Economics on Structural Floor Systems of Super Tall Buildings

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Abstract

An economic analysis is one of the most dominant factors to determine the project feasibility of super tall building. In economic considerations, it is very important toadopt optimum structural floor systems because these are dependent on both the cost and the duration of construction.

The economics affected by structural floor systems are more distinct athigher story. As the story increases, the construction cost of floor system is accumulated linearly,while the cost of lateral resisting system is increased geometrically.

The purpose of this study is to investigate the economical effects of super tall buildings through application of optimum structural floor systems. Three types of structural systems(RC beam-column frame, RC flat plate frame, and Steel frame) of super tall buildings having 60-stories are considered in this study and compared to RC flat plate slab with other systems. Analytical result shows that RC flat plate slab using lightweight concrete ismost effective in both the cost and the duration of construction.

1. Introduction

The framework cost to the total construction cost would increase in tall buildings as the story increases. Fig.1. shows the construction cost of framework in the super tall buildings according to stories. The cost of floor construction is accumulated constantly with no relation to story number, while the cost of column and lateral resisting structure are increased rapidly in accordance with higher story number. And the floor construction also has the critical path in the duration of construction. On the basis of these, it would be mentioned that the floor system is the most dominant factor to both the cost and the duration in evaluation of economic considerations. Thus, the selection of floor system is one of very important factors for the tall building feasibility.

In the conventional construction of reinforced concrete(RC), the formwork construction, especially the formwork labor, has the highest portion of total framework cost ; about 50% as shown in Fig.2. And, as the formwork of floor construction has the most portion of total formwork in tall building construction, saving cost of formwork is to saving both cost and duration of construction.

This study presents a case study on the economics of tall buildings having 60-stories for the economic evaluation in accordance with different floor systems. Three types of the structural systems will be considered in this case study - RC-beam and slab, RC-flat plate slab, and Steel-composite slab structure.

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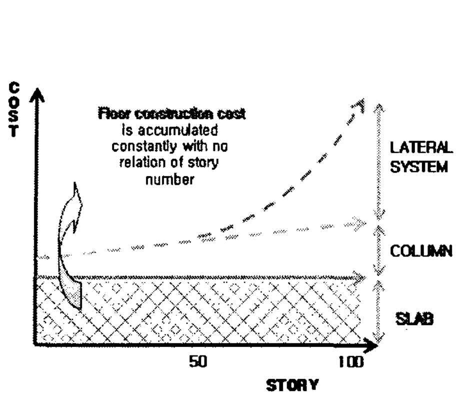


Fig. 1 Construction Cost of Framework

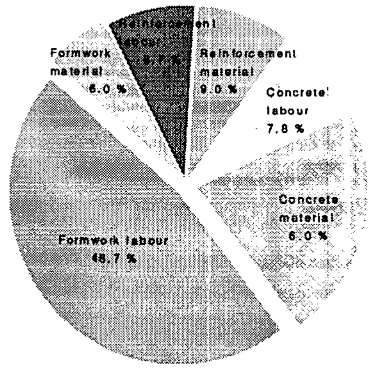
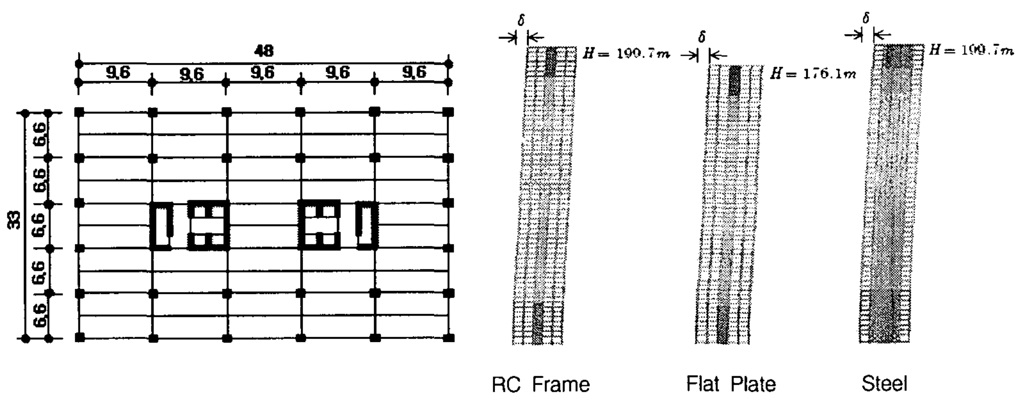


Fig. 2 Construction Cost Proportion
Example in RC Framework

2. Design model

Three types of structural systems(①RC beam-column frame, ②RC flat plate frame, and ③Steel frame) are considered in this analytical study. These are consisted of 60-stories office buildings with one outrigger floor at the 0.455H, which recommended by Taranath, from the top and story heights are 3.3m in system ① and ③ and 2.9m in system ②. Each system is compared with the alternative case using lightweight concrete(unit weight : 1.8 t/m^3) for evaluating the effects of reduced dead load.

