studies have all mentioned that SMEs are still depending on the conventional construction methods and processes as opposed to the modern construction methods despite their known advantages. For this research, it is initially assumed that SMEs cannot compete with large developers by focusing solely on the efficiency and cost of production, although product differentiation, added values and design innovation are the means for market survival. Moreover, SMEs must not focus only on the production, but emphasizing on the design innovation in response to the customers' needs. In this context, the term "innovation" is defined as something original, more effective or the application of better solutions that meet new requirements, unarticulated needs, or the existing market needs (Maranville, 1992); every innovation needs to be assessed/ justified in the specific context. In order to develop a feasible design innovation framework for prefabricated housing components particularly for SMEs, this research provides an understanding of the ongoing practices in prefabricated construction in Thailand, the changing demographics, and the market demand.

PRACTICES IN PREFABRICATED CONSTRUCTION IN THAILAND

Established in 1962, South East Asia Construction (later known as Seacon), a Thai construction company, developed their own pre-built column and beam system for the construction of row houses and single detached houses as a mean to survive and be competitive. Seacon, together with an American real estate developer, began building a housing estate comprising of 800 single-family houses. The project was an extraordinary success story in Thailand's housing estate since it was the first time that Thai people had a long-term loan for buying their home. The pre-built components were assembled together and welded on-site before filling in the non-shrink concrete to cover the joints. (Fig 1)

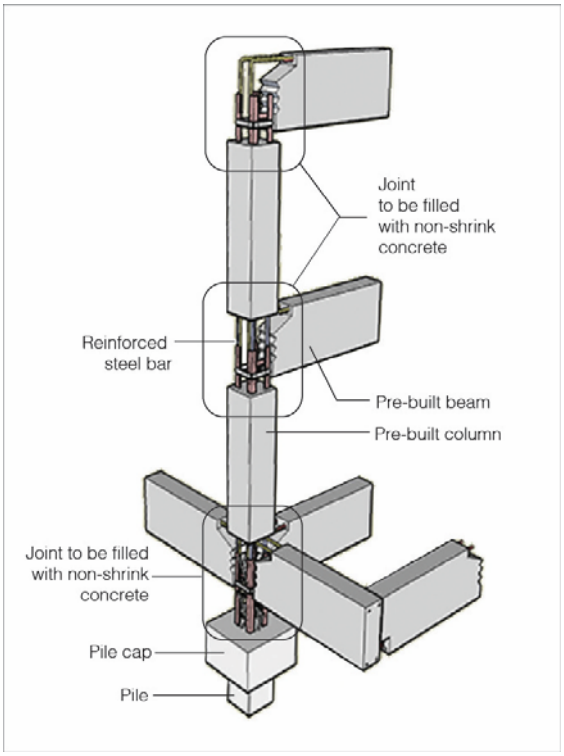

Fig 1 Seacon's Pre-built column and beam

In the late eighties (1988-1994), Thai economy experienced an unprecedented economic boom in Asia, and several local property developers began adopting the precast concrete panel as a structural system in building apartment buildings to be completed in the shortest time possible. The first mid-rise building built with prefabricated concrete panel is Baan Suanton-Puttabucha which comprised of 68 identical buildings, 4 units on each floor, 24 units in each building, and 1,632 units in totals. (Fig 2)

Fig 2 Baan Suanton- Puttabucha

In 1993, the largest Thai property developer, Pruksa,introduced the use of Tunnel forming technique for the construction of townhouses and were sold with competitive pricing of being less than 500,000 Baht per unit. Later in 2005, Pruksa built its first precast concrete panel factory by importing a complete set of fully automated precast concrete production from Germany. Its 6th and 7th precast concrete factories were completed in 2014. With its seven operating factories, Pruksa's production capacity can erect 1,120 Houses per month. All single detached houses built by Pruksa uses the precast concrete panel as the load-bearing structure (Fig 3). Each house can be assembled on-site within 21-days completion. Besides single detached houses, all of the mid-rise condominiums in Bangkok and its vicinities, are constructed by using the precast concrete panels as mentioned earlier.

Fig 3 Precast concrete panels are used as loading-bearing structure for house construction.

In 2009 SCG Heim was established as a partnership between Siam Cement Group (SCG) and Japanese company, Sekisui Chemical. SCG Heim has invested over 2,000 million Baht in its production facility with the production capacity of 1,000 houses per year. The prefabrication utilizes the modular system of a standard unit of 2.5m x 6.0m x 3.0m (Fig 4). Its structural components are comprised of high tensile steel (SS400) coated with Zinc, Aluminum and Magnesium for maximum rust protection. The wall is a thermal insulated wall system; using light gauge steel as framing with the smart board for the exterior cladding, gypsum board for interior finishes, and fiberglass insulation in the middle. Double layers floor has made an allowance for a cavity of 55 cm between the service floor and the ground floor for all building systems to run beneath so that building maintenance can be easily achieved.

