SUGGESTING IMPROVEMENT METHODS OF FORM WORK FOR COST REDUCTION IN THE MID-RISE APARTMENT HOUSING

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ABSTRACT: In recent days, the study of urban regeneration has been conducting with purposeful and sincere intent starting out with the residential environment improvement works. Within the range of urban regeneration, the low-cost housing technology means development of totally-integrated housing technology that may be applied to the regeneration project, especially for the rundown areas where infrastructure facilities in the urban zone have been degraded and obsoleted. In line with this, among many and varied methods in order for realization of the low-cost housing as a part of urban regeneration project, this study should like to propose an improvement methods of the key technologies in relation to the construction works by type of work with which construction costs (directing cost) would be reduced. And, in order to elicit the method for element technology that has been developed and improved in the most optimal manner centering on the selected construction work by the type of work, the researcher conducted comparative review of summary of element technologies related to the construction works concerned, characteristics, and construction method thereof. In particular, the researcher investigated the expenses (construction cost and labor cost), constructions (contractibility and productivity), safety, quality of works, and the technical status in environmental aspects, and the researcher also conducted analyses and evaluations thereof.

Keywords: Construction Key Technology, Low-cost Housing, Improvement Methods of Cost Reduction, Form work

1. INTRODUCTION

1.1 Research Necessity and Purpose

In Korea, a certain number of multi-family houses are being supplied to low-income people. Focus has been placed, however, only on providing the number of houses required by laws and systems, while the houses' surrounding environmental, social, and cultural characteristics as well as the potential residents' economic levels and requirements are disregarded. Thus, these multi-family houses have been alienated from their surrounding residential complexes, have different types of buildings, and undergo different management, although their developers are the same as those of their surrounding apartments. This situation creates problems with respect to the formation of urban communities that integrate various social classes. In particular, there are no real housing programs for the urban poor, disaster-struck low-income people, impoverished elderly people, and other marginalized members of Korean society. There is also insufficient research on residential management, the types of housing, and housing supply and improvement methods. As a result, a vicious circle of social problems is being created such as residential dilapidation, slums, mass production of street sleepers, and alienation of particular areas (The study by the Urban Renaissance Center, 2007).

Against such a backdrop, a full-scale research on urban regeneration is being conducted, beginning with residential environment improvement projects. It is also imperative to develop integrated and holistic cost-reduction-oriented housing technologies across the full spectrum of housing design to production, supply, management, and operation. This way, marginalized members of society who live in areas with dilapidated urban infrastructures in urban regeneration districts will be able to acquire or rent and sustainably maintain and manage housing.

Thus, as part of this urban regeneration project, this study examines measures and key technologies aimed at implementing low-cost housing, selects work types with construction costs (direct costs) that can be cut, examines factors that influence related work types and their status, and proposes alternatives to such key technologies and possible improvements to them.

Therefore, future research will evaluate the proposed optimum improved and developed alternatives in view of key technologies, and effectively apply them to Mid-rise multi-family residential units (i.e., under-12-story houses), which are examples of low-cost housing models.

1.2 Research Scope and Method

In this study, Mid-rise multi-family houses were surveyed in areas and districts that need residential environment improvement. First surveyed were large work units and their subordinate medium-sized work units that need to be developed and improved for cost-cutting. Next examined were key technologies and improvement schemes for the medium-sized work units.

In the first survey, related literature in the past five years on key technologies and previous researches were studied, and the construction costs of Y Building in K City, in the residential environment improvement district of construction projects initiated by D Corporation, were examined. Of all these examined work types, priority work types for cost-cutting were determined. Also, of these priority work types for multi-family house construction projects, the form work that was deemed to have significant effects on labor ratio reduction and construction cost-cutting was examined.

Based on the first survey results, a second examination of form work methods was conducted that targeted the redevelopment construction project for multi-family residential units of M Building in D City, which P Company ordered and which was constructed by the frame specialist firm S. Also, to determine the optimum key technological methods for improvement/development, key technologies and construction methods for related work units were compared and examined. In particular, they were evaluated in terms of cost (construction costs and labor costs), construction (workability and productivity), safety, quality, and environment.

Based on the examination results, further research will be conducted to draw up cost-reduction-oriented technical manuals by method and to develop and utilize low-cost housing technologies. Towards such ends, such technologies' cost-efficiency, productivity, and utilization in Korean Mid-rise multi-family residential units will be reviewed. This will be accompanied by a holistic evaluation of the social and economic expectations from such technologies and their ripple effects, as well as by the establishment of measures for their practical use and utilization.

