PRIMARY STUDY OF THE IMPACT OF IN-SITU AND FACTORY PRODUCTS IN SRI LANKAN CONSTRUCTION INDUSTRY

Manoj Thudugala* and L. D. Indunil P. Seneviratne
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

In an environment of aggravating labour shortage, it is inevitable for the construction industry to face number of difficulties. Therefore it is essential to explore ways and means to develop less labour intensive products, and identify whether these provide real solutions in reducing time and cost with enhanced quality. Further, it is obvious that the current construction industry is in a dilemma with lack of knowledge on behaviour of those aspects. Contactors hesitate to use factory products as these products are expensive, even these would lead to time savings and reduction of labour requirement and also towards sustainability in construction through many aspects. Therefore the need for a comparison between in-situ and factory made products on time, cost and quality is a need of time.

This ongoing research mainly focuses on the usage of factory made and in-situ products based on the respective pros and cons. This was done by initiating a survey among various expertise in the industry. Further, prioritizing the most labour intensive products was very essential to identify what trade areas are the main concerns. Therefore the overall time, cost and quality aspects of in-situ products can be compared with correspondent factory products and identify the challenges on the contractors for using the effective alternatives.

This paper contains the preliminary findings of a literature review conducted on the use of in-situ and factory based construction components both locally and globally.

Keywords: *Cost; Factory Made; In-Situ; Labour; Quality Time.*

1. INTRODUCTION

Advancement of technology has led the construction industry to go beyond its boundaries. According to Albuquerque *et al.* (2011), today it searches for more innovations and demands more efficiency in the construction process and to minimize waste. Further, the emergence of off-site production is also similarly has a potential to address many industrial issues. When the fear of skill shortage embraced the construction industry which wholly depends on its work force, many researchers (Gunawardena and Jayawardena, 2001; Praveen *et al.*, 2011) have indicated the necessity for immediate solutions. As one of the prominent solutions the factory based construction could be identified and its applicability to the Sri Lankan construction industry needs to be determined. The applicability may depend on many factors which are inherent to the factory based or offsite productions. There are benefits as well as the drawbacks of these systems. As construction projects are unique from one to another the benefits or draw backs may address the project in different ways. Therefore the pros and cons of off-site production over the in-situ products should be analysed very carefully.

In order to take an idea of level of usage of factory based products in Sri Lanka, in an environment where the established knowledge is less with regard to factory production, the needs to look at the international construction industry to form a firm basis to proceed. Therefore this research is aimed at identifying the nature of skill shortages in Sri Lanka and benefits over in-situ constructions that could be adopted and identify drawbacks that should be minimized. The knowledge published on other countries are analysed in order get a basic and to identify the potentials for expanding the factory based production in Sri Lanka.

*Corresponding Author: e-mail - manojtudugala@gmail.com

2. THE SKILLED LABOURER

According to Wikipedia (2012) a skilled labourer is any worker who has some special skill, knowledge, or (usually acquired) ability in their work. That particular worker may have gained his knowledge or skill from a college, university or technical school or gained it from his experience. In construction industry a worker can achieve skills on various fields such as masonry, carpentry and finishing.

3. SKILL SHORTAGE IN SRI LANKA

With the end of thirty years of civil war, the Sri Lankan Construction Industry has begun to expand rapidly to all areas as never before and is experiencing increased investment on infrastructure and high-rise and medium scale buildings (Praveen *et al.*, 2011). However, despite of this boom in construction, still it heavily depends on its labour force (Gunawardena and Jayawardena, 2001). The studies done on challenges faced by construction industry have shown that skill drain and shortage as a significant problem in the Sri Lankan construction industry (Rajakaruna *et al.*, 2012). Therefore it's clear that this problem is becoming worse and cannot be easily neglected.

Meeting the client's requirements of cost, time and quality of the work heavily relies on the performance of skilled labour and their acquired training and skills. The level of skill and updated knowledge about recently introduced techniques and technology are also important matters to be considered along with the adequacy of skilled labour. Ineffective manpower training and introducing to the construction labour force in both numbers and requisite skills can present continuing problems not only for the contractors but also for other stakeholders of the industry (Gunawardena and Jayawardena, 2001).

