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REVIEW ON THE PRACTICING OF PREFABRICATED BUILDING CONSTRUCTION TECHNOLOGY IN ETHIOPIA VS WORLD EXPERIENCES

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ABSTRACT
Prefabricated Method of Construction (PMC) is a prior method of construction in the world. Especially after WW II many European countries use PMC to solve their housing demand. This technology was also introduced in Ethiopia before thirty years ago. Nevertheless, the development and expansion is limited and it could not be saturated the sector. The purpose of this article is to review the implementation and expansion of PMC in Ethiopia versus the World experience. The study identified greater than 40 prefabricated buildings constructed for the last 30 years since the factory established and its distribution. The study showed that, the development of concrete prefab in the country were dramatically declining and its expansion was limited in the capital city Addis Abeba. Whereas, the agro-stone and steel prefab is in contrary.

KEY WORDS: Building, Expansion, Method of Construction, Prefabrication.

INTRODUCTION
Prefabrication is defined as a continuity of production implying a steady flow of demands, standardization and integration of the different stages of the whole production process, a high degree of organization of work, mechanization to replace manual labor wherever possible, and search and experimentation integrated with production process [1]. The government of Ethiopia operates a housing building program to address the high demand for affordable housing brought about by the fast growing rate of urban expansion [2]. However, this plan cannot be easily achived by means of conventional method of construction (CMC). Incontrary, the prefab factory in Ethiopia becomes to terminating. PMC is more adopted method of construction in the world. It was also introduced in Ethiopia before thirty years ago. Nevertheless, the development and expansion is limited and it could not be lead the sector. Now in Ethiopia, different types of buildings are under construction for different purposes especially apartment buildings. However, the constructions are carried out by using CMC. This can shows that, the dependency of the construction sector on CMC. This dependency on CMC leads the sector to different problems. CMC focuses on on-site operations and results in long cycle time and high cost. Due to that, project delay becomes a commomn problem in Ethiopia [19].

REVIEW ON WORLD PRACTICES

The Britain experience
The first example of prefabrication by Europeans can be seen in the 1850's. In 1851 the Crystal Palace was constructed for Britain's great exhibition. The building was made up entirely of prefabricated glass panels, wood, and cast-iron components. Once the Great Exhibition was over, the building was then deconstructed and moved [3]. This implies that, the flexibility and effectiveness of prefab in both erection and dismantling process. And the steel structure prefab building technology was begins in 1851. Most industrialized countries had begun industrialization of housing construction during WWII. The 1950s saw wide ranging attempts at mass housing using PMC and it became a mainstream construction technique, whose attractiveness has risen [4].

The Former Yugoslavian Experience

Demand for housing in the former Yugoslavia, like the other European countries, was very high after the end of the WW II. This helped them to develop a pre-casting system, IMS system, which was meant to fulfill: structural safety, fast rate of building, and rational use of building material and labor. Since then, the system has proven its flexibility and adaptability to newly arisen situations and has found acceptance in many countries, such as in Cuba, Hungary, Egypt, Angola, China, Italy, Austria and Ethiopia. The IMS is formed from precast concrete elements assembled in structures of different spans by pre-stressing cables to form monolithic entity. The first IMS buildings were erected in 1957 and 1982 over 60,000 housing units mainly schools, health institutions, office buildings, hotels, had been erected [1].

The American Experience

In US, manufactured housing was originated in 1950s. It starts with the mobile house. It is the rudiment stage in the development of manufactured housing. In 1976, Congress passed the national manufactured housing construction and safety act. At the same year, HUD (Department of Housing and Urban Development) started to establish the industrial standard for manufactured housing. This implies how much the government gives emphasis to implement PMC [5]. PMC in the US can be said to have started over 100years ago. The post-WWI years brought a strong stimulus to prefabrication. The U.S. continued to experiment with prefabrication, while Europe built with it [3].