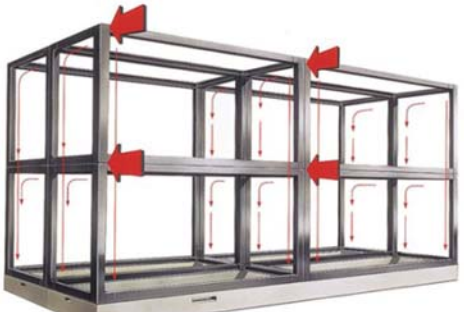

Fig 4 SCG Heim's modular system

Another well-known house-builder company, PD House, has used the precast concrete column and beam to build houses. In 2016, the company launched their new product "PD Steel House" using the alternative material, light-gauge steel, for the prefabrication of panel system or modular steel units for house construction (Fig 5).. Steel framing works as a load-bearing structure. Its exterior wall panel is comprised of high-tensile steel frames, with 50 mm rock-wool insulation and sandwiched by gypsum boards as the interior cladding and 2 layers of fiber cement boards for the exterior cladding.

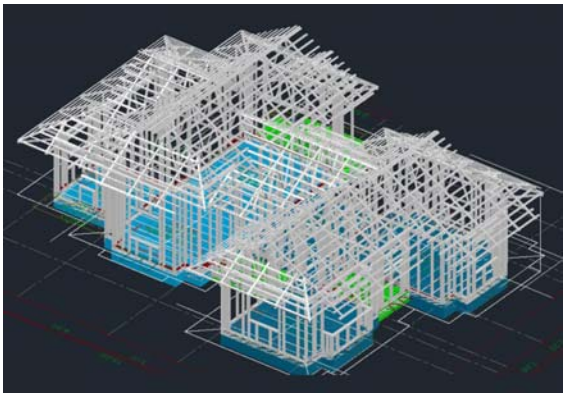

Fig 5 PD Steel House's light-gauge steel panel system

From the above, there are currently 4 prefabricated construction systems that have been commonly practiced among Thai developers and contractors, namely, (1) the Precast concrete panel system, (2) the Precast concrete column and beam, (3) the Steel modular system and, (4) the Light gauge steel panel system. The precast concrete panel system has become the most commonly use prefabrication system being adopted by most Thai property developers and contractors.

ADVANTAGES, PROBLEMS AND TRENDS OF PREFABRICATED CONSTRUCTION IN THAILAND

It has been a common perception among Thai customers that concrete construction is more durable and easy to maintain than other materials. Presently, the precast concrete panel system is the most available and acceptable system by both customers and developers. The advantages include; minimizing of the on-site construction time since the wall slabs perform as the structure of the house, mechanical systems and electrical wiring are embedded within the precast concrete panels when casting. Moreover, the cost of cement is more stable and cheaper than steel since it can be locally sourced. The budget can be easily controlled especially for using concrete being made with local material. Prefabrication also allows for improving construction efficiency. In summary, the advantages of prefabricated construction include; (1) reducing the need of construction workers, (2) minimizing the construction time, (3) getting a better control on the construction schedule, (4) achieving a better quality of construction and, (5) minimizing the construction waste and environmental impact.

Irrespective of the associated advantages of prefabricated construction system, there still exists many problems that cause an unwillingness among SMEs in implementing the system. These problems include: (1) technical difficulties; there are numbers of technical specifications needed to be properly handled, therefore people involved in the process must be well-trained, (2) high initial investment cost; formwork for casting concrete and preparation process is very expensive, (3) repetitive character of design; efficiency and productivity can only be achieved by producing large number of panels, thus leading to repetitive character of design, and (4) a high logistic cost; logistic cost could exceed the material cost for a long-distance delivery. When the delivery distance exceeds a certain limit, the precast concrete construction will no longer be feasible.

Nowadays, there is an increasing number of SMEs showing an interest in adopting a prefabricated construction method using the precast concrete panel despite existence of technical difficulties, high initial investment cost, and large number of minimum order quantity. Additionally, more SMEs are shifting towards prefabricated components for items such as concrete plank, hollow core plank, column and beam, fence, stair, exterior cladding. Additionally, small suppliers and home - builders are looking for alternative construction materials and construction system instead of the precast concrete panel due to the associated high energy and high logistics cost, thus becoming a barrier for market entry. In the meantime, more technologically advanced material like cold-rolled steel has been progressively utilized due to its structural capacity, lightness and its advanced surface coating. The recent natural disaster, especially earthquake, had caused a rising interest in the structure that can resist the seismic loading. There is also a rise in the global trends towards sustainable design and energy saving which become the major criteria that drive the SMEs to create new added values and not just focusing on competitive pricing. Universal design is also a major concern for aging customers since Thailand has now entered the aging society.

