CHEMICAL ENGINEERING TRANSACTIONS
VOL. 66, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216
DOI: 10.3303/CET1866194

Design and Application of Styrofoam Board and BIM Technology in Fabricated Building Structure

Yun Zhang*, Bingyong Xue, Xinghai Song

Hebei University of Water Resources and Electrical Engineering, Cangzhou 061001, China
sjzjinchun@163.com

Fabricated building is a new type of build model that can achieve an upgrading of construction industry from artificial product to intensive machine production. It must have a bright prospect and economic benefit in the future. This paper describes the applications of polystyrene foam board and BIM technology in the design of fabricated building structure. The best thickness of polystyrene foam measures up the insulation layer for fabricated buildings. What are explained here include BIM technology principle, concept and feasibility of its application in fabricated building. In the end, a real case is cited to reveal how about the application of BIM technology in this architecture and in construction phase. It is concluded that the BIM technology benefits the fabricated building structure. In theory, this study will be leading the development of the construction industry in China.

1. Introduction

Fabricated building as a modern architecture model can effectively improve architectural accuracy, reduce construction costs and increase build efficiency (Lin et al., 2010). In the wake of widespread application in foreign countries, fabricated buildings have achieved a certain effect in application process. Since then, it has also flooded China in an attempt to facilitate the modernization of China's construction industry and achieve energy conservation and emission reduction, thus driving industrial development forward. (Davis et al., 2001).
Currently, China's fabricated building model is just at its initial stage, there is in dire need of scientific and effective simulation procedure, management method, and material analysis approach for leading a rapid, steady, and quasi-development of fabricated building (Yuan et al., 2007). As a process of creating, applying, and managing models about building information, BIM features visualization, coherence, simulation, etc. It can hit off the defects of the fabricated construction such as low level of information management and obsolete management model, to achieve project information integration and management across the industry (Jeannerat et al., 2016). In addition, how to choose the appropriate insulation materials in fabricated construction projects is a great challenge that long perplexes designers. The introduction of polystyrene foam boards is no doubt an effective complement to this for the fabricated building materials (Karan et al., 2016).
This study first describes the concepts and the processes of fabricated buildings, BIM, and polystyrene foam insulation computation, and focuses on the analysis of the BIM simulation during the design and construction phase of prefabricated buildings. Its real effect and application efficiency are analyzed with a practical project as a case (Yang et al., 1974). In this sense, this study has a certain directive significance for stimulating the development of China's construction industrialization and informatization.

2. Theoretic basics

2.1 Polystyrene foam

The polystyrene foam board, also called polystyrene board (EPS), is a kind of foamed plastic board formed by heating pre-foam process using a viable polystyrene beads containing volatile liquid foamer as a chemical raw material. According to the type of fire protection, it can be divided into ordinary type and flame retardant type (Arora et al., 1999). It features light density, high heat insulation, certain elasticity and water absorption. The polystyrene board behaves better as compared to other insulation materials as shown in Table 1:

Please cite this article as: Zhang Y., Xue B., Song X., 2018, Design and application of styrofoam board and bim technology in fabricated building structure, Chemical Engineering Transactions, 66, 1159-1164 DOI:10.3303/CET1866194

Table 1: Polystyrene board and other insulation materials performance comparison

Material name	Weight(kg/m^3)	Thermal Conductivity(w/m.k)	Water absorption
Polystyrene board	10-50	0.032-0.047	small
Bubbles	350-710	0.0837-0.174	big
Glass wool	100	0.052	medium
Vermiculite board	920	0.086	big
Expanded perlite	200-300	0.056-0.065	big
Slag wool	350	0.07	big

It is found that it EPS is more adaptable to fabricated buildings than other chemical materials and has better properties (Lyeâ and Yeong, 1996).
In general project, equivalent thickness approach is used to measure the insulation layer, then calculate it using the principle that the total thermal resistance of insulation base should be equivalent to the total thermal resistance of natural permafrost (Rossacci and Shivkumar, 2003). As given in Formula 1:

$$H_m = 0.003\ 6\lambda^m(\frac{1}{\alpha} + \frac{\delta}{0.003}\ 6\lambda + \frac{S}{0.003}6\lambda_s) \quad (1)$$