2. SELECTION AND ANALYSIS OF TARGETS FOR COST REDUCTION

2.1 Examples and Priority Criteria for Target Selection

To examine cost-reduction-oriented key technology improvement measures, targeted in this study were the Mid-rise multi-family residential units of Y Building in the first stage of the residential environmental improvement district project in K City, which D Corporation initiated in 2006. The target residential area has apartments that cover an area of 51 ㎡ to 84 ㎡, and 716 households. The project incurred a total construction cost of 70,600,897,000 won, and was built over a total construction period of 1,033 days and over a net construction period of 823 days (for the actual construction and civil engineering).

To determine key technologies for priority work units that need to be improved and developed, large work units were divided into the following five categories: construction, machinery, electricity, communication, and civil engineering. These categories were further divided into 37 work units that consisted of 17 construction work units, five machinery work units, three electricity and machinery work units, and 12 civil engineering work units. Then the construction costs of each of these work units were examined. The following work units were considered the priorities for cost reduction: major medium-sized work units that accounted for over 3% of the total construction cost, and the labor cost of which exceeded 60% of the total itemized cost accounts such as the materials costs, labor costs, and other costs.

2.2 Analysis Results

The construction cost ratios of the multi-family residential units of Y Building in K City, which were constructed by D Corporation, were examined according to large work units (construction, machinery, electricity, communication, and civil engineering). The construction work cost ratio of the large work units (68%) was more than double the combined cost ratio of the machinery, electricity, communications, and civil engineering (32%) (The landscaping work cost ratio of 3.7% was excluded from the construction work cost).

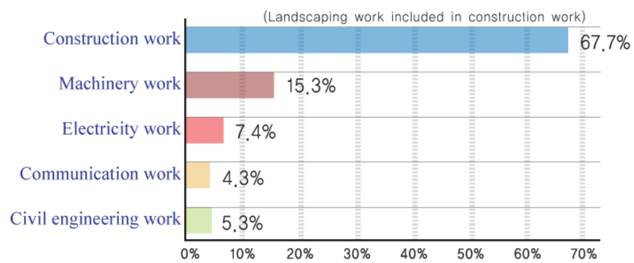

Figure 1. Construction cost ratio by large work unit (Apartments of Y Building in K City)

Thus, in determining the priority work units in association with the securing of cost-reduction-oriented key technologies and their improvement scheme, only large work units with high construction cost ratios were selected. Related medium-sized work units were also selected.

As shown in the following figure, of the total 37 medium-sized work units, the ratios of the materials costs and the labor costs to the construction costs were examined. Of the material costs, remicon work (86.40%), interior finishing work (85.91%), and window and glass work (77.03%) had the largest shares of the construction cost, in that order. Of the labor costs, form work (82.90%) and plaster work (60.68%) had the largest shares, in that order.

To propose alternatives to cost-reduction-oriented key technologies, the construction cost details were examined in this study and 12 major work units with very high net construction ratios of over 3% of the total cost were selected from the total 37 medium-sized work units. Of the selected 12 major work units, the target work units were narrowed down to two major work units (form work and plaster work) with presumed high cost reduction effects, as their labor cost accounted for over 60% of the total itemized costs.

