

A review on offsite construction plant design in Auckland. Una revisión del diseño de la planta de construcción fuera del sitio en Auckland.

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ABSTRACT

The main objective of this paper was to review the design considerations and challenges for offsite construction plant in Auckland. The goal is to provide the reasons for selecting the design criteria. For this the production plants Willmot Dixon in UK, CRC in Australia and Fletcher in New Zealand were considered. This plant can be used for products in residential buildings, hospitals, educational buildings and commercial buildings using Lightweight steel and timber framing, Factory assembled bathrooms (FABs) or pods, Cross-laminated timber and Prefabricated and precast concrete. The four design communication alternatives for an offsite production plant based on the requirements for adaptability, efficiency in assembly and production economy are explained according to the needs. The main urban challenges which were faced by Auckland for offsite production plant like speed of construction, cost, waste materials, machines and workers are reviewed using the method of engineering called Design for Manufacturing and Assembly (DFMA) by which the production costs and the time for products to reach the market are reviewed.

Keywords: Offsite, Design, Materials, DFMA

RESUMEN

El objetivo principal de este documento fue revisar las consideraciones de diseño y los desafíos para la planta de construcción fuera del sitio en Auckland. El objetivo es proporcionar las razones para seleccionar los criterios de diseño. Para ello se consideraron las plantas de producción Willmot Dixon en Reino Unido, CRC en Australia y Fletcher en Nueva Zelanda. Esta planta se puede utilizar para productos en edificios residenciales, hospitales, edificios educativos y edificios comerciales que utilizan estructuras de acero y madera ligeras, baños o vainas ensamblados en fábrica (FAB), madera contralaminada y hormigón prefabricado y prefabricado. Se explican las cuatro alternativas de comunicación de diseño para una planta de producción externa en función de los requisitos de adaptabilidad, eficiencia en el montaje y economía de producción según las necesidades. Los principales desafíos urbanos que enfrentó Auckland para la planta de producción fuera del sitio, como la velocidad de construcción, el costo, los materiales de desecho, las

máquinas y los trabajadores, se revisan utilizando el método de ingeniería llamado Diseño para fabricación y ensamblaje (DFMA) por el cual los costos de producción y el tiempo para que los productos lleguen al mercado se revisan.

Palabras clave: Offsite, Diseño, Materiales, DFMA

INTRODUCTION

A large number of civil infrastructures around the world are in a state of serious deterioration today due to carbonation, chloride attack, etc. New Zealand construction industry had been mostly linked with their ineffectiveness in taking up the risk to implement new technologies. Though it has an industry which is too busy, the final product delivered to the customers where not been satisfiable as they find it difficult to deliver the product within framed time as well as cost. Permanently, in traditional design process and construction, main aim of the contractor is to achieve building standards as per the building code and the most complicated issues were solved using predefined examples and this made the final product as same as what they had done before. Design and construction of energy efficient as well as sustainable buildings are necessary nowadays, as the major problem our planet facing now is the emission of greenhouse gases and other environmental problems. There comes the importance of offsite construction. Offsite construction has made dramatic changes in the industry by the way it makes construction so easy. Planning, design and manufacturing is done at a location and assembling is done in another location. This makes the construction process so easy and helps in constructing much energy efficient buildings. This also helps to reduce the risks of workers, decreases pollution due to construction activity and help designers to make more innovative ideas in their design. (Arif & Egbu, 2010)

However, to practically implement offsite construction methods, most important thing is to setup manufacturing units that are capable of producing necessary components and units required for the building in the required capacity and efficiency. Thus, only speed and efficiency of the work can be increased and thus benefit to the ongoing work. Production plants must be in such a way that they are easily accessible from construction sites, are spacious enough to produce larger units, include lifting equipment's for loading and unloading heavy parts, and technologically highly efficient for developing complicated units.

DESIGN CONSIDERATIONS

To design an offsite manufacturing plant in Auckland aiming a boom in the construction industry, various factors must be considered. Worldwide offsite construction has made dramatic changes in construction industry in many ways and the benefits that United Kingdom, United States of America, Australia and Germany have made must have to be taken to mind.

The first unit considered for this research is the manufacturing plant of Willmot Dixon, an offsite manufacturing company based on UK. Major factors considered are: -

- Using light gauge steel and timber frame units that makes construction 20-25% faster than using traditional components.
- Reducing energy cost by providing high thermal efficiency as well as air tightness.
- Providing dimensionally accurate building blocks that make the construction process so easy and much faster.