Further, Gunawardena and Jayawardena (2001) stated that the ongoing training programmes are supplying insufficient number of workers in comparison to the anticipated growth in the construction jobs, annually. Very low percentage of the workers at the craftsmen level categories in the Sri Lankan construction industry has undergone formal training similar to the countries Kenya (Njeri, 2008). Therefore the short supply of skilled labour is a key issue which need to be analysed and better solutions should be identified.

Razak (2012) also reported that there is a prevailing skilled labour shortage in craft person level and middle level technicians caused by the insufficient investment of training. Razak (2012) further reported that this may affect to the ongoing development processes if preventive measures are not taken immediately and that will hit on national economy severely.

Ratnayake (2013) stated that construction industry as a labour intensive industry as it employs a large work force. Numerous workers are engaged in construction industry all over the world, informally and their common intention is to earn a reasonable income, formal training, and recognition and retain in the sector until they are strong enough to involve in hard works. However Ratnayake (2013) concluded that very few percentage of workers retained in the industry after they reached 45 years of age and have experience higher than 10 years, unfortunately. Hence the industry is running with a risk of having a large unskilled workforce creating a skilled labour vacuum in the industry which should be addressed thoroughly. Therefore it's obvious that means of training skilled labourers should be promoted while necessary steps are taken to retain the valuable experienced skilled labourers within the industry.

4. AVAILABLE SOLUTION TO SKILL SHORTAGE

In the study done by Praveen *et al*. (2011), it was identified that the skill shortage can be minimized by increasing the intake to the training institutions, developing the existing training institutions and establishing new centres to yield a sufficient supply of skilled labour, motivation of new entrants to the skilled labour market and to sustain the existing skilled labourers by an acceptable attractive

minimum salary scale for skills, introducing productivity based payment systems and recruiting minimum number of permanent or long-term contract based workers may encourage the employers to provide necessary trainings to the their workers. However Ratnayake (2013) in his research recommended a different option of factory based a construction which is less popular in Sri Lankan construction industry as one of the solutions to the skilled labour shortage in Sri Lanka. Further, Ratnayake (2013) stated the necessity for further research on the applicability of factory-based construction for the Sri Lankan construction industry which is the basis for this research. Although Praveen *et al.* (2011) determined those ways of minimizing the skill shortage, the option stated in Ratnayake (2013) requires less effort and less additional cost of implementation.

5. IN-SITU PRODUCTS AND FACTORY MADE PRODUCTS

According to Chudley (2005) and Friedman (1992) there can be two types of approaches to construction of buildings. They are *conventional method* and *industrialized method* which is also called as the off-site construction. The traditional methods are simple and more labour intensive and according to Chudley (2005) as it was taught to most of construction apprentices as a basis to enter the construction industry. The conventional type of construction is casted on site or stick built. That means construction products are produced at its permanent place. These are built from basic materials at the location (e.g.: brick walls, in-situ concrete slabs). However in the industrialized methods which are more advanced and complex are generally attached with mechanized processes. Chudley (2005) further argued that the conventional type is better to use in small construction projects and industrialized approach is for projects where there is a need of large number of units on a same site. On the other hand Chudley (2005) stated that industrialized methods are rationalized and are used to produce complete elements such as floors, walls and roof frames.

As defined by Stephan and Christopher (2010, p.485) factory made products are,

> "Building components that are constructed at a location where usually in a factory, remote from the building site. Off-site production is another term widely used to describe the manufacture of a prefabricated building. The Manufactured building or building parts are then delivered to the site and assembled in their final position."