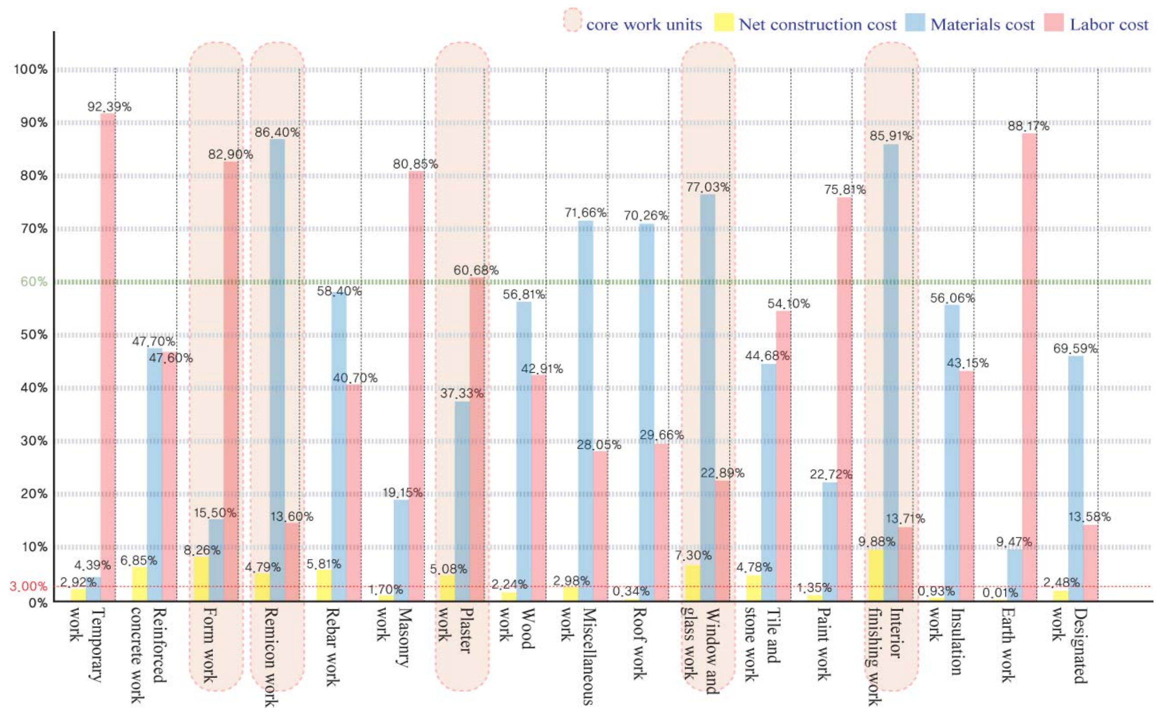

Figure 2. Construction cost ratios by work unit and itemized accounts

Of the 37 medium-sized work units, this study targeted the construction work that accounted for a big share of the construction costs and the cost reduction effects of which were deemed to be significant, and divided it into structural work (form work and staircase work) and finishing work (interior finishing work and plaster work). This study was limited to form work, for which there is a high possibility of improvement of its key technologies and of the development and practical use of new technologies. This study thus determined improvement measures for cost reduction.

3. FACTORS THAT INFLUENCE FORM WORK AND CHARACTERISTICS BY METHOD

3.1 Factors that Influence the Selection of Methods

To determine alternatives to cost-reduction-oriented form work methods and the work's improvement scheme, related literature were first reviewed and experts on the concerned construction site were interviewed to determine the factors that influence the selection of form work methods. Such factors, which are closely related to the characteristics of the construction site, include cost-efficiency, the construction period, labor-management situations, the site conditions, the building conditions, the required quality, the temporary construction plan, safety, and environmental problems.

Item	Factors that influence the selection of methods
Cost	-Reduction of construction costs and labor costs, shortening of the construction period to reduce indirect costs, and minimization of early investment costs
Quality	-Review of the concrete strength and structure, examination of the creation of rubble stones and cracks, and standardization of component materials
Technology	- Plans for productivity, cost-efficiency, constructability, and cranes
Manpower	- Examination of skilled workers' ability and ratio, and of the manpower dependence ratio
Environment	-Examination of the characteristics of the construction site, noise and vibration, and possible civil complaints
Safety	- Examination of safety during installation and dismantling, and safety in workspaces

Figure 3. Factors that influence the selection of form work methods

These factors were narrowed down to six, namely, cost reduction, quality improvement, technology development, manpower development, environmental improvement, and securing of safety. Moreover, 16 factors that influence the selection, such as construction cost and labor cost reduction, review of the concrete strength and structure, productivity, and cost-efficiency, were determined.

3.2 Survey and Examination of Diverse Existing Form Work Methods

(1) Form Work Outline

Form work costs account for about 10% of the total construction costs. In particular, they account for a hefty 20-30% of the reinforced concrete work costs. Form work has significant effects on the quality of the entire building, including of the finishing work, as well as on the construction period and costs. To ensure effective form work, several requirements should be met with respect to form strength, accuracy of members, concrete surface adequacy, workability, productivity, and transferability. Forms by method--after hardening concrete--are divided into temporary forms aimed at creating a structure, and burial forms that are used as construction materials. There are diverse form work methods according to the characteristics of forms, the construction scale, the construction parts, the members used, and the purposes. This study which targets temporary form work methods examined aluminum forms and conventional euro forms, which have been significantly used and which are deemed to have significant cost reduction effects while enhancing cost-efficiency and productivity according to the various parts of a form.

(2) Examination and Evaluation of Form Work by Method

To determine favorable alternative methods of cost reduction, this study examined aluminum forms (walls: aluminum forms; slabs: aluminum) and conventional euro forms (walls: euro forms; slabs: coated plywood or panels) with the same area sizes, and compared their general characteristics. In particular, the aforementioned six factors that influence form work methods, namely, cost, quality, construction, manpower, environment, and safety, were examined to compare their characteristics as well as their strengths and weaknesses.