The Indian Experience

In India, prefab came into effect with the foundation of Hindustan housing factory in 1950 as a solution to the housing crisis. This factory, mainly prefabricates precast concrete for various civil and architectural projects throughout India. Prefabricated materials are well-known for their durability and quality in India. Protection from climatic damages, precision work in factories and environmental-friendly techniques have attributed to the good quality standards of prefab. These building systems are gaining popularity in India due to the need to use very scarce resources optimally. They also have the potential to address the problem of mass housing crisis in India that they face today. India started a fully precast residential G+23 building project in Parel, Mumbai in 2011. Speedy construction and design conforming to all IS design codes with less cost operations were the major objectives achieved by this project. A numerous of prefab companies are emerging within India in order to serve the housing demand of one of the most dense, heavily populated, and fastest growing economy in the world. Therefore, prefabricated residential projects can significantly reduce the cost of housing and could be effective solution to the massive shortage of housing. [17]

The Japanese Experience

The manufactured housing in Japan starts around 1960s. Due to WWII, lots of houses were destroyed. After the baby boom, the demand for residential houses was urgent. In order to construct more houses without sacrificing quality, Japanese companies used the prefabricated housing approach. Japan has its own industrial standard for PMC and construction process is finished in factory such as walls and floors, are pre-made following certain industry standards [6]. Around 1966 the ministry of construction of Japan announced "fundamental idea on industrialization of housing building" and promoted the construction of 4 to 5 story apartment houses with the aim of popularizing industrialization of housing, stabilizing building costs and improving the quality of houses. Building codes and standards were introduced to regulate structures, capacity and application for building permits and to improve quality and reduce cost and specifications of parts and accessories for public housing were standardized. In this sense 800, 5000 and 12,000 houses were built in 1962, 1963 and 1964 respectively. Prefabrication of building elements has brought great advantages in the development of industrialization and mechanization of the building industry in Japan [1].

The Chinese Experience

In China, the housing industrialization began in 1953 in Hong Kong, and in 1998 in Mainland China. In this year, the Chinese government implemented the commercial residential building reform. In about 10 years (from1998-2008), there was a significant growth in demand in the housing market and prefab materials increased from 17% (in 2002) to 65% (in 2007) since Chinese people usually live in apartment buildings

with many floors due to the huge population and limited land. Therefore, problem for Chinese real state companies was how to build more houses faster and with higher quality [6].

The Korean Experience

In Korea, the leading prefab company is Daewoo Corp, which developed a multi-room modular construction system used for multi-story buildings. The company typically has a prefabricating facility set up on the project site. Because the preassembly is completed onsite, the construction company does not have to deal with the transportation issues. All of the precast concrete modules are manufactured onsite and then lifted into position by a crane at the rate of one floor per day. Daewoo states that, their system was three times faster than conventional methods because all the factory-built panelized walls incorporated all of the mechanical and electrical systems. Like most other Asian countries, Korea's large population provides a great opportunity for using offsite construction techniques which have been widely adopted in constructing high-rise buildings that exceeded fifteen floors. [18]

The Swedish Experience

Due to the scarcity of houses, the Swedish government resolved a housing shortage into a highly professional construction industry that produced high-quality affordable homes. Today 90% of Sweden's housing is prefabricated, and most Swedes associate energy-efficiency and durability as a must with prefabricated construction. Because, PMC is a high-quality and "green" commodity [7].

The Russian Experience

Precast concrete technology was introduced in the former Soviet Union in the late 1920's, but found wide application between 1930-1936, mainly for industrial construction and for the erection of single story buildings. In 1950 and 1955 the volume of precast concrete reached 1.3 million m^3 and 5.3 million m^3 of concrete, respectively. The major prefabricated structural elements include: rectangular beams with length reaching up to 15m, roof beams (rectangular, T, I, and box section up to 1m length, crane runways, roof trusses, small span slabs (solid and ribbed) stairways and landing [1]. Lift-slab system with walls and pre-stressed slab-column systems were introduced in Soviet Union (period 1980-1989) in some of the Soviet Republics, including Kyrgyzstan, Tajikistan, and the Caucasian region of Russia [8].

The Singapore experience

Singapore has developed effective methods for offsite construction, especially in using precast reinforced concrete technology to construct multi-story buildings. At the same time, the Housing Development Board (HDB) has developed two systems to solve the shortage of houses. (1) fully prefabricated precast reinforced concrete systems: in this system, pre-cast column-beam-slab are connected together using bolts and anchors and post-tensioned flat plate floor system and (2) semi-precast reinforced concrete building system: in this system, the main building elements are made cast-in-place and other elements are pre-cast in factories [9]. Since its inception the HDB is credited with constructing more than 750,000 apartments for housing, which is about 86 % of Singapore population. According to Singapore's experience, the standardization of building components is the key to successful utilization of offsite construction technologies. This standardization greatly reduces the number of modules needed to precast the concrete components and thus speed up the erection work [1].

