Overview of Prefabrication in Residential Construction

(With an addendum on "MEP Prefabrication" by Mark Daniels, Graduate student)

Summary

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Abstract

The rapid growth in the automation in the construction industry is driving towards the adoption of prefabrication in construction. The construction market, especially the residential construction, is shifting towards prefabricated construction practices due to the skilled labor shortage and the need to improve the construction quality. The objective of this report is to describe different levels of prefabrication in residential construction along with their advantages and disadvantages. This report initially provides a brief overview of the residential construction industry along with statistics related to the present construction market and labor trends. It then describes different levels of prefabrication in detail. These include material prefabrication, panelization, pre-manufactured building units or modules, and factory-built homes, including the manufactured and the modular homes. In the end, it provides the advantages and disadvantages of factory-built construction based on factors such as, cost, completion time, and the type of construction methods used for factory-built

versus site-built construction. Finally, it provides the state of prefabrication in residential construction across the world including, the USA, China, India, Japan, Sweden, UK, and Australia.

After this study was completed, additional work was done by Mark Daniels, CM graduate student, on MEP prefabrication for multi-family and commercial buildings. An introduction of that work is provided in the end as an addendum.

PREFABRICATION LEVELS

Prefabrication in construction refers to building components that are manufactured in a factory prior to construction and are delivered pre-assembled to the construction site. In simple terms, prefabrication is the act of collecting segments of a structure in a processing plant or other assembling site and moving complete facilities or sub-facilities to the building site where the structure is to be constructed (Wikipedia contributors 2020; Kim 2009). Based on the level of manufacturing and the extent of off-site assembling, there are four main categories of prefabrication in construction based on the level of completeness in the construction process and the component usage.

- The first category of prefabrication can be termed as "materials" as it is the lowest form of raw materials that are manufactured in the factory and are used for construction after being transported to the site. It can be further divided into 2 subcategories:
  - Pre-manufactured "raw" materials – Examples include, 2x4's, floor tiles, brick, CMU, shingles, plywood, etc. While these materials are often referred to as "raw" materials and not thought of as prefabricated construction, the argument can be made that this is the lowest

level of prefabrication as these materials are pre-manufactured in a factory and then delivered to the construction site.

- Factory-made building materials – These require more processing and has a predetermined singular purpose. Examples include precast concrete walls, roof trusses, floor joists, structurally insulated panels, etc.

- The second category is called "panelization". This refers to pre-manufactured building panels that have structural, plumbing, and electrical, insulation, and enclosure aspects. These include exterior walls, interior walls, and roof or floor panels. These panels are complete and need only to be secured properly once in place.
- The third category of prefabrication in construction is "Pre-manufactured building units or modules." This refers to entire rooms or a specialized part of houses that are built in a factory and are delivered to a construction site and placed using a crane. This practice is common with bathroom and kitchen modules.
- The last form of prefabrication in construction is the entire home constructed in a factory in one or multiple modules and then, delivered to the site. This is most common with modular and manufactured homes.

ADVANTAGES/ DISADVANTAGES OF FACTORY-BUILT HOMES

Advantages

The Modular Home Builders Association (2020) cites certain benefits of modular homes including the variety to choose the shape and style of house from a simple ranch to a highly customized contemporary home and providing a custom design which adheres to local

building code requirements and workmanship. It expedites the construction process as the work is never delayed due to weather constraints, missing materials, and subcontractor no-shows. The modular construction techniques can significantly increase the sustainability and energy-efficiency of a modular home. Additionally, the modular home construction benefits the builders, as well, in certain aspects such as reducing the overhead costs, better job and cost control, sales and marketing support, custom design, quality, and service. The list below summarizes some of the advantages of the modular construction based on the responses from architects/engineers, contractors, and owners (Modular Building Institute, 2018).

Advantages as seen by Architects:

1. Schedule reduction
2. Cost control
3. Quality assurance
4. Waste reduction
5. Weather avoidance
6. Predictable process
7. Labor shortage solution
8. Productivity gains

Advantages as seen by Contractors:

1. Schedule reduction
2. Quality assurance
3. Predictable process
4. Labor shortage solution
5. Worker safety increase

6. Productivity gains

7. Waste reduction

8. Cost control

Advantages as seen by Owners:

1. Schedule reduction

2. Predictable process

3. Labor shortage solution

4. Quality assurance

5. Cost control

6. Waste reduction

7. Productivity gains

8. Weather avoidance

Disadvantages

The Dodge Data & Analytics (2020) Smart Market Report states several challenges associated with the factory-built construction. According to the report, the respondents believe that the supply chain for factory-built construction companies is limited and needs to be expanded. It points to the need to bring automation in the factories as the respondents believe that the companies are still using manual methods of construction and there is a scope for upgrading the tools and technologies that can be used for construction. Another challenge encountered in factory-built construction is financing as the lenders do not fully understand the parameters of off-site construction practices. Similar to the listed

advantages, the listing below summarizes some of the barriers to modular construction (in order of frequency) based on the responses from architects/engineers, contractors, and owners (Modular Building Institute, 2018).