Generally factory made products have the potential to improve productivity of the project. When using factory made products, the project duration may reduce and as a result of this, labour cost might also reduce. Other than that it can streamline the supply chain as cited in Haas *et al.* (2000).The builders are utilizing the factory made products in several forms. They can be identified as *modularized units*, *prefabricated units* and *preassembled units.*

Modularized units are factory-built units completely assembled or fabricated in a manufacturing plant away from the work site. After the fabrication, these are transported and assembled on site. The modules are large in size and possibly may need to be broken down into several smaller pieces for transportation. Buildings formed from modular units normally consist of multi-rooms with three-dimensional units, which are constructed and pre-assembled complete with trim work and services installed (Haas *et al.*, 2000). Although Chudley (2005) argued factory based construction are suitable for small type of construction the above statements determines that factory based products can be used for large scale projects also.

Generally, as Haas *et al*. (2000) defined prefabrication term is used for one skill or trade, such as electrical, piping, or rebar. As Tatum (as cited by Haas *et al*., 2000) defined this type of product as a component produced at a specialized facility, in which various materials are jointed to form a component part of a final installation. The components that are manufactured offsite and do not form a complete system are considered to be prefabricated and these prefabricated components often only take part in a work of a single craft.

Preassemble units refers to components that are comprised with various types of building materials, prefabricated components, and equipment joined each other at a remote location for subsequent installation. It is generally focused on a system, rather than a product according to Tatum (as stated by

Lu and Bausman, 2009). (e.g.: roof trusses, platforms, piping, and ladders)

However according Lu and Bausman (2009) there are four types of factory products that can be used in building construction. In this study by Lu and Bausman (2009) it is stated that hybrid systems which are prefabricated a fully factory finished building facilities with completed internal furnishes and building services (e.g.: bathrooms and office spaces), panelized building systems which consist of the construction of the structural frame, or building envelop, using building panels manufactured in a factory. Further, the Constructing Excellence Ltd. web (2012) states that off-site production and uniqueness in construction are not incompatible and also the use of standard products does not limit the scope for design innovations. On the other hand, it's clear that in above researches it's tried to classify the factory based construction according to its degree of factory based production. From the small piece of element to total construction it varies.

Precast, pre stressed concrete structural elements which are often heard in building construction are crisp, slender in relation to span, precise, repetitive (Allen and Iano, 2009). They can offer economical framing for many kinds of buildings by combining the rapid all-weather erection of structural steel framing with the self-reproving of site cast concrete framing to offer economical framing. Since precast concrete is the newest and least developed of the major framing materials for buildings, its architectural aesthetic is still maturing according to Allen and Iano (2009). Allen and Iano (2009) further stated solid and hollow-core are ideal both functionally and economically, hence they have become an accepted part of structural vocabulary in schools, hotels, apartment buildings, and hospitals. Precast concrete has gifted the relaxation to Engineers and Architects of using that technology in longer-span building types, especially warehouses, industrial plants, and parking structures where its unique structural potential and efficient serial production of identical elements can be fully utilized and openly expressed. It can be identified that achieving highest architectural quality both inside and outside of buildings that consist of precast concrete, becoming increasingly successful. Therefore, Allen and Iano (2009) forecasted that it is reasonable to think that many innovative buildings in the coming years will be built of this sleek, strong, rapidly developing new technology. Since, factory based products related to other trades shall also be promoted using the pre-cast concrete as an example.

6. INDUSTRIALIZATION AND FACTORY PRODUCTION

According to Kumar *et al.* (2011), Industrialization means “industrial method employed with reference to mechanization, standardization and prefabrication”. Warszawski (1999) stated that industrialization process is used for maximizing production output, improving quality and minimizing labour resources by investment in equipment, facilities and the technology to produce the elements inside a factory premises instead of directly on site. Industrialized construction is a process of standardization of the work processes in the industry to reach cost efficiency, higher productivity and quality and focusing on mass production and mainly factory production where work is centrally organizedas cited by Grimscheid and Scheublin (2010). Further it supports to produce a high quality, custom built environment, through an integrated process, optimizing standardization, organization, cost, value, mechanization and automation (Grimscheid and Scheublin, 2010). Introduction of Industrialized Building System (IBS) is one of the successive efforts towards construction industrialization. Warszawski (1999) defined the system building as a set of inter connected elements that are joined together and characterized it as a set of interrelated elements that act together to enable designated performance of building. Industrialisation in combination with transport improvement has earned the potential of avoiding from declining of local sources of building materials, since manufactured building materials have become available almost everywhere, allowing a wide choice of construction options for the clients.