The Egyptian Experience

In Africa, before 5000 years ago (around 2700 B.C), the Egyptian pyramid was constructed (fig.1b). It is composed of 2.3 million limestone blocks, some weighing 15 tons. The blocks were manufactured off-site and transported (pushed and pulled) in to place (on-site) by human muscles. This implies that there was the application of prefabricated construction process and the idea started thousands of years ago in Africa [10].

The Ethiopian Experience

A modern prefabricated building industry was introduced in Ethiopia in 1985 by the former Yugoslavian technical assistance under the former Ethiopian Building Construction Authority (EBCA) by the name of

Prefabricated Building Parts Production Enterprise (PBPPE). The establishment of prefab housing factory in Addis Ababa has brought new techniques for the construction industry and it was supposed to provide solution for the vast building needs. On top of this, it was aimed to accommodate the ever-increasing demand of housing within the shortest possible time and to minimize the pressing need of timber for formwork.

The factory has been producing structural elements for the construction of office, apartments, hotels, schools etc. (from G+0-G+9) by using IMS precast concrete system. At a time the IMS system has found acceptance in many countries, such as in Cuba, Hungary, Egypt, Angola, China, Italy, Austria and Ethiopia as well. However, now a day in Ethiopia, precast concrete is widely used for non-structural elements such as pipes, lintels, cladding, poles and for institutions fence work.

The other prefab factory, Ybel industrial plc was established in 2009 in Addis Abeba to construct buildings by applying prefab technology. It is the first and pioneer private prefab factory and in adoption of mechanized agro-stone panels and magnesium board technology in Ethiopia in the prefab building industry. The factory produces steel building structure, magnesium board (4.5-10 mm), agro-stone panel, light gauge steel frame (LGS), and PVC doors and windows. The factory has been constructed residence houses, project camp houses, guest houses, etc. by using steel frame, agrostone panel, magnesium board and PVC opening and ceiling in different places of Ethiopia.

The obelisks of Axum

The Axum obelisk is one of the prefabricated obelisks found in Ethiopia. The tallest of all was 33m and the second is 24.6m in height (fig, 1a). The Aksum obelisks were erected before thousands of years, during the Axum civilization, long before Christianity was permanently established as the state religion. They detached these huge blocks of granite from the adjacent mountain and transported them to the site where they were to stand and to raise them in to position. This implies that, there was a concept of prefabrication process because they prepare at the mountain (off-site) and transport to the site (on-site) [11].

During that time people prepared very big size obelisks off-site several kilometers away at the quarries of “Wuchale Golo” to the west of Aksum, and dragged from there into the city. They transport the monuments to another place by using perhaps wooden roller and whether the rather African elephant could have been utilized in helping to maneuver these giant stones is not known, but makes an interesting speculation. They also erect the obelisks with the aid of earthen ramps and tremendous human effort [12].

The figure (fig 1a.) shows that, the idea of multi-story building construction concepts by putting a grooved windows and door shapes in serious of distances in a multi-story floor styles. It also elaborates that the relation of prefab and architecture at the time. But at the time there was no school of engineering in the world, no technology, no university, no school of architecture, no standard, no codes and rules to manufacture and no cranes, trucks, heavy equipment’s to transport. However, the country could introduce amazing prefab obelisks.

The stele of Tiya

Tiya is one of Ethiopia’s UNESCO registered sites in home to Gurage tribes (fig.1c). It is found 80km south of Addis Ababa in Soddo Gurage zone. Most of the statues measure up to 3 m and the longest is about 5 m. Tiya is famously singled out from over 160 archeological discoveries at the site. The site contains 36 monuments, including 32 carved stele [13]. The tradition of erecting megalithic monuments is very ancient in Ethiopia. The largest and most representative collections of stele are to be found near the village of Tiya. Originally 46 steals were erected in between the 14th and 15th centuries [14]. This shows that, prefabrication concept was introduced in Ethiopia thousands of years ago.

