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제조·조립을 위한 설계(DfMA) 기반 건축 활성화 방안 연구

A Study on Design for Manufacture and Assembly(DfMA)-based
Construction Development Measures

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This study proposes to expand the current system and policy support and revitalize design-based architecture for manufacturing and assembly as a practical means to address immediate concerns in the construction industry. For this purpose, we first shared concepts and characteristics different from conventional site-oriented construction and analyzed their architectural significance. Then, we examined buildings built in Korea through processes similar to manufacturing/assembly construction and underlined their achievements, issues, and limitations, and finally compared them with advanced foreign cases to suggest institutional and policy alternatives that correspond to our conditions.

Chapter 2 identifies the concept and purpose of DfMA construction, its utilization effects, and directions for implementing DfMA construction.

DfMA (Design for Manufacture and Assembly) is a design method to increase the efficiency of manufacturing and assembly of product components by reflecting the conditions required for subsequent manufacturing and assembly processes at the product design stage. DfMA is basically a set of design methodologies that make product design more accessible and more efficient and enable product manufacturing and assembly with minimal time, effort, and cost. The purpose of using DfMA is as follows. First, it simplifies the production structure and reduces the costs involved in production and assembly. Second, it identifies and responds to problems in production and assembly in advance. Third, it supports cost management for contract negotiations between demand and suppliers, ultimately achieving environmentally friendly effects along with minimizing material waste, reducing industrial site risks, and ensuring uniform quality.

DfMA construction focuses on streamlining the design process, improving material selection, and optimizing construction planning and logistics for buildings. The resulting architectural effects include improvements in safety, quality, and economic feasibility during the building construction process, less wasted resources and transportation costs, and reduced energy use and waste generation, thereby contributing to building a sustainable environment. Countries that proactively introduced DfMA use DfMA as a means of responding to the challenges currently facing the construction industry, including low construction productivity, ongoing safety accidents at construction sites, frequent design changes and resulting declines in construction quality, and increased construction costs, construction noise and various waste disposal issues, and civil complaints. These countries have confirmed its effectiveness and are expanding the market.

Three major strategies are needed to expand the use of DfMA in the construction industry. First, a viable DfMA strategy should be prepared that corresponds to the internal and external specialties of architecture, such as architectural production methods, policies, and industrial conditions. Second, a digital software-based platform (BIM, etc.) is needed that facilitates collaboration and management by allowing all construction stakeholders to participate together. Third, in construction, the pre-manufacturing rate should be increased regarding manufacturing and assembly efficiency. DfMA architecture is fundamentally a construction method based on manufacturing; it is necessary to decide which building components will be manufactured (industrialized) in a factory. Improving the assembly process by introducing individual building elements to the site can also be a way to realize entry-level DfMA construction.

Chapter 3 reviews the current status of DfMA construction in Korea by checking the absence of DfMA building standards, the recognition system, the establishment of BIM guidelines and ordering system, and policy support.

In the Building Act, Standards of Building Structure, Equipment, Evacuation and Fire Prevention and Standards of Building Energy Conservation and Sound Insulation are structured around buildings with reinforced or steel-reinforced concrete structures built on site. In particular, the standards for preventing condensation, floor impact noise, and sound insulation structures of walls in apartment complexes under the Housing Act specify the thickness of walls and the construction method of floor plates for apartments with reinforced concrete wall structures. Meanwhile, DfMA buildings, such as modular construction, in which members and parts are produced in a factory and assembled and joined at the site, are judged to meet the relevant building standards only by recognizing individual components.

The only recognition system for DfMA buildings concerns industrialized houses under the Housing Act. The performance standards for industrialized houses are divided into detached houses and apartment complexes. In contrast, the production standards are divided into concrete, lightweight foam concrete, and other prefabricated members based on the material characteristics of the prefabricated members. In addition, the recognition of industrialized houses is valid for five years and is rigid; when the size, area, or materials of the recognized house change, separate recognition should be obtained.