7. ADVANTAGES AND DISADVANTAGES OF IN-SITU AND FACTORY MADE PRODUCTS

Haas *et al*. (2000) identified that if local labour for onsite work may be very expensive or inefficient, overall cost for a project that uses offsite work can be less than a traditional on site work. Severe onsite conditions and adverse weather conditions can lead to costly delays that can be avoided through off site work. Weather is a not an effective factor in prefabrication or modularization of construction products. In a controlled environment where direct effect of sunlight and harsh weather cannot effect the works are not delayed and quality is high (Baba *et al.*, 2012). Work is not interrupted and productivity can remain at a high level. Further, site congestion and interference can be avoided which increases the productivity and lowering unnecessary costs. The onsite construction duration can be substantially shortened through the use of factory products. More work for a project can be completed inside the factory, therefore the construction schedule is decreased. This is very important factor for owners who are in a hurry to take the return from their investment immediately. The safety of site can be improved through the use of offsite work and the risk to owners and contractors of worker accidents and lost time thereof can be minimized with construction work that is transferred away from the site (Haas *et al*., 2000).Further onsite work can be less safe due to ever changing conditions, elevated work, and congestion. On the other hand the quality of the work can also be improved due to the usage of controlled factory and production conditions and repetitive procedures and activities, along with automated machinery or robotics. A positive side effect of using factory products is the ability to decrease the environmental impact of the project due to reduced jobsite construction duration. There is generally a constant, employed workforce for offsite pre fabrication plants. Therefore simultaneous production or parallel work is possible within the factories. Since construction activities can be broken down and completed simultaneously at multiple locations instead of performing tasks in a strictly linear sequence onsite. This is also minimizing the length of construction duration and reduces onsite congestion (Haas *et al*., 2011).

Further, Constructing Excellence Ltd. web (2004) states that due to the offsite work the maintainability and the replacements become easy. The standardization of building elements which will use the components, manufacturing methods or processes extensively, may increase the productivity due to the repetition.

It's noteworthy that, Manalo (2013) specifically commented on recycled pre-fabricated wall panels in his research made of rigid polyurethane foam and Magnesium Oxide board. Other than the common advantages of off-site production of environmental friendship (renewable resource, recyclable, and biodegradable) and lower cost these systems bear benefits of less energy consumption, light weight, and good specific mechanical properties. Manalo (2013) further commented on these systems of their numerous potential advantages in prefabricated housing construction such as better quality control, improved health and safety of workers, and less duration for construction. Prefabricated housing systems are easy, fast and economical to install as it requires minimal handling and reduces energy in the transportation (Hossain, 2000)

Haas *et al*. (2000) further stated the off-site production of building components can provide better precision in assembly, shorter construction periods due to simultaneous work, better value, and greater predictability. By producing in a controlled environment, it is possible to improve the safety of manufacturing, reduce waste and promote recycling, and lessen the damage to elements that can happen within site. However it should be understood that these benefits are in a tradeoff with its disadvantages. Although the controlled environments are supported by the ergonomically designed equipment, it leads greatly labourers with little room for skill advancement or intellectual challenge.

Another benefit that are being provided by factory product is creation of job opportunities away from the site which can diminish the problem of local labour shortage. Further, less number of workmen may need to be transported to the site which in turn can reduce the transport cost although material transportation cost is considerable issue of factory made products (Taylor, 2009).

When the notion of Manalo (2013) is considered despite its many advantages, the practice of prefabricated composite walls is low due to lack of standards and design. Currently, there is very little

knowledge on the design and construction methods using new composite materials, performance and behaviour of this construction system under imposed loads. Singleton and Hutchinson (2009) indicated that due to the shortage of appropriate design guidelines, most factory based systems have noticeably failed to meet expectations by the owners.