Fig.3(a) shows the typical floor plan and Fig.3(b) shows the structural analysis model and the limit of maximum lateral displacement (H/500) of this case study. All design models are designed by Korean Design Codes. Structural analysis and design programs used are MIDAS GENw(ver.5.3.0), MIDAS SDSw(ver.5.3.0), and MIDAS SET-Art(ver.2.2.2). Concrete compressive strengths used are ranged from 24 N/mm^2 to 80 N/mm^2 and higher strength concrete are used in low rise columns and shear walls.



(a) Typical floor plan (b) Case study model

Fig. 3 Case study model(60 stories)

3. Economic Analysis

Economic analysis was conducted to evaluate the economics of different structural floor systems. Unit costs of construction materials and labor are presented in Table 1. All listed unit costs are referenced as domestic standard cost of construction in spring 2004. The exchange rate considered is 1,153won per 1US$. The results of these analysis are summarized in the Table 2. From the Table 2, the amounts of construction materials(concrete, form, rebar et al.), cost and duration of framework are compared to one another. Comparative graphs are also shown in the Fig.3(a).

3.1 Amount of materials

For convenience of explanation, call the RC beam-column-slab system, RC flat plate slab system, and Steel composite slab system to system(1), system(2), and system(3) as follows, respectively.

The amounts of concrete are 44,675m^3, 61,537m^3, and 25,135m^3 of system(1), system(2), and system (3), respectively. Due to the increase of slab thickness in the flat plate system, the amount of concrete in system(2) is calculated higher than system(1). And by replacing normal weight concrete to lightweight concrete the amounts of concrete are reduced down to 5.6%, 5.5%, and 3.8% of each system as shown in Table 2.

The amounts of form are 210,652m^2 and 145,590m^2 of system(1) and system(2), respectively. Due to the decrease of slab form area in the flat plate system as removal of beams, the required amount of form in system(2) is calculated 31% lower than system(1). And also reducing dead load by use of lightweight concrete led the amounts of form down to 2.4% and 1.7% of system (1) and system (2), as shown in Table 2.

The amounts of rebar are 5,687ton, 8,195ton, and 4,179ton of system(1), system(2), and system(3), respectively. Due to the increase of slab thickness in the flat plate system, the amount of rebar in system(2) is calculated higher than system(1). And by replacing normal weight concrete to lightweight concrete the amounts of rebar are reduced down to 1.0% and 19.0% of system(1) and system(2) as shown in Table 2. And the amount of steel frame is reduced down to 19.5% (3,818.5ton) in system(3).

3.2 Cost of construction

The cost of framework construction including basement is summarized in Table 2 according to the relative cost ratio of systems to each other. The construction costs of concrete are $2,993,500, $3,848,400, and $1,818,900 of system(1), system(2), and system(3), respectively. As the slab thickness increases in system(2), the construction cost of concrete is increased. The construction costs of rebar are $3,512,200, $5,060,300, and $1,566,100 of system(1), system(2), and system(3), respectively. As the slab thickness increases in system(2), the construction cost of rebar is also increased. The costs of formwork are $6,505,700 and $2,754,800of system(1) and system(2). As the formwork area decreases in system(2), the construction cost of form is distinctly decreased.

Fig.3(b) presents the relative proportion in the system(1) and system(2) in the framework. From the figure, it would be known that it could be cut down the portion of formwork cost, especially cost of formwork labor, as a results of applying system form in the flat plate slab.

Reducing dead load by use of lightweight concrete led the construction costs of framework cuts down $1,930,200(-15%), $299,500(-2%), and $2,075,800 (-11.5%) of system(1), system(2), and system(3), respectively. The effects of reducing dead load are most obvious in the Steel structure with high unit cost of material. Fig.3(a) shows the total framework costs of each system in accordance with specified construction.