The second one considered is the production plant of CRC from Australia. Major factors that considered in this plant are: -

- Reducing building weight by changing heavy weighed products to light weight thus making good savings on energy as well.
- 100% integrated systems for providing perfect fire, thermal and acoustic performance.
- The perfect façade that the customer gets that provide 100% aesthetic solutions.

The third company considered is the Fletcher builders from Auckland. Major factors considered are: -

- Wall, floor and roof components of the building will be manufactured including windows and wiring and plumbing systems. This makes the onsite activity much less.
- Construction duration considerably reduced and almost 50% of time can be saved by this.

PRODUCT LINE AND THEIR APPLICATION

Construction speed and accuracy of an offsite construction work mainly depends on the production capacity of its plant that makes the assembling work faster as well. Increasing production without compromising with the quality and dimensional accuracy of products is an important factor in the success of the company. The plant designed have a capacity of 500 to 2000 units per year and having an area of about 20000-25000-meter square. The plant will make units for residential buildings, educational buildings, hotels, hospitals and commercial projects.

Major products that the plant is going to produce are as follows: -

- Lightweight steel and timber framing
 - Factory assembled bathrooms (FABs) or pods
 - Cross-laminated timber
 - Prefabricated and precast concrete.
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- Light weight steel and timber framing

- Light weight timber and steel framing helps to complete the construction 20-30% faster than traditional methods.
- Faster production enhances faster construction and the clients will be getting their buildings before than expected.
- It provides high thermal performance and air tightness.
- Higher thermal performance reduce the energy cost.
- Accuracy of factory assemblies increase the internal finishing.

➤ Factory assembled bathrooms

- High quality internally finished bathrooms with perfect dimensioning makes the work much easy and fast.
- Using highly skilled permanent workers for the making, decreases the reliance on sub-contractors and helps in reducing cost.
- Improved quality control reduces waste levels in factory up to 1%.
- For buildings with typical alignment, construction will be easy and also reduces time considerably.
- Project certainty will be increased because of high quality control.

➤ Cross laminated timber

- Thickness and length of the panel can be easily increased by adding more layers and joining panels together
- It is a sustainable material and thus increase sustainability of the building thus reducing carbon emission.
- Manufactured using multiple layers of wood increases the thermal insulation pod the building.
- Light weight of the material decreases the load on foundation which eventually decreases the construction cost.
- Light weight also reduces the need of heavy machinery for lifting and placing.

➤ Prefabricated and precast concrete

- Labour works at site will be considerable reduced which results in decreasing site accidents.
- Efficiency of the work will be increased as casting of major concrete products are done in a controlled atmosphere.

- In urban projects, site disturbance can be considerably reduced.
- Air and noise pollution can be highly controlled.
- Requirement of skilled labour at site can be reduced which adds on to cost efficiency. (Ballard, Harper & Zabelle, 2003)

DESIGN COMMUNICATION

The four design communication alternatives in offsite production based on the requirements for adaptability, efficiency in assembly and production economy. They are as follows: -

- Entire design and production will be controlled by the architect selected by the client and there will not be any value for the production consideration. Production facilities will have to be improvised as per the design of the client as technically prefabrication can satisfy all the requirements of an architect. All conventional design approached will be over throne as per the designer's concept. (Luo, Zhang & Sher, 2017)
- Pre specified products and general products will be designed and manufactured according to the producer's design. This will be adapted mostly for similar type of buildings or for a certain group of clients. The producer will have to satisfy the clients regarding the benefits that they get with the proposed design.
- General specifications and rules will be followed for the production. These specifications will be based on the dimension and location of the elements. Specifications of the client and manufacturer will have to be considered. Also, the designer will get enough options to design as common systems will be used. Also, production will be easier in a way that the producer will have to make only limited amount of predefined parts.
- Client will make the design for production according to some common rules and also making sure that it's viable with the component system of the producer. It is a closed system by which only limited amount of components will be manufactured and erected. (Meiling, Backlund & Johnsson, 2012)

Of all these alternatives, the 2nd and 3rd alternatives are chosen in this paper for designed production plant.