Barriers as seen by Architects:

1. Owner perception and education
2. Historical stigma
3. Regulatory code officials, inspectors
4. Design restrictive / aesthetics limitations
5. Transportation logistics
6. Designer's knowledge of modular
7. Early engagement of modular manufacturer

Barriers as seen by Contractors:

1. Owner perception and education
2. Historical stigma
3. Designer's knowledge of modular
4. Regulatory code officials, inspectors
5. Transportation logistics
6. Traditional contracts (tie with seven and eight)
7. Early engagement of modular manufacturer

8. Cost estimating and budget

Barriers as seen by Owners:

1. Historical stigma

2. Owner perception and education

3. Transportation logistics

4. Traditional contracts

5. Designer's knowledge of modular

6. Project finance

7. Early engagement of modular manufacturer

TRENDS

Prefabrication in construction has seen significant development in recent years. A recent study predicts that the modular construction will grow by 6.9 percent every year and reach $153 billion by 2023, mainly driven by the absence of skilled work labor and increasing acceptance (Zitzman 2020).

With the innovation in technology, many small manufacturers have created innovative, green building structure designs, thereby expanding their market share and boosting customer trust. Recent innovations have made it possible for various prefabrication styles and modular building structures to get bigger and taller. For instance, the recent opening of the 21-story CitizenM Bowery Hotel in NYC showcased 100,000 square foot space with 300

modular guest rooms. Many international building developers have indicated that they intend to pare down their on-site construction plans to only 25 percent by 2025 by adopting prefabrication in construction (Zitzman 2020). According to PR Newswire (2019), the global Modular Construction Market is anticipated to gain momentum from the rising adoption of technologically advanced manufacturing techniques. The market is projected to reach USD 107.21 Billion by 2026 from USD 64.85 Billion in 2018.

The Global Residential Building Construction Industry Market is projected to surpass more than US$ 8063.90 Billion by 2025 at a compound annual growth rate (CAGR) of 10.3% (Market Research Engine 2020). The following sections present the trends in Off-Site Construction across the globe and will present a brief overview of the state of the factory-built construction in the USA and some other nations.

Addendum - Prefabricated MEP Rack Systems

A major trend in construction prefabrication is the Prefabricated MEP Rack System, which is a prefabricated rack with mechanical, electrical, and plumbing systems fabricated and assembled in the rack. The MEP components vary based on the type of construction, but for the most parts are constructed with the following: ductwork, conduit, cable tray, hot and chilled water lines, and plumbing pipes (Figure 1). Prefabricated MEP rack systems are usually fabricated off-site and then transported to the project site, where they can be rolled into the building and hoisted into the ceiling space. MEP rack systems are used in corridors of buildings, where MEP utilities are traditionally designed to go. Furthermore, the rack systems are typically 5 to 10 feet wide and constructed in 10 to 30-foot long sections,

depending on the feasibility of shipping and maneuverability on the jobsite. These sections are designed sequentially, so they can be connected, and the systems can be tied together.

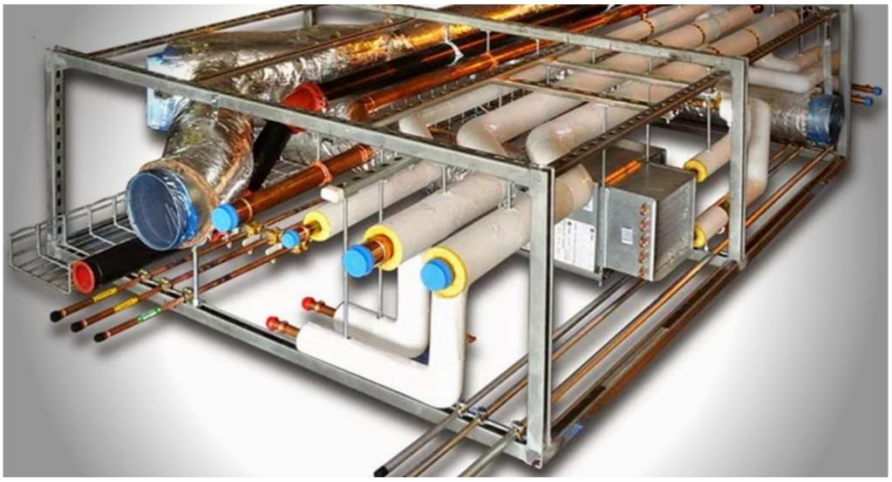

Figure 1: Prefabricated MEP Rack System (Source: Limbach Co. and Shaw Electric Co., 2018)