Across all ministries, the government prepares and implements BIM framework guidelines, implementation guidelines, and application guidelines for each field in the construction industry to introduce and facilitate BIM, which is recognized as a core tool of smart construction that maximizes productivity, constructability and efficiency in the building construction process. The BIM framework guidelines provide basic procedures for conducting construction projects, such as collaboration, data management, standards for BIM application, and directions on BIM application principles, steps, methods, and plans. The BIM implementation guideline divides the owner, designer, and constructor into specific detailed standards that can be used by public and private owners, as well as methods and procedures for creating, delivering, and utilizing BIM products.

The current ordering method for construction work, including buildings, was formed and is being operated on the premise of a wet construction method that completes the structure through on-site construction based on design drawings produced through a design office. As a result, the factory production process of units that should play an essential part in the overall building production process based on advanced technology is treated as a simple manufacturing process, preventing the advancement of related technology or accumulation of expertise.

A 13-story modular construction was demonstrated through the national R&D project Development of Mid to High-Rise Modular Construction and Productivity Improvement Technology. Subsequently, to revitalize the modular construction industry, policy research on specialized construction business registration and ordering systems, performance recognition systems, and development of element technologies of modular construction such as ondol system, connecting hardware, interior and exterior finishing materials, variability, wooden module, and PC module were carried out. Because these national R&D projects tend to focus on the technological development of modular construction, one of the various types of DfMA buildings, they have limitations of not reaching the level of innovation and development of a new ecosystem across all stages of building production through design for manufacturing and assembly.

Chapter 4 analyzes DfMA buildings regarding utilization and effectiveness at each assembly level and reviews DfMA building systems and policy cases in foreign countries.

For Level 1, considering Korea's road penetration rate, road structure, and product loading regulations, the Level 1 method of product manufacturing and on-site assembly for each construction area is advantageous, reducing 10% of labor costs and 30-40% of material costs. In Level 2 cases, total and material costs were reduced by more than 10% and 8%, shortening the construction period by 12%. Concerning performance, the airtightness increased to 30-70%, and energy consumption decreased by up to 18%. At Level 3, construction costs are reduced by up to 40%, and energy-saving effects are expanded from 38% to 80%. Level 4 reduced labor costs and construction period by up to 40% and improved labor productivity by mass production of standardized modular units based on large-scale facility equipment.

Singapore has a systematic government organization, including the Building and Construction Authority (BCA) and its BIM Committee, as policymakers. In addition, the Housing Development Board (HDB) plays a significant role in implementing policies by carrying out research, development, and construction projects that incorporate government policies. The United States falls under a private sector-led system where the private sector competes to secure competitiveness in the construction industry. As the world's largest construction market, OSC recognizes it as an inevitable choice to secure competitiveness. Accordingly, private organizations such as AIA, CII, and MBI lead in creating related guidelines and standards. The UK and Hong Kong are examples of public-private cooperation, and the government's presentation of a vision, policy implementation strategies, and implementation plans are specified through public-private cooperation organizations. The UK government consistently presents national policies for innovation in the construction industry and establishes and operates the Centre for Digital Built Britain (CDBB), comprised of industry, academia, and policymakers, as an organization that supports construction industry innovation policies. It also forms the Construction Innovation Hub (CIH) together with the Manufacturing Technology Center (MTC) and the Building Research Establishment (BRE). Hong Kong is pursuing an active construction innovation policy, following the UK and Singapore as precedents, and has formed the DfMA Alliance, involving stakeholders such as government, industry, and academia, to act as a coordinator between the government and industry. However, it is currently gradually transitioning to a government-led MiC activation policy.

Each country actively introduces smart technologies to improve the productivity of its construction industry. The UK, Singapore, Hong Kong, and the US, all surveyed, promoted BIM activation policies as a critical requirement for innovation in the construction industry. In order to respond to the rapidly changing construction environment through digital innovation, the UK established CDBB, became a leader in global BIM, and promoted the National Digital Twin Program. Singapore promotes BIM to improve construction productivity and establishes a BIM steering committee under the BCA to increase utilization. In order to respond to decreased available labor in the construction industry, Japan drives the ‘I Construction’ policy to enhance productivity by actively introducing information and communication technology to construction sites.

Chapter 5 proposes institutional improvement measures, standard model development, project model development, and technology development measures to revitalize DfMA construction.

Support is needed to build product manufacturing facilities and implement designs to enable DfMA construction. Considering construction market conditions, the government should establish regional manufacturing plants that are capable of automatic production based on BIM and have sufficient space for product performance testing, manufacturing, and movement of transportation equipment, and should introduce policy support measures such as site leases or financial support.