(a) (b) (c)

Figure 1: the obelisks of Axum, Ethiopia (a), Egyptian pyramid, Egypt (b) and stele of Tiya, Ethiopia (c)

RESEARCH METHODOLOGY

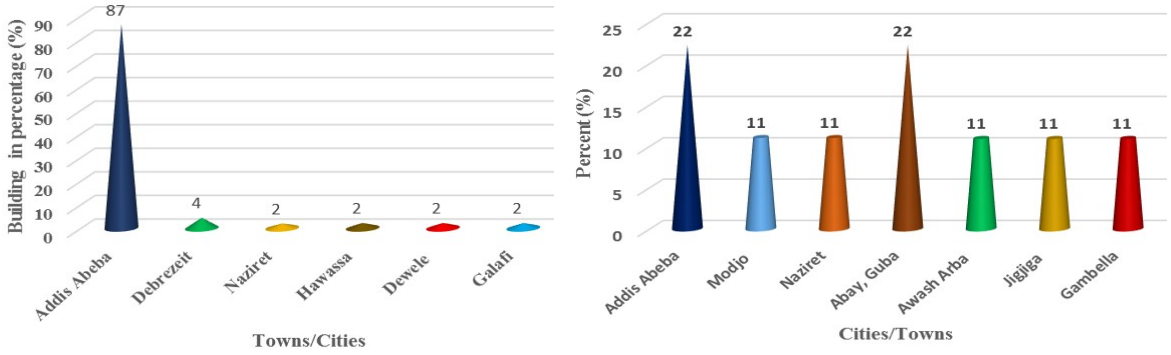
The research area focuses on two of prefab building factories that are found in Addis Ababa: Prefabrication Building Parts Production Enterprise (PBPPE) and Ybel Industrial plc. One is governmental and the other is private. The areas were chosen by considering the experience and availability of prefab buildings factories.

A descriptive case study method was used to address the stated objectives. Descriptive case study is a kind of research method that is more suitable to study as it exists at present and past. Such studies usually go deep into the causes of things or events using very small samples [15]. In this study, both primary and secondary data sources were used. Primary data were collected by direct communication with respondents through personal interviews, focus group discussions with professionals and field observation on the prefab factories. The secondary data were collected from both PBPPE and YBEL industrial reports, proposals, filed documents, magazines, web sites and other available documents.

RESULTS AND DISCUSSION

Expansion of prefabricated buildings in Ethiopia

Prefabrication technology is not new in Ethiopia. However, the development of the technology was not widely distributed to the other regions except some cities they are near to the factory. The following graph (graph 1) shows the expansion of prefab buildings in Ethiopia. The result revealed that (graph 1a) the highest percent (87 %) of prefab buildings were constructed and concentrated in Addis Ababa. This means that the distribution or expansion of the technology was restricted in a specific area. The second (4 %) were found in Debrezeit and the least (2 %) were found in Nazeret, Hawassa, Dewele and Galafi. This implies that the expansion of PMC in the other cities of the country was extremely limited. When the distances increase from the factory (AA) the distribution of prefab building to the regional cities decreases due to the transportation and logistics problems. That is one of the problems to limit the expansion of this technology in the country.



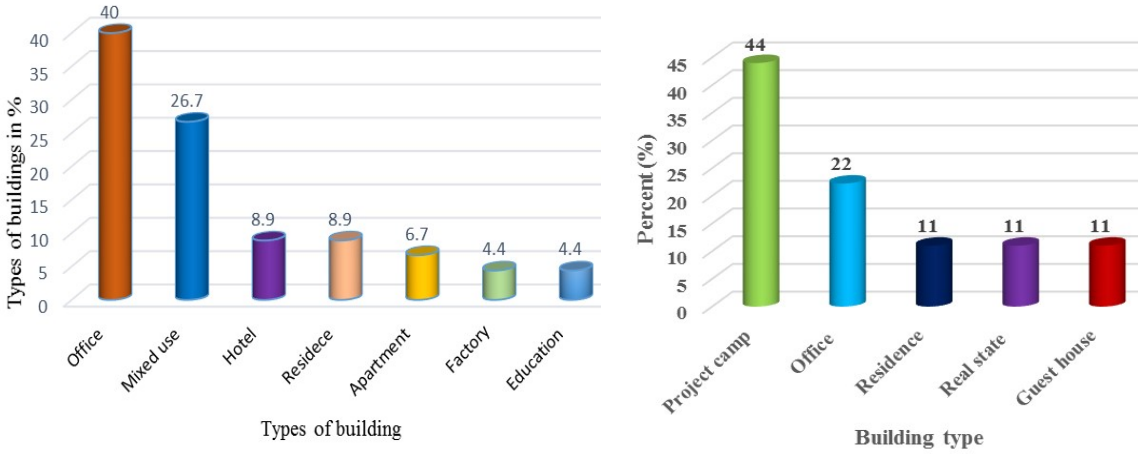
(a) (b)