Where $\mathrm{H_m}$ is the permafrost depth as designed on the project site, meters; λ^m is the equivalent thermal conductivity inefficient, W/(m·k); α is the surface heat emission coefficient, α=13$\sqrt{\tau}$; S is the insulation thickness, meters; λ_s is the thermal conductivity of the insulation material, W/(m·k).
With the equivalent thickness approach, when EPS is applied for insulation layers of fabricated buildings, the insulation layer should be calculated first in thickness based on the conditions of application sites. Only in this way can we save materials and improve the installation efficiency on the site.

2.2 Overview of fabricated buildings

2.2.1 Properties and profile of fabricated buildings

The fabricated building is such that the completed building is divided into a number of fabricated reinforced concrete components. After manufacturing in the factory assembly line, they are lifted and transported to the construction site where the building will be completed by assembly, joint and splice operations (Smith, DK et Al, 2005). Fabricated buildings differ from other buildings in the following ways:

2.2.2 The service condition of labor force, engineering, and assembly construction, no need of huge amounts of manpower.

(1) Saving resources, energy consumption, energy and water conservation, land saving, nodal wood.
(2) Bull construction machinery and vehicles, hoisting equipment are required.
(3) High labor efficiency, mechanization, and short construction period.
(4) Less environmental impact, dust and noise, construction waste.
(5) Residential performance and space can be rebuilt with sustainable green and long life.
As compared to the traditional buildings, fabricated buildings reduce more labor costs, conserves more energy and are more eco-friendly. And beyond that, they have higher production efficiency, shorter construction period, and good project quality and safety (Dobrawa et al., 2005).

2.2.3 Issues involved in the development of fabricated buildings

(1) Low construction and installation efficiency on the site
Unlike traditional buildings, fabricated buildings require more scientific field management. Due to unfamiliar business operations and lack of project experience, ineffective ordering arrangement in the construction, transportation, storage management, vertical crane transport, and so on, the installation efficiency is low.
(2) Low construction and management level
The construction of prefabricated buildings requires higher specialization and technologies and rigid management capacities, for example, production process of component factories, the transport of component distribution, the operation of technicians, and the supporting installation machinery, as well as precise positioning, lifting, splicing and other processes from design to installation. As the construction model of a prefabricated building has a break-in period at the threshold, construction technology and management capacity remain underdeveloped.
(3) Low project involvement, organization and coordination of all parties

As a sign of the building industrialization, a complete and effective system is required. To assemble all building parts, each participating party should cooperate with others. Effective synergy among project participants can facilitate the scientific development of China's fabricated buildings.

2.3 BIM technology

2.3.1 Concept and composition

BIM, the Building Information Model, is not only a product but also a process (Rowan et al., 1997). In term of product, 3D integral model is built based on engineering data with a triple digit; while in term of process, it refers to the processes of model establishment, application, and management (Cai and Newby, 2008).

2.3.2 Application analysis of BIM technology in fabricated buildings

(1) Feasibility analysis
Fabricated buildings have a vast market in China, but there are gaps in the practical application process such as lax legal specifications, big errors in detail design, tardy information exchange, and low project management capacity (Arayici et al., 2011). To fill up the above gaps, BIM technology provides appropriate measures against these. The feasibility analysis process of BIM technology applied to prefabricated buildings is shown in Fig. 1.