Table 1. Comparison of characteristics between aluminum form and conventional euro form

Item	Aluminum form	Conventional euro form
Frame process	6-7 days	8-9 days
Weight	26 Kg	40 Kg (20×2 Ea)
Staircase work	Single-unit aluminum form	Euro form and conventional style
Form reinforcement	According to structure (1 or 2 levels)	Required (horizontal and vertical)
Frequency of transferable use	120-150 times	15-20 times
Decoration work	Decreased by 25-35% compared with the euro form	Much workload
Site management	Easy to manage and to secure passages	Passage inconvenience, safety negligence
Form stripping	Secure work space (safe)	Narrow work space (unsafe)
Form lifting	Reduced by 40% compared with the euro form	Slow lifting speed
Joint	1 line (frame and sheets in a single unit, only joints are created)	3 lines (joint lines of plywood and frame, rivet traces, etc.)
Concrete surface	Much decoration work is required, leading to oxidation of the concrete and aluminum surfaces, thus slightly lowering the surface quality (coating of stripping agents is crucial)	Less decoration work is required, requiring the form surface to be treated with plywood (coasting), and thus creating a superior surface
Chamfer	Chamfer for the aluminum form is created, thus smoothing the surface and creating less desorption	Welding is conducted onto narrow steel panels, creating desorption. Also, the steel form has a very smooth surface, but creates rubble stones

Examples by method		

In line with their aforementioned characteristics, the strength and weakness of the aluminum form and the conventional euro form were examined in terms of influential factors for selection of form work methods, such as cost, quality, workability, manpower, environment, and safety. Technical review was conducted with personnel in form production, site managers and workers (technicians and skilled workers) along with interviews with experts. Thus, characteristics, and strength and weakness are compared as follows.

Table 2. Strengths and Weaknesses between aluminum form and conventional euro form

Strengths and Weaknesses		**Aluminum form**	**Conventional euro form**
Strength	Cost	• Reduces labor costs, thus significantly reducing costs • Significantly reduces construction costs of medium- and high-story houses	• Makes plywood work possible depending on the number of floors, thus reducing costs • Significantly reduces construction costs of medium- or lower-story houses
	Quality	• Ensures superior structure quality after form stripping (less decoration work for rubbles and joints) and reduces frame costs	• After coating with stripping agents, the frame quality is less affected by the rainy season
	Construction	• Cost-efficient for medium- or higher-story floors • High use transferability (durability)	• Cost-efficient for medium- or lower-story floors • In association with slab work, significantly shortens the construction period
	Manpower	• Easy for unskilled workers • Less dependent on manpower	• In association with slab work (coating of panels), yields greater productivity
	Environment	• Eco-friendly and favorable for recycling • Produces more rubbles and waste	• When removing slabs, less noise and vibration are created (urban work)
	Safety	• Favorable for secure work spaces (safe)	• Safer when removing slabs
Weakness	Cost	• Greater initial investment costs • Less significant cost reduction effect for medium- and low-story houses	• Less significant cost reduction effect due to higher labor costs • Less significant cost reduction effect for medium- and high-story houses
	Quality	• After coating with stripping agents, the frame quality is very much affected by the rainy season	• Unfavorable for securing structural quality (creates much decoration work in rubbles and joint areas, lowering quality and increasing frame costs

	Construction	• Less cost-efficient for medium- or low-story houses • Less significant construction period reduction effect	• Less cost-efficient for medium- and high-story houses • Lower use transferability (durability)
	Manpower	• Lower productivity in slab work	• Lack of skilled and young workers • Great dependence on manpower
	Environment	• When removing slabs, greater noise and vibration are produced (for urban works)	• Pollutes the environment and unfavorable for recycling • Produces a lot of rubbles and waste
	Safety	• Less safe when removing slabs in association with the movement of materials	• Narrow work spaces (unsafe)

4. PROPOSED ALTERNATIVES FOR COST REDUCTION IN FORM WORK AND IMPROVEMENT DIRECTIONS

Various form work methods were surveyed and examined, and alternative cost-reduction-oriented form work method for Mid-rise multi-family residential units is proposed in the following figure.