TREND OF FAMILY SIZE AND HOUSE SIZE IN THAILAND

From the National Statistics of Thailand, it is reported that the family size was constantly falling with an increasing average population growth rate during 2000-2010 at 0.72% per annum. When comparing to the average population growth rate during 1990-2000, which was 1.1% per annum, it decreased by 0.38% per annum. Moreover, the Thai family size contracted corresponding to the constant decreasing birth rate; the average birth rate in 1952 was 44 per 1000 persons and reduced to 15 per 1000 persons in 2012. Presently, there is a tendency for the Thai Family to live separately. In 2006, there were 65% of children living with their parents while in 2013 the number reduced to 61%. Additionally, the elders also prefer to live independently. In 2007, 59.4% of the elders lived with their family while in 2011 the number reduced to 56.5%. In general, the average number of family member is decreasing; the average number of family member in 1990 was 4.4 persons / family while in 2010 the average number of member was 3.1persons per family.

From the survey on "Market demand for living space", 60.7% of the respondents have 2-4 persons in the family. When questioning about the affordable price, more than 50% of the respondents would be willing to pay between 1.0 – 2.5 million baht. The survey from the 29th Housing and Condominium Fair in 2013 showed that 55% of the respondents would be willing to pay between 1-3 million baht for a single detached house. The information from the same fair in 2015 was similar; showing that 59% of the respondents would be willing to pay between 1-3 million baht. The information from the survey is aligned with the real supply in the housing market; in 2013, there were 115,138 units of housing supply and 59% of them costs between 1-3 million Baht.

FRAMEWORK FOR "DESIGN INNOVATION FOR PREFABRICATED HOUSING COMPONENTS FOR SMES"

The aim of this research is to provide a design innovation for prefabricated housing components to be used by SMEs. It was initially assumed that SMEs cannot and should not compete by focusing only on the efficiency and cost of production, although product differentiation, added values and design innovation are the means for competitiveness. SMEs should pay more attention not only to the production, but to the design innovation in response to the customers' needs.

From the extensive field research, literature review and interview, it is evidence that the prevailing precast concrete panel construction is not the most viable system for SMEs due to its technical difficulties, high initial investment cost, large number of minimum order quantity, an involvement with complicated preparation and production process, and high logistics costs. Precast concrete panel construction is applicable for the design with repetitive components and large-scale projects comprising of repetitive character of design. Economies of scale help to compensate its high investment and preparation cost. Precast concrete panel construction is thus far better appropriate for large property developers and large-scale projects.

Comparing to the precast concrete panel construction, light gauge steel framing offers better advantages due to its low initial investment cost, ease of production, adaptability, ease of expansion as well as eliminating the need for repetitive character of design, and components. The design innovation must consider these advantages together with the current demographics situation and the market's affordability to set up the relevant design framework. The proposed design framework is outlined as follows:

1. Structure material: light gauge steel
2. Structural system: load-bearing wall or modular system
3. Wall finishes: fiber cement board, gypsum board and OSB
4. Price: 1.0-3.0 million Baht
5. Number of user: 2-4 persons
6. Floor area: 50-100 m^2
7. Land lot: 10m x20m
8. Standardized components must be able to combined to achieve "variations" in order to response to different customers' needs (Mass-Customization).
9. The design must be able to accommodate future changes in living (flexible, adaptable, expandable)

DESIGN EXPERIMENT: EXPANDABLE HOUSE

The design experiment is a collaborative project between Future Living lab, School of Architecture and Design, KMUTT and Thanakoon International, a supplier of cold-rolled steel who would like to expand its services to the home - builders. The work showcased in this paper, Jenga House, (Fig 6) is selected from 10 student projects to illustrate the possibilities of design innovation for prefabricated housing components for SMEs.

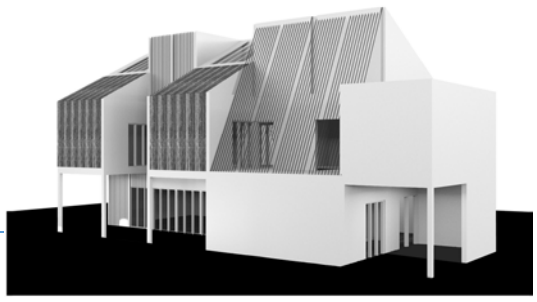

Fig 6 Jenga House[1]

Taking the wooden block toy, Jenga, as an inspiration (Fig 7), the design proposes a system comprising of 4 standard modules of 3.0m x 6.0m x 3.0m to accommodate 4 typical sets of functions; 1) Living + W.C. 2) Working 3) Kitchen + Dining 4) Bedroom+ W.C. These functions are integrated together within a nine-square grid to create different variations of floor plans (Fig 8).