The reason for choosing alternative 2 is as follows: -

- I. Production plant design is supposed to construct educational buildings, housing complexes and hotels which always have identical patterns of design and thus components can be similar. This makes production and casting much easier.
- II. Carefully making market studies and influencing customers on the designing and

making of typical buildings helps the process very much and this helps in increasing the efficiency in production and assembly of the plant.

Reason for choosing alternative 3 is as follows: -

- I. Production difficulty will be minimised as the range of products to be manufactured will be less and dimensions of the manufactured products will be almost identical. This will enhance quality as well as the quantity of production units as well as the products.
- II. Erection of the prefabricated components will be much easier irrespective of the layout and most components will be easily used in many locations which make fabrication as well as erection much easier.

DESIGN FOR MANUFACTURING AND ASSEMBLY

Design for Manufacturing and Assembly (DFMA) is a method of engineering by which the production costs and the time for products to reach the market will be minimised by increasing the easiness in production of individual units and also the assembling of these units. This will be done at the early design stages itself which makes the method much acceptable. For getting immediate benefits in an integrated approach, DFMA is so helpful. DFMA not only helps in the design, it also helps in the assembly of precast products. (Selvaraj, Radhakrishnan & Adithan, 2008) There are several applications for DFMA in offsite construction, both is design and assembling.

Major applications of DFMA in the design process are as follows:-

- As professionals from various disciplines such as client, designers, contractors, engineers and all other important streams are collaborated in the earlier stage itself, the design process will be much easier. Decisions can be made much easily. In this method, construction cost will be more in the design stage than in the construction stage as most reworks can be eliminated and thus reducing cost in the construction stage.
- Standardisation in design helps the designers in such a way that, they can reduce the errors in components. Mostly designing lesser components increases efficiency in design and decreases the time frame that helps in better working environment.
- Geometry of components will be reduced that makes the design process much easier. Reduction in geometrically complex shapes and structures reduces the workload on the designer and also this helps the designer in increasing the perfection of the proposed design.
- Reliability of the project gets increased and this gives much confidence for the designers in designing. Decrease in number of components lowers the chances of

failure to a great extent and thus reliability of the project increases considerably this adds on to the confidence and working ease of the designers as well.

- Eliminating tight tolerances by identifying the capability of a component. Designers will be familiar with the capacity of a components going to design and this helps to reduce tight tolerances in the design stage itself. Requirement of improved component capacity can be identified in the design stage itself and any changes to be made can be identified so earlier. Also, components design must be in such a way that it should allow some variance if needed in the later stage.

Major applications of DFMA in the assembling process are as follows:-

- Standardisation of design components decreases the excess complexity in the process of assembling. More types of components to assemble increases the toughness of assembling and maximises the chances of making an error as well. Also designing of paired parts in a left – right manner helps to increase the ease in assembly and also it helps to achieve much profit than the mirror image parts.
- One of the major benefits of DFMA in construction and assembling of components is that, major works are done offsite, and this reduces the amount of work to be done on site. This helps to get much ease in work as the workers, safety procedures to be followed, toilet facilities needed in the site, cleaning and other miscellaneous setups can be reduced considerably. This also benefits to the contractor in the construction stage and reduces the costs of work. (Favi, Germani & Mandolini, 2016)
- Reducing the type of components to be constructed and thereby much other costs like assembling costs, cost to order components, works to be done at the site and time for automation can be considerably minimised. Also manufacturing of the components also will be very easy as almost the parts are typical and manufacturing errors can be considerably reduced.
- Normally, the handling and assembling of flexible components made of materials like rubber, gaskets, and cables are very difficult. Eliminating or minimising the used of components made of these materials decreases the difficulty in the assembling stage. This makes assembling much easier than traditional construction.

Sustainability and quality of assembling will be increased by the introduction of automation in assembling process and this add-ons to the efficiency of the process. Use of DFMA reduces the site waste considerable. Most of the products are prefabricated and thus site wastes will be much less as compared to a normal construction activity. Also, lesser vehicular movements in the site reduces air pollution at the site. Limitations of DFMA are it can be applicable only for large quantity production and if there is any design change after planning it is difficult for the designers.

URBAN CHALLENGES

Construction works in urban areas are very challenging as there will be many obstacles to overcome while doing the construction activity. Urban development is inevitable and thus the challenges must be overcome, and the work has to go on. Auckland and Wellington are the two major cities in New Zealand, where population density is much higher and city centres are too congested because of less space. Major challenges in doing a construction activity in these cities are as follows.