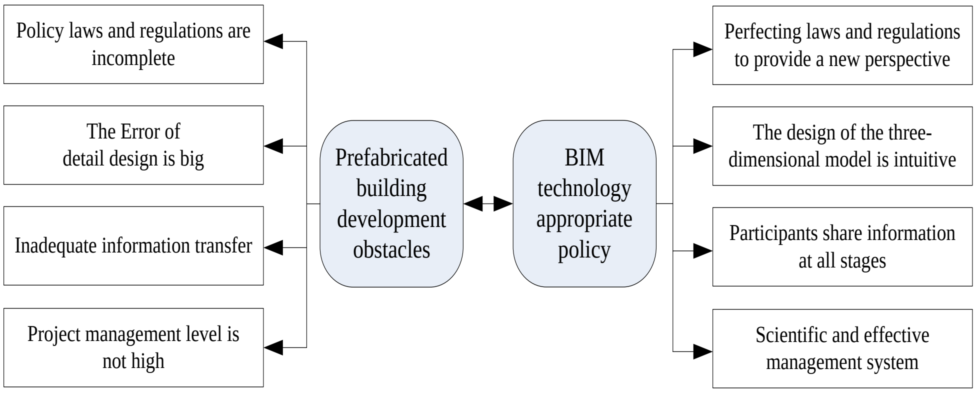

Figure 1: The analysis chart of BIM applied to housing industrialization

(2) Value analysis
BIM technology provides a database as a reliable information platform for owners, construction party, the design institute, operator, and build manufacturers. It enables efficient design in professional and collaborative design process; prefabricated component manufacturers can extract component dimension while reducing occurrence of production errors; provide 3D model rendering for construction schemes and improve construction efficiency.
The application of BIM technology makes the fabricated technology tend to be perfect and reasonable, as technical and managerial support for the development of fabricated buildings. In this sense, it should be widely applied in fabricated buildings (Kim et al., 2013).

3. Application case of BIM in fabricated building

This paper takes a public rental housing project with fabricated concrete structure as an example to demonstrate how the BIM technology is applied in fabricated housing. The project has a 27-storey with standard floor height of 2.8m and total building height of 80m as estimated. The prefabricated construction process runs in the buildings above of floor 4 in 1, 9, 10-1, 10-2 and 10-3# building, including prefabricated interior and exterior walls, stairs, balconies and parapets. The next, the application of BIM technology will be introduced in the design and construction phases.

3.1 Analysis of application in design phase

BIM technology underlies EPC project with design-manufacture-construction industry chain. It works with 3D model and information sharing, provides the design team with instant information exchange between designers, improves design quality and efficiency.
BIM abandons the traditional design approach. It transforms planar 2D drawings into stereoscopic 3D models as a variant from CAD technology.

As shown in Fig. 2, the BIM technology simulates the overall model rendering for the 10-2 building and the 3D stereogram for a house type.

(a) 10-2# architectural rending (b) BIM three-dimensional apartment layout diagram

Figure 2: The BIM technology simulation diagram

BIM technology provides the clusters for fabricated components, from which the designer searches for matching components according to the types and quantities of components to be fabricated. The concrete exterior wall in this project consists of reinforced concrete wallboard, graphite polystyrene plate (SEPS), and polystyrene foam board. Based on the geometric dimensions, material composition, and component location information, BIM will automatically generate a list of components to facilitate the designer for the mastery of specific information and follow-up works.
In addition to basic concrete components, BIM technology can also simulate hydropower design for prefabricated buildings and further provides clues to construction. The modification of simulation for the hydropower collision is shown in Fig. 3.

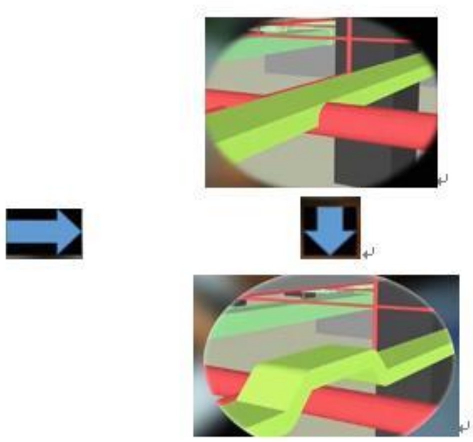

Figure 3: The collision and modification of pipeline

3.2 Analysis of application in construction phase

The construction phase is important for the life cycle of prefabricated buildings. BIM can maximize the information integrity and provide effective guarantee for the smooth completion of the project.