Fig 7 Wooden block toy – Jenga

Fig 8 Four standard modules to accommodate 4 typical sets of functions

Starting with a frame of nine-square grid and any three pre-defined standard modules, 16 variations of floor plans can be achieved (Fig 9). With the given lot (10mx20m), 4 of nine-square grids can be fitted, two grids on the first floor and another two grids on the second floor. Total configurations of 65,356 variations of house plans can be achieved within the given plot. However, not every configuration will be practical at the same level. Floor plan assessment has to be completed during the design development stage. The same square grid system is applied to the design of the roof to keep the overall design systematic. (Fig 10).

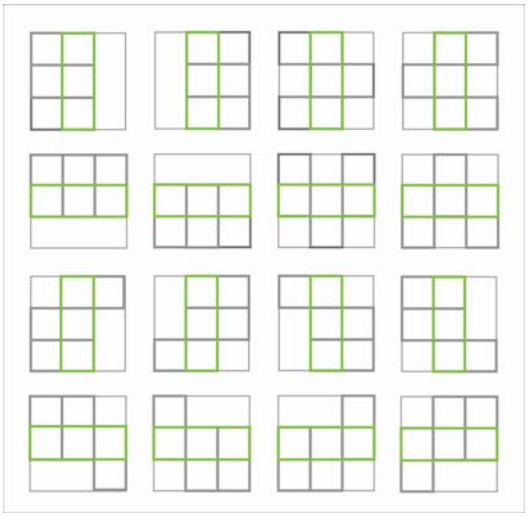

Fig 9 Variations of floor plans within one square grid.

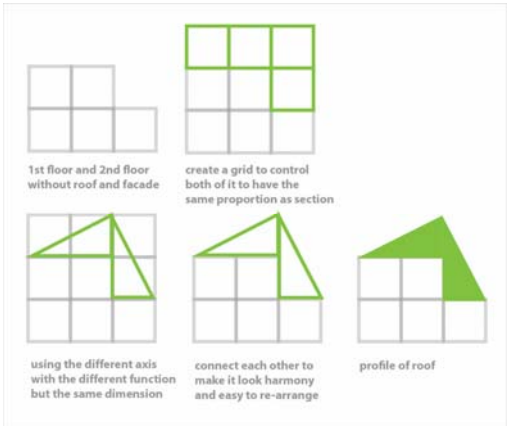

Fig 10 Square-grid system is applied to the design of the roof

At the conceptual level, the design stylishly utilizes the advantages of prefabrication. With only 4 typical modules of the same dimension (3m x 6m x3 m), the combinations allow 65,356 different configurations of house plans. The necessity for repetitive design to achieve an economy of scale, usually applicable to any prefabricated house and precast concrete house, in particular, is valid only on the typical modules. However, the overall appearance of houses can be varied according to different combination of the 4 typical modules responding to the customer's need. The choices of material and construction, light-gauge steel

[1] Jenga House is a design proposal during the 4th year studio "Expandable House" by Ms. Boontarika Suwanteepratch.

framing system, also allow for future adaptability; any house can be modified or expanded to accommodate the changing needs, lifestyle or number of family member (Fig11).

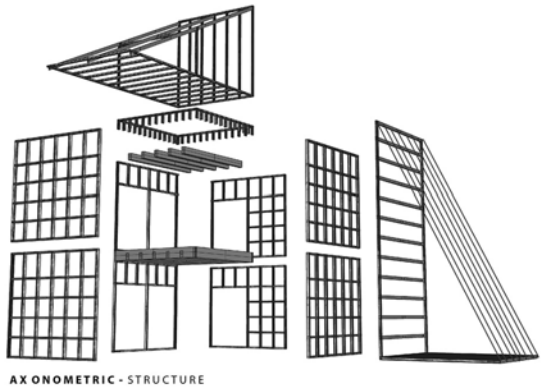

Fig 11 Structural diagram of Jenga House

CONCLUSIONS

Design innovation for prefabricated housing components proposed in this research chooses light-gauge steel as an alternative material for construction to avoid technical difficulties of precast concrete production, high initial investment cost and high logistic cost. The design proposal assumes the resilient nature of light-gauge steel and offers the design that would allow for future adaptability and changes. Without the constraint to be repetitive as precast concrete construction, the housing design can offer different variations without compromising with the economy of scale. By focusing on design innovation, with the understanding of materials and construction, SMEs will remain competitive in the aggressive market conditions.

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