Table 1. Unit cost considered in economic analysis

Classification	Material				Labor	
	Unit	Property	Cost (US$)	Note	Cost (US$)	
Rebar	ton	HD10	467.74		16.05	
		HD13	461.41			
		HD16 ~	457.07			
Concrete	m^3	25-24-18	50.22		5.29	
		25-30-18	55.47			
		25-40-18	68.34			
		25-50-18	73.72			
		25-60-18	95.90			
		19-80-18	173.46			
		25-L35-18	86.73			
Form	m^2	Wood Form	4.60		16.57	
		System Form (SKYDECK)	8.34	lease	8.03	
		Deck Plate	12.92	0.8T	3.90	
			24.28	1.6T		
Steel	ton	H-Steel	569.82		Erection	47.70
					Bolt	28.62
					Stud	0.87

Table 2. Comparison of Amount, Cost, and Duration

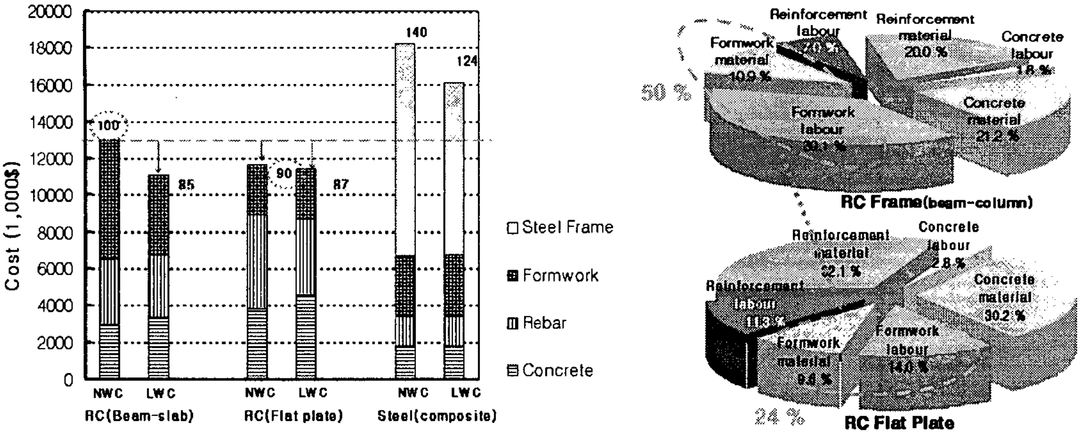
구 분		RC		Flat Plate		Steel	
		NC	LC	NC	LC	NC	LC
Amount (%)	Concrete	100	94	138	130	59	56
		ref.	-6	+38	+30	-41	-44
	Form	100	98	69	68	59	59
		ref.	-2	-31	-32	-41	-41
	Rebar	100	99	144	117	73	73
		ref.	-1	+44	+17	-27	-27
	Steel					100	80
						ref.	-20
Cost (%)	Concrete	100	111	129	152	61	60
		ref.	+11	+29	+52	-39	-40
	Form	100	97	144	117	45	45
		ref.	-3	+44	+17	-55	-55
	Rebar	100	67	42	42	51	52
		ref.	-33	-58	-58	-49	-48
	Steel					100	81
						ref.	-19
	Sum	100	85	90	87	140	124
	± Ratio	ref.	-15	-10	-13	+40	+24
Duration (day)	1 story	7		4		5	
	60 stories	420 (14Month)		240 (8Month)		300 (10Month)	
	± Ratio	ref.		-180 (-6Month)		-120 (-4Month)	

4. Conclusion

The framework cost of RC flat plate system is decreased to 90% of conventional RC beam and slab system. Additional merit of flat plate system is reducing story height to about 0.4m per story. This is the effect of reducing building height to 23.6m and equally about 7 stories.

Asthe effects of reducing dead load by replacing normal weight concrete(2.4t/m3) to lightweight concrete(1.8 t/m3), the costs of construction are cut down to 15% in the RC beam and slab system, 2% in the RC flat plate system, and 11.5% in the Steel structure system, respectively.

The duration of construction in the RC flat plate system could be reduced to 6 months in consideration of 4day to 7day cycle framework of RC flat plate system to conventional RC beam and slab system.



(a) Comparison of framework cost

(b) Effects of flat plate system

Fig. 3 Estimations of Economics

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