Graph 1. Expansion of concrete based(a) and Agrostone & steel based (b) prefab buildings

Light weight steel structure and agro-stone panel prefabrication technology are newer than concrete prefab in Ethiopia. However, the development of the technology were increased and distributed in good status to the other regions. The following graph shows that the distribution of LWSS and agro-stone panel prefab buildings constructed by YBEL industrial in Ethiopia. The graph shows (graph 4.8) that, about 22% of prefab buildings are in Addis Abeba and Abay, Guba and the rest 11 % are found in Modjo, Adama, Awash Arba, Jigjiga and Gambela. This implies that, the expansion of Ybel is widely distributed than the PBPPE.

Types of prefabricated building

The study result shows that PBPPE constructed different types of buildings (see graph 2a.) such as offices, mixed use, hotels, residence houses, Apartments, factories, school, etc in different part of Ethiopia.The study result (graph 2a.) shows that, about 40 % buildings were office and 26.7 % were mixied-use buildings. Education center takes the least percent (4.4%). Nevertheless, in developed countries, health and education centers take 49% and 42% respectively while the other manufacturing constitute (42%), low-Rise office (40%), public (40%) etc [16]. However, in Ethiopia PMC is very low when compared with the other countries. The graph shows that (graph 2a) out of past prefab buildings, the appartment housing takes only 6.7%. But now a days in Ethiopia the government plans to construct more than 75,000 condo houses during the GTP II using PMC. This implies that there is a huge gap on implimenting PMC on house building program.



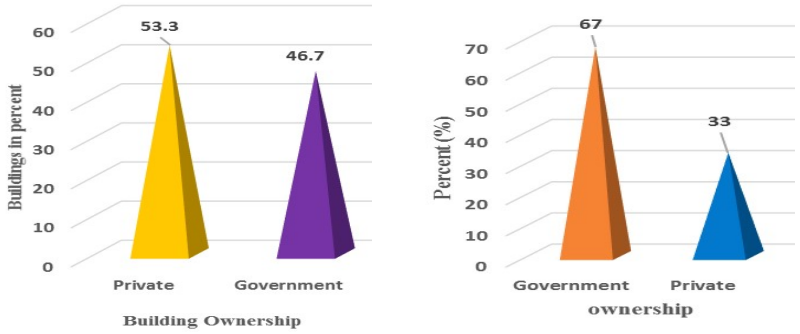
(a) (b)

Graph 2. Types of concrete based (a) and Agrostone & Steel based (b) prefabricated buildings

The study result shows that YBEL industrial constructed different types of buildings as shown on graph 2b such as offices, mixed use, hotels, residence houses, apartments, factories, school, etc in different part of Ethiopia. The factory were carrying out the construction work using prefabricated steel, mechanized agro-stone panel and light gauge steel. The above graph (graph 2b.) showed that, 44% of agrostone prefab buildings were constructed for construction project camp housing and the second 22 % were for office building. Finally 11% of buildings were constructed for residence, real satate and guest hose buildings. The result implies that, LWSS housing method is more applicable in housing projects espcialy for project camps.

Ownership and Story level of prefab buildings construct by PBPPE

The PBPPE factory constructs prefab buildings for both private and government sectors. However, the study result shows that (graph 3a.) over half (53.3 %) of the past prefabricated buildings were constructed for the private sector. This denotes that there is a good awareness and acceptance on private sectors than the government on the effectiveness of prefab technology. The government sector follows by 46.7 %. When we compare with private sector, the government sector was weak to implement the technology.