Considering the BIM conditions in the Korean construction industry, there is a need to consider the government's proactive support for expanding the use of BIM. The driving force behind the revitalization of the DfMA construction market in overseas countries is not irrelevant to the government-led strategy of increasing the use of BIM. In response to Korea's poor use of BIM, the government should seek ways to expand the use of BIM as a basis for revitalizing DfMA. Based on the BIM framework guidelines currently published and distributed by the Ministry of Land, Infrastructure, and Transport, regulators need to provide information by adding the DfMA construction section and develop a BIM library applicable to public projects that require mandatory submission of BIM design documents. When doing so, they should prepare and accumulate a global data-sharing strategy to lead the way in applying and spreading it to the private market in the future.

BIM as a tool, various project experiences, result analysis, and accumulation of technical know-how are necessary together with specialized manufacturers and manufacturing plants to revitalize DfMA construction, which is suitable for the project promotion of integrated design and construction. Also, there is a need to create a differentiated project model that corresponds to Korean architectural culture by attempting a gradual transition to DfMA construction projects for apartment complexes implemented by Korea's LH and local housing development corporations.

In Korea's public ordering projects where design and construction are ordered separately, the relevant standards (standards for deliberation on bidding methods for large-scale construction, etc.) were recently revised to enable turnkey ordering when smart construction technology is applied, creating an environment for promoting construction projects using the DfMA method. However, depending on the type of target projects (purpose, scale, etc.), it is necessary to diversify the design-build method and consider developing various business models such as design-led or construction-centered integrated ordering.

Hong Kong and Singapore provide incentives of a 10% floor area ratio to expand the private market for DfMA construction. This policy is well received in Hong Kong and Singapore, where rents are high, as a means to increase the possibility of project expansion in the private market in the future. A 10% relaxation in the floor area ratio may be an attractive incentive to select the DfMA system for complex buildings intended for sale within the Korean subway area. Accordingly, by applying the mitigation standards stipulated in Article 5 of the Building Act and Article 6 of the Enforcement Decree of the same Act, DfMA construction was included in the mitigation targets, and floor area ratio, building-to-land ratio, height restrictions, and open space within the site were specified as mitigation targets. In addition, by defining it as a special structure building, the target was added to the special structure building target standard No. 1 so that standards differentiated from general types of buildings could be applied. In addition, a constructability and productivity evaluation system based on DfMA should be introduced to provide measures such as easing building standards for each grade, providing floor area ratio incentives, and awarding bid points.

Regulators need to resolve the negative perception that manufactured and prefabricated buildings are construction sites, temporary offices, warehouses and factories, and auxiliary facilities to general buildings, and provide accurate information that this is a construction method that can secure not only performance but also design excellence. Based on public order projects, they should provide expert knowledge, such as how to promote DfMA construction and seek ways to induce social interest and change in awareness by promoting information that the general public can understand.

Among the strategies to revitalize DfMA construction presented in this study, the DfMA application evaluation system can serve as a guideline for business owners (building owners) to select business methods and scope of manufacturing and assembly. A driving force for this system to operate in the construction market should be provided by developing evaluation systems such as how to manufacture and assemble the architectural structure, finishing, and equipment members from Level 1 to Level 4 or how to assign points to the items decided and selected at the design stage. In addition, alternatives should be prepared by considering the correlation with current systems on using the evaluation score in the construction process.

As mentioned earlier, regulators should analyze and refer to the guidelines of countries actively promoting DfMA construction, such as the UK, Hong Kong, Singapore, and the United States, and develop guidelines for each process and sector that comply with the building construction process in accordance with the Korean Building Act and related laws.

In response to the motivation of low BIM utilization, a BIM library is necessary to supply government-led data. Therefore, regulators need to collect, analyze, and systematize BIM standard data used in the international market, and in particular, they should explore ways to discover DfMA construction design elements that have a high proportion of work in the design stage and utilize mutual sharing in the public-private construction market. Furthermore, proper means to share international BIM data for DfMA construction should be explored.

Keyword

Manufacturing, Assembly, DfMA, Design, Construction, Productivity, Cost