One of the major disadvantage of the off –site production is the transportation according to Haas *et al.* (2000), because of the large and heavy sections need transported to the site from the factory premises some times over a long distances. Therefore this affects to the project cost highly and the duration may be affected due to inability to transport the factory made elements on time. Therefore Haas *et al.* (2000) further stated that the utilization of factory made products must be followed by the extensive design and planning. An interference analysis must be conducted in the planning stage to identify the handling difficulties at site, as the factory products are less flexible in handling and possibility of doing changes may not be easy after the manufacturing process starts.

Smith (2010) argued that usage of factory products are not an all-round solution that promisingly lower costs and higher quality. While greater reliance on manufactured production has created a bland, monotonous landscape, the cost and quality of buildingdoes not wholly depends on its method of fabrication. Smith (2010) further argued although factory productions reduce material waste, and it does not imply that the materials used in off-site construction are environmental friendly. Similarly, although it is said that buildings that may be disassembled as easily as they were assembled and reused and therefore the environment is preserved, these have limited to concept level that have not been addressed satisfactorily in the construction industry.

Therefore it's clear that factory based construction has its own advantages and disadvantages as discussed above. Since it's obvious, these have to be considered very well according to the scenario before determining up to what degree a particular construction shall be comprised with factory based products. The designer should be well aware of this situation.

8. APPLICATION OF FACTORY BASED PRODUCTS IN CONSTRUCTION INDUSTRY

Constructing Excellence Ltd. web (2004) has cited that it is necessary to have some awareness on the opportunities of using factory based products from the project inception, through the concept design and scheme design stages. It is said that there is a less use of investigating new opportunities after the scheme design phase. Further it says that in order to achieve full benefits client and contractor should have think of the factors such as standard frameworks or conventions for geometric fit, standard forms of construction process or methods, standard building elements, project standards and preassembled components or modules and the decision to whether on or off-site preassembly, from early planning phases of construction.

However, Griffith (as stated by Manalo, 2013) indicated that failing to understand the latest technology and the behaviour of innovative materials are the causes to inadequate performance of prefabricated building components which in turn causes in rejection. In addition, there is also no or less standards to guide the performance requirements regarding strength and serviceability for prefabricated composite wall systems in many countries. As there are very less number of scientific research have been undertaken to support the benefit of using new composite materials in prefabricated systems of construction most engineers continue to rely upon experimental test data while evaluating the structural performance of factory based products according to Toro *et al.,* (2007).

It has been very difficult to use the factory based construction due to above constraints, although it is said to use from the inception (Constructing Excellence Ltd., 2004). On the other hand without published standards and knowledge it's hard to evaluate the factory based products. Therefore the application of factory based products has been limited.

Although above problems were raised regarding the factory based construction products, the pre-cast concrete elements seems to be familiarized within the construction industry. According to Allen and Iano (2009), higher-strength, reuse of steel forms for hundreds of times, reducing waste, efficient

usage of raw materials due to controlled environment, less sand use in finishing, ability to use optimized designs, ability to use high-quality architectural finishes which reduces the need for volatile organic compound emitting paints or other finish coatings, ability to withstand damages by moisture and prevention of mould growth, ability to create properly sealed joints in wall panels which can lower permeability to air leakage, ability to reduce building heating and cooling costs and contributing to good indoor air quality and its reusability made concrete elements more popular.

However, it is necessary to note that off-site production is not a sole solution to use across the whole of the industry or for a project totally according to Constructing Excellence Ltd. web (2004). According to the nature and the size of the project and its construction elements, the appropriateness of the preassembly or prefabrication is determined. It should be kept in mind that off-site production takes more time and effort to be applied at the beginning of a project although they can help ensuring higher quality standards and reduced on site construction time (Constructing Excellence, 2004).