3.2.1 Site layout and construction simulation

The BIM technology is used to model the construction site, which not only facilitates the storage and management of construction materials but also provides construction orientations for giant machinery such as lifting equipment, and indirectly ensure the safety of construction personnel. In construction simulation phase, it simulates the lifting sequence of the components to avoid rehandling.

3.2.2 Construction management

BIM technology provides a standardized process from the factory to transportation and storage of components. There is unique QR code on every component, this ensures the accuracy in the market construction and installation process, avoid secondary installation, reduce the error rate and improve the field construction efficiency. The access process of components is shown in Fig. 4.

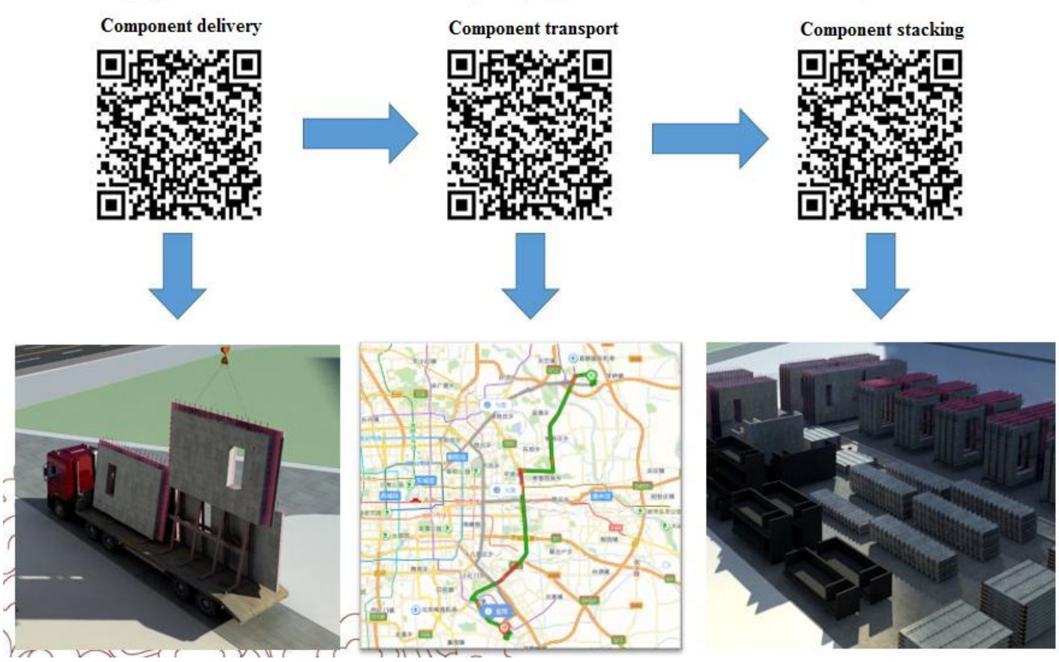

Figure 4: Component approach flow chart

The role that the BIM technology plays in construction management is not only reflected in schedule management, but also effective in quality and safety protection. Due to the component standardization production, transportation, storage, and construction processes, quality management can be easily traced. A public rental house project is taken as an example to reveal that the BIM technology is applicable to the fabricated concrete construction in the EPC project management model, the polystyrene foam board as the project insulation layer features light weight for easy transport, stable properties for easy storage, and better insulation effect.

4. Conclusions

As a pop new type of construction industry, fabricated buildings are finding applications in more and more construction projects. This study aims to lead the application of fabricated buildings in chemical insulation materials and simulation software. First, the introduction of theoretical basics lays a foundation for demonstrating the advantages and feasibility of the application of polystyrene foam board and BIM technology in fabricated buildings. Not only that, the application effect of the two in prefabricated buildings is further affirmed by project case. The findings of this paper are given as follows:
The application of polystyrene foam board in fabricated buildings has some forward-looking and better chemical and economic effects and can be widely used in fabricated buildings.
As a simulation technology of fabricated buildings, BIM technology expedites the development of building industrialization and informatization with a good application effect.