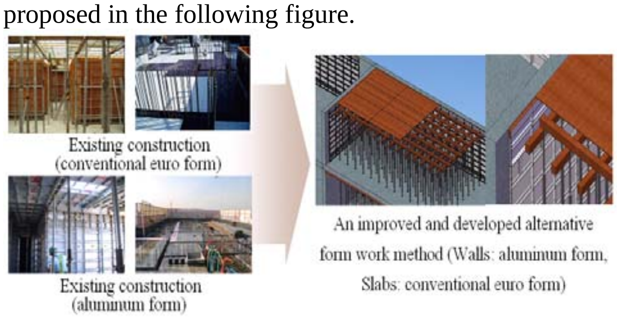

Figure 4. Suggesting an Improved/developed alternative form work method

Moreover, the improved/developed form work method is featured as follows, along with its concept and combination of various characteristics according to the parts of the form. Based on the examination results, the application of and the improvement directions for the alternative method are presented.

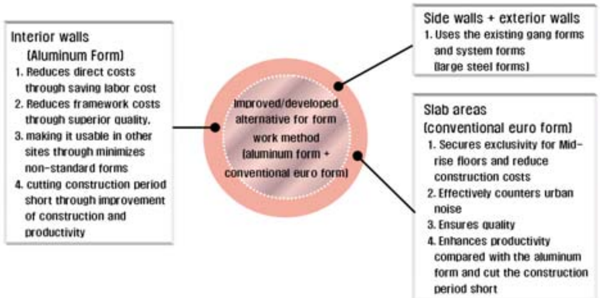

Figure 5. Suggesting component of an Improved/developed alternative form work method

First, the aluminum form work method was found to be more favorable for interior wall construction in Mid-rise or lower floors. It made the installation of standard panel forms easier, and cut labor costs by allowing for the hiring of unskilled workers. Moreover, by stripping forms and smoothing the workload for rubbles and joint areas, it remarkably reduced the accompanying waste amount, and thus ensured superior structural quality and reduced the overall frame costs. It also allowed the standardization of the parts (subsidiary materials) used in construction areas, and thus minimized non-standard forms and boosted their transferability (durability) to other construction sites. In addition, it boosted workability and productivity, and thus cut the construction period short.

Second, the conventional euro form work method was found to be favorable for construction in slab areas on Mid-rise and lower floors. Depending on the number of floors, it made plywood work possible, cut costs, and addressed the problems of high costs and lower quality due to slipping agents, which frequently arise with the aluminum form method. Productivity is also better with the conventional euro form than with the aluminum form, and the construction period can be shortened to reduce costs. This method can replace the aluminum form work method, which is unfavorable for urban construction work because it creates noise and vibration during slab form stripping.

Lastly, through a combination of aluminum forms (interior walls) and conventional euro forms (slab areas) by area, an optimum improved/developed form work method can be worked out. The examination of the combination of characteristics and strengths and weaknesses of these form work methods pointed out a significant cost reduction effect in Mid-rise and lower multi-family houses. If a greater number of parts are standardized and the connection members by area and the staging system are structurally verified, not only workability and productivity will be enhanced, but also quality, security, and the environment.

5. CONCLUSIONS

Cities today are fast expanding in scale and functions, but they are not properly functioning in line with today's high level of economic growth. Urban renovation still remains at the physical level, and has yet to take on economic and social regeneration. Thus, in recent years in Korea, researches on successful examples of urban regeneration in Japan, Europe, etc. are being conducted and related technologies are being developed to change and improve the physical, social, and cultural environments of cities. In particular, state and public agencies are leading efforts to research on urban regeneration, beginning with projects to improve residential environments.

As part of these urban regeneration efforts, this study examined the form work method, which, if improved, is deemed to greatly reduce construction costs and thus make possible the construction of low-cost houses for marginalized members of society, including low-income members. Towards this end, the construction costs of a selected apartment building were examined. Also, form work methods were examined with respect to six major work units and 16 factors that influence the selection of form work methods, to compare and determine their characteristics as well as their strengths and weaknesses. In addition, an alternative cost-reduction-oriented form work method and work improvement scheme was worked out.

This study had the following limitations. Only details of multi-family residential units were examined, and the results of the technical structural review of the methods and the examination of their cost-efficiency were not verified, which makes it difficult to generalize the results of this study.

As such, this study is intended to be used in similar researches and technology development efforts to reduce the direct costs of multi-family houses. It is also intended to be applied to Mid-rise multi-family residential units as a low-cost housing model. In addition, research will be further conducted to review the technical structure and verify the cost-efficiency of the itemized cost accounts, so as to reevaluate and verify the optimum improved/developed key technologies.

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