- Urban pollution and environmental impacts: - Construction activity always causes much pollution to the surroundings and the living beings in those surroundings. Pollution happens in all ways such as air, water and noise pollution. Harmful chemicals and other wastes expelled out from the construction site to air and water makes difficulties for construction workers as well as people using the area. Urban areas will be always busy and thus the effect of pollution will be much high. (Choi, Chen & Kim, 2017) Air and noise pollution is mainly caused by the use of heavy machineries mostly with diesel engines in site and vehicles coming in and out carrying construction materials also contribute to it.
- Confined spaces and community disruption: - Construction activity always requires some area as the works to be carried out are much complex. Mostly the machines required, and the number of workers required for a construction work to keep going is much bigger than any other activity. Precautions can be taken as the work is going to be in an urban area, but still space for machineries and all other site setups will have to be in place which creates problems for the community directly or indirectly.
- Increased construction cost: - construction in urban areas increases the expenses of the contractor in many ways. Activity area will have to be perfectly sealed and considerable amount will have to be spent to decrease the outside disturbances. Activities like delivery of materials, storage of materials, requirement of security people, making alternative walkways and cycle ways for people, labour transportation and so on will be costly which makes the total construction activity much expensive than expected. (Choi, Chen & Kim, 2017)
- Increased duration of construction: - Construction in urban areas are much time consuming and unexpected problems and issues sometimes causes in delays in the construction activity and thus delays the hand over. This caused much financial liability to the client as well as the contractor. Delay in projects also affects the reputation of the company as most companies receives advance from customers before starting the activity and delay in delivery makes the company pay fines to the customers which further increases the financial issues.
- Waste dumping: - most construction activity leaves behind a handful of wastes and

dumping of these wastes is a tiring process. Demolition and land clearing results in loads of waste materials which cannot be reused. These materials will have to be perfectly dumped in convenient places and the locations for this will not be available in urban areas. So, the company themselves will have to take care of this.

All these five urban construction issues can be addressed by using the proposed offsite construction plant. Main objective of this plant is to decrease the urban construction issues in major cities of New Zealand. That can be achieved in these ways: -

- i. Urban pollution and other environmental issues can be controlled by decreasing the amount of site activity and site machineries. Major construction components will be made in the offsite plant in a confined atmosphere. This shifts 60-70% of site activities to the plant and thus reduces urban disturbances considerably. Using more light weight steel and encouraging more timber products for construction also reduces the emission of carbon and will help to decrease the environmental effects in the future. (Taylor, 2010)
- ii. Lesser number of machines and workers at the site reduces the requirement of other spaces. Workers facilities and parking spaces for heavy machines makes the work area much congested. So, elimination of these reduces the need of much outside space and this decreases the disturbances caused to the community living around because of the ongoing activity.
- iii. Increase in construction cost can be controlled by better planning and perfectly implementing these plans at site. Production of components can be done smoothly and safely in the offsite plant. Raw material storage, storage of manufactured components. Raw materials delivery done to the plant and easy ways to load and unload raw materials and components will simply reduce the construction cost. (Blismas, Pasquire & Gibb, 2006)
- iv. Speed of construction can be considerably increased by using offsite construction. Components will be manufactured in the plant and planning the delivery of required products in necessary quantity at required time will enable the smooth working of the site. Also using lightweight materials minimises the need of large foundations which reduces the time for construction. Also, it reduces activity in the site which will be also beneficial. (Lu & Liska, 2008)
- v. Mostly assembling works will be only done at site that makes the amount of waste materials much less. Also using light weight recyclable steel for construction enables 99% of them to be recycled and thus steel wastes will be almost nil. Production will maximum try to reduce the usage of non-recyclable materials. This also adds to the decreased carbon emission and thus provides much environmental stability to the work. (Li, Shen & Alshawi, 2014)

CONCLUSION

To conclude the findings it is really easy to say that the offsite construction can make positive vibes over the construction industry. There may be many types of problems that may have to face during the offsite manufacturing but there are always solutions to rectify that situation in the industry. The offsite construction will definitely increase the quality of the products as well as enhance the economy of the construction sector. The cities like Auckland and Wellington the major concern in construction is the cost increment. But allocating new methods in offsite construction can solve these problems and make better living conditions.

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Received: 15th February 2021; Accepted: 04th May 2021; First distributed: 04th May 2021