9. USAGE OF FACTORY PRODUCTS IN PRESENT CONSTRUCTION INDUSTRY

The findings of Lu and Bausman (2009) indicated that "offsite construction techniques are incorporated into 23% of new building construction, in 2006 in the US construction industry". The use of offsite construction techniques was restricted only within offsite preassembly techniques, such as precast concrete products and preassembled trusses although it is highly developed region (Lu and Bausman, 2009). Contradictorily, "the use of prefabrication and preassembly in US is estimated to have almost increased by 86% within the last 15 years", according to Haas *et al.*, (2000).Further, the three main driving factors of the prefabrication and preassembly usage in US were schedule, workforce issues, and economic factors (Haas *et al.,* 2000).

Taylor (2009) stated that "value of off-site construction of buildings, building elements and structures is around 2- 3 billion Euro per year and accounts for around 2% of the total construction market.This had been a market share increase by 25% per year in construction industry in Europe". Further it should be noted that volumetric or modular constructions have been popularized in North America, Scandinavia, and Japan according to Stephan and Christopher (2006).

All these researches have emphasized an upward trend in usage of factory based products. However underneath that change, a lower level of current usage is highlighted. Since it is clear, although statistics says about an upward trend, the factory based products have not been sufficiently promoted among construction industry at the moment. At the same time in countries like Sri Lanka there are no evidence for ascertaining the degree of using factory based products in construction industry.

10. CONCLUSION AND RECOMMENDATIONS

The construction industry is always challenging. Therefore it is essential to be always updated regarding new developments which can afford functional and economical solutions to prevailing issues in the industry. Although off-site production is not a new concept to the construction industry, its modern advancements has made a way for improving the construction productivity, reducing durations and wastages which in turn reduce the unnecessary costs which helps to keep a reasonable profit margin in a highly competitive market. In case of Sri Lankan construction industry, independency from the weather and other outdoor effects has been the best advantage, which over few years had experienced very unpredictable conditions.

The crucial benefit of the off-site production is its potential to provide solutions to skill worker shortage which most of the researchers have foreseen. With the industrialization of the manufacturing of building components the on-site work is reduced and less number of skilled workers are required in forming the building components within the factory supported by the automation activities.

According to many previous researches the quality of the factory made products are very high as they are formed in controlled environments where the harsh or the adverse weather not affecting factor. Similarly this will also help to reduce the duration as parallel works are possible within the factories.

However they do have their own draw backs as well. Therefore it is clear that the decision for using factory based products depends on many factors including preference of the client on the inherent benefits and nature and size of the project. This may be a cause for many writers to see the factory based products as not a sole solution for the construction industry or totally for a project. On the other hand one can raise a question that, if factory products can reduce the cost, why are they still not matured in developing countries like Sri Lanka where the people are always searching for the less cost solutions. However, still these problems are unresolved because of the inadequate knowledge on material prices of offsite products.

Although it is not clear to what extent the factory based products are used in Sri Lankan construction industry at present, other countries shows a provision to use of factory made components. The literature finding has justified the need to identify the labour intensive trades in the Sri Lankan construction industry to adopt factory based construction concepts.

11. REFERENCES

Albuquerque, A., Debs, M. and Melo, A., 2012. A cost optimization-based design of precast concrete floors using genetic algorithms. *Automation in Construction*, 22 (1), 348-356.

Allen, E. and Iano, J., 2009. *Fundamentals of Building Construction: Materials and Methods*. 5th ed. New Jersey: John Wiley and Sons.

Baba, A., Joseph, R. and Shamil, N., 2012.*0ff Site Production and Benefits in the UK Construction Industry*: Theoretical Approach [Online] Available At: http://www.ppml.url.tw/EPPM/conferences/2012/downioad/SESSON5_A/19%20E148.pdf

Chudley, R., 2005. *Construction Technology*. 5th ed. England: Prentice Hall

Constructing Excellence, 2004. *0ff-site production* [online] Constructing Excellence Limited. Available at: http://www.constructingexcellence.org.uk/pdf/fact_sheet/preassembly.pdf

Friedman, A., 1992. Prefabrication versus conventional construction in single-family wood-frame housing. *Building Research and Information*, [Online]. 20 (4), pp. 226-228.