References

Arora K.A., And A.J.L., Mccarthy T.J., 1999, Preparation and characterization of microcellular polystyrene foams processed in supercritical carbon dioxide, Macromolecules, 31(14), 4614-4620, DOI: 10.1021/ma971811z.

Arayici Y., Coates P., Koskela L., Kagioglou M., Usher C., O'Reilly K., 2011, Technology adoption in the bim implementation for lean architectural practice, Automation in Construction, 20(2), 189-195, DOI: 10.1016/j.autcon.2010.09.016.

Cai Y., Newby B.Z., 2008, Marangoni flow-induced self-assembly of hexagonal and stripelike nanoparticle patterns, Journal of the American Chemical Society, 130(19), 6076-7, DOI: 10.1021/ja801438u.

Davis S.A., Breulmann M., Rhodes K.H., Zhang B.J., Mann S., 2001, Template-directed assembly using nanoparticle building blocks: a nanotectonic approach to organized materials, Chemistry of Materials, 13(10), 3218-3226.

Dobrawa R., Lysetska M., Ballester P., Grüne M.A., Würthner F., 2005, Fluorescent supramolecular polymers: metal directed self-assembly of perylene bisimide building blocks, Macromolecules, 38(4), 1315-1325, DOI: 10.1021/ma047737j.

Jeannerat D., Pupier M., Schweizer S., Mitrev Y.N., Favreau P., Kohler M., 2016, Discrimination of hexabromocyclododecane from new polymeric brominated flame retardant in polystyrene foam by nuclear magnetic resonance, Chemosphere, 144, 1391-1397, DOI: 10.1016/j.chemosphere.2015.10.021.

Karan E.P., Irizarry J., Haymaker J., 2016, Bim and gis integration and interoperability based on semantic web technology, Journal of Computing in Civil Engineering, 30(3), 04015043, DOI: 10.1061/(asce)cp.1943-5487.0000519.

Kim H., Anderson K., Lee S.H., Hildreth J., 2013, Generating construction schedules through automatic data extraction using open bim (building information modeling) technology, Automation in Construction, 35(2), 285-295.

Lin C., Liu Y., Rinker S., Yan H., 2010, Dna tile based self-assembly: building complex nanoarchitectures, Chemphyschem, 7(8), 1641-1647, DOI: 10.1002/cphc.200600260.

Lyeâ S.W., Yeong H.Y., 1996, Associativity modelling of a mould assembly for expandable polystyrene foam, International Journal of Production Research, 34(4), 1161-1170, DOI: 10.1080/00207549608904956

Rossacci J., Shivkumar S., 2003, Bead fusion in polystyrene foams, Journal of Materials Science, 38(2), 201-206.

Rowan S.J., Hamilton D.G., And P.A.B., Sanders J.K.M., 1997, Automated recognition, sorting, and covalent self-assembly by predisposed building blocks in a mixture, Journal of the American Chemical Society, 119(10), 2578-2579, DOI: 10.1021/ja963320k.

Smith D.K., Hirst A.R., Love C.S., Hardy J.G., Brignell S.V., Huang B., 2005, Self-assembly using dendritic building blocks - towards controllable nanomaterials, Progress in Polymer Science, 30(3), 220-293, DOI: 10.1016/j.progpolymsci.2005.01.006.

Yang S., Li J., Hong R., Group L.C., 1974, Application study on bim technology in prefabricated concrete structure construction of senile apartment, Heart, 36(9), 872-9.

Yuan H., Little J.C., Hodgson A.T., 2007, Transport of polar and non-polar volatile compounds in polystyrene foam and oriented strand board, Atmospheric Environment, 41(15), 3241-3250, DOI: 10.1016/j.atmosenv.2006.08.057.