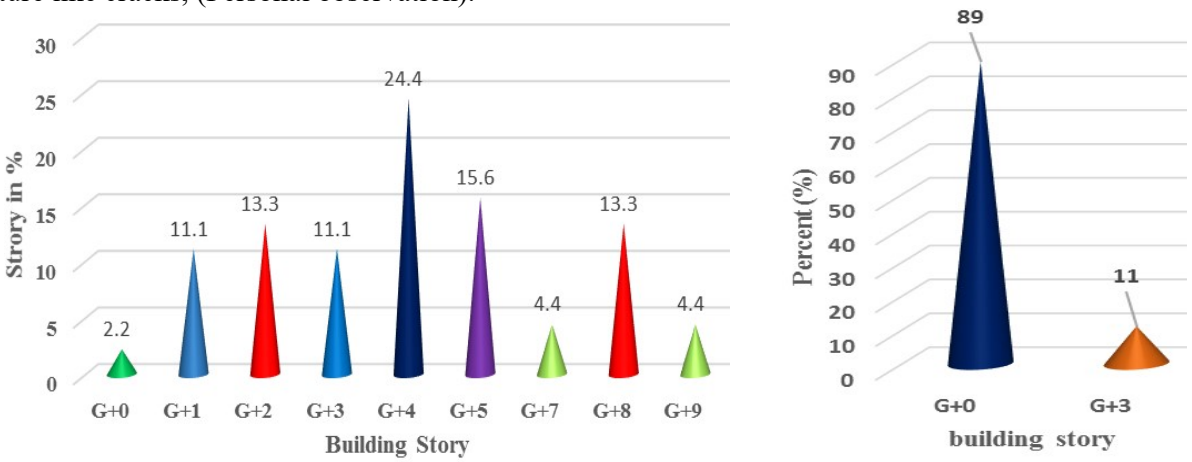
(a) (b)

Graph 3. Ownership of concrete based (**a**) and Agrostone based (**b**) prefab buildings in percent

YBEL industrial is constructing different types of buildings in different areas of Ethiopia for both private and government projects. Based on the study result (graph 3b) most of (67%) steel prefab buildings were construced for governmental projects while only 33 % accounts for the private projects. This implies that, for governmental projects houing and for temporary and permanent camps construction LWSS method of construction is more preferable than concrete prefab buildings.

Story level of prefab buildings

The PBPPE was constructing buildings in different stories from G+0 up to G+9. This shows that, there were a capacity to implement the prefab technology in multi-story building construction in the country. Based on the study result (graph 4a.) the highest percent (24.4%) of prefab buildings were G+4 followed by G+5 (15.6%). The other (G+2 and G+8) and (G+1 and G+3) and (G+7 and G+9) prefab buildings were taking 13.3 %, 11.1 % and 4.4 % respectively. The least percent (2.2%) corresponds to G+0 prefab building. This implies that, the technology was mostly implemented on multi story buildings than ground buildings. It encourages the effective usage of our land resources properly. If the factory goes as a beginning, now a days it is possible to build a high rise buildings. Based on the field observation, the past prefabricated buildings are interesting, beautiful and accurate in their surface, shape and quality and also there is no defects on the structure like cracks, (Personal observation).



(a) (b)

Graph 4. Story level of concrete based(a) and Agrostone based(b) prefab buildings in percent

Ybel industrial is constructing buildings in different stories from G+0 up to G+3. This shows that, there were a capacity to implement the technology in multi-story building construction. The result reveal that (graph, 4b.), in contrary to concrete prefab building, about 89 % of the buildings using steel prefab building are G+0. However, the other 11% (G+3) building shows that it is possible to construct story buildings using LWSS system.

Some of the prefabricated buildings in Ethiopia

(a) (b) (c)

Figure Hotel (a), Public School (b) and Apartment (c)

CONCLUSIONS

The concrete based prefab building development (PBBPE) were dramatically declining and the expansion was also limited in the capital city of Addis Ababa. The agro-stone panel and light weight steel prefab building development (YBEL) showed a reasonable increment and the expansion was widely spread to other cities beyond the capital city of Addis Ababa. Attention is not given to the prefab technology and its development in the country is not growing as it was in the beginning. The using of prefabricated building elements in Ethiopian building industry are limited to non-structural elements such as: precast beam, PVC openings, blocks and Agro-stone panels for wall and partion. However, condominium houses are easy for PMC due to the uniformity of design for the repetitive production and standardization process.