Grimscheid, G. and Scheublin, F., 2010. *New perspective in industrialization in construction; a state-of-the art report*. [Online] CIB publication. Available at: http://cibworld.xs4all.nl/dl/publications/tg57_pub329.pdf

Gunawardena, D. and Jayawardane, A., 2001. *The training need of construction workers in Sri Lanka*. [Online] Sri Lanka: The Institute of Engineers. Available at: http://iesl.ceylonhost.com/IESL_publications/ [Accessed 06th April 2013].

Haas, C., O'Connor, J., Tucker, R., Eickmann, J. and Fagerlund, W., 2000. Prefabrication and preassembly trends and effects on the construction workforce. Ph. D. Austin: The University of Texas.

Hossain, A., 2000. Axial load behaviour of pierced profiled composite walls. *Engineering Insight*, [Online]. 27 (1), Available at: http://ijes.info/1/2/4254127.pdf. [Accessed 27 February 2013]

Kumar, M., Hamid, A., Azman, A. and Ahmad, S., 2011. Industrialized Building System (IBS): Revisiting Issues of Definition and Classification. *International journal of emerging sceinces*, 1 (2), 120-132.

Lu, N. and Bausman, D., 2009.*Comparative Study on 0ffsite Construction Techniques in the U.S. Building Construction*. [Online] Associated school of construction, Available at: http://ascpro0.ascweb.org/archives/cd/2009/paper/CPRT101002009.pdf. [Accessed 05thApril 2013].

Manalo, A., 2012. Structural behaviour of a prefabricated composite wall system made from rigid polyurethane foam and Magnesium Oxide board. *Construction and Building Materials*, 41 (1), 642-653.

Praveen, R., Niththiyananthan, T., Kanarajan, S. and Dissanayake, P., 2011. *Understanding and Mitigating the Effects of Shortage of Skilled Labour in the Construction Industry of Sri Lanka*. [Online] Sri Lanka: Department of Civil Engineering, University of Peradeniya. Available at: *www.civil.mrt.ac.lk/ICSECM_2011/SEC-11-73.pdf* [Accessed 06th April 2013].

Ratnayake, R., 2013. *Study on construction workers behaviour in the informal sector for effective and efficient project delivery*. MS.c. Colombo: University of Moratuwa.

Razak, A., 2012. Focus: 'Labour Shortage in Construction. *The Nation,* [online]. Available at: http://www.nation.lk/edition/biz-news/item/3719-labour-shortage-in-construction? [Accessed 12 February 2013].

Singleton, M., and Hutchinson, J., 2009. *The Development of FRP Composites in Building Construction* [Online] Available at: http://www.compositesuk.co.uk/LinkClick.aspx?fileticket= 2tZQmjgn23c%3Dand[Accessed 05thApril 2013].

Smith, R., 2010. *Prefab Architecture: A guide to modular design and construction*. [e-book] New Jersey: John Wiley and Sons. Available at: http://books.google.lk/books?id=NZOL4TKggo8 Candlpg=PP1&pg=PP1#v=onepage&q&f=false [Accessed 13th February 2013].

Stephan, E. and Gorse C., 2010. *Barry's advance construction of Buildings*. 2nd ed. UK: Blackwell's publishing

Taylor, S., 2009. *0ffsite Production in the UK Construction Industry* [Online] Available At: http://www.buildoffsite.com/downloads/off-site_production_june09.pdf [Accessed 05th April 2013].

Toro, W., Salenikovich, A. and Mohammad, M. and Beauregard, R., 2012. Racking and bending tests for prefabricated wall panels. Maderas. *Ciencia y tecnología*, [Online]. 9 (1), 3-14. Available at: http://www.scielo.cl/scielo.php?pid=s0718-221x2007000100001andscript=sci_arttext

Warszawski, A., 1999. *Industrialized and automated building systems*. 2nd ed. London: E and Spon

Wikipedia, 2013. *Skilled Worker* [Online] Available at: *en.wikipedia.org/wiki/Skilledworker* [Accessed 18th April 2013].