RECOMMENDATIONS

Public awareness is also a strategic function (either in government or private) if the prefab construction process needs to be changed. A bridge must be built between the customer and house manufacturer to render the market chain more efficiently and to expand PMC to the regional level. A universities should done academic and industry based research works in the area to better understand how PMC adoption and implementation can add real value to the construction process and improve the sector. Further study on supplementation of building element production with locally available material may improve the adoptability and reduce scarcity of material to solve the housing problems of the community. Visionary leadership is also required to see the current and future problems within the industry, challenges and plan towards achieving integration of available technology, innovation, and project development process. Finally, there should be a concerted effort by relevant government bodies, professionals, private investors, financing institutions, and the general public in solving the problem radically and improve the well-being of the society and the country as well.

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REFERENCES

1) Abebe Dinku. 2014. Building Industrialization and Maintenance, Addis Ababa University, AAiT, Civil Engineering Department. Addis Abeba, Ethiopia. P.2
2) Dirk Donath. 2012. Experimental prototypes for emerging housing constructions in Addis Ababa, Ethiopia, Sustainable Futures: Architecture and Urbanism in the Global South Kampala, Uganda, 27 – 30 June 2012. P.121-122
3) Carl T. Haas, James T. O'Connor, Richard L. Tucker, Jason A. Eickmann, Walter R.Fagerlund.2000. Prefabrication and preassembly trends and effects on the construction workforce, Center for Construction Industry Studies, Report No. 14. The University of Texas at Austin. Austin, Texas. P.5-7

4) Mathew Aitchison. 2014. TRANSLATION: Four Observations Concerning Prefabricated Housing, in Proceeding of the Society of Architectural Historians, vol. 31. P.401
5) Xin Xu and Yao Zhao. 2010. Some Economic Facts of the prefabricated Housing, Department of Supply Chain Management and Marketing Sciences. Washington Street, Newark, NJ 07102, January 2010.
6) Chu, X., 2009. The Path of Industrialized Housing in Hong Kong. Design Community, 35, 82 – 87
7) Howe Jeff, Jim Bowyer and Kathryn Fernholz. 2007. What's New In Eco-Affordable Housing? Combining Green Building Innovations with Affordable Housing needs. Dovetail Partners, Inc. p.6
8) Svetlana Brzev and Teresa Guevara-Perez. 2015. Precast Concrete Construction. British Columbia Institute of Technology, Canada. P.2-9
9) Gibb, A. 2001. Off-site fabrication: prefabrication, pre-assembly and modularization: Whittles Publishing, UK.
10) Brummett; Edgar; Hackett; Jeushury; Taylor; Baikey; Lewis; and Wallbank. 2000. Civilization Past and present, ninth edition. P.36
11) Pankhurst Sylvia. 1955. ETHIOPIA: A CULTURAL HISTORY. London: Printed and Made in Great Britain by Fletcher and son LTD, and the leighton-straker bookbinding co, LTD.P.62
12) Munro-Hay Stuart, S. 1991. Aksum: An African Civilisation of Late Antiquity, Aksumite Kingdom History. British Library Cataloguing in Publication Data. P.114-116
13) ICOMOS. 2004. World Heritage in Africa. International Council on Monuments and Sites. ICOMOS Documentation center. P.36-39 Home page http://www.international.icomos.org/centre_documentation
14) UNESCO. 2015. Heritages. http://whc.unesco.org/en/activities/159 (accessed on 02 October 2015)
15) Kothari. 2004. Research Methodology: methods and Techniques, Second revised Edition. New age International Publishers. P. 4, 96,115
16) Mevhibe Barton. 2011. "Prefabrication and Modularization: Increasing productivity in the Construction Industry" Smart Market Reports: McGraw-Hill Construction. P.5-6
17) Krish R. Villaitramani and Dhruv P.Hirani. 2014. Prefabricated construction for mass housing in Mumbai. International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 9 (October 2014). P.135-136
18) Na L., 2007, Investigation of the designers' and general contractors' perceptions of offsite construction techniques in the United States Construction Industry. Clemson University:America
19) Abdo A, Abebe D. Assessment of Delay in Ethiopian Public Building Projects Executed by Local Contractors. EACE Journal. 2007; 4(3): 13p.