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Cost Comparison and Parametrical Investigation of the R/C Shear Wall Core of a Tall Building

Theodoros Chrysanidis, Ioannis Tegos
Department of Civil Engineering
Aristotle University of Thessaloniki
Thessaloniki, Greece

Vassilis Panoskaltsis
Department of Civil Engineering
Democritus University of Thrace
Xanthi, Greece

***Abstract*—This work analyzes a tall building using two different design methods. One is the preliminary design and the other is the final design. The structural system used for supporting the building is a widely used worldwide system of the type of a brace shear wall core system. The preliminary analysis takes place using hand calculations while the final analysis takes place using computer software suitable for static and dynamic analysis and design. After analysis and design have taken place for both methods (preliminary and detailed method), the calculation of the cost for the reinforced concrete part of the structural system takes place. The reinforced concrete part has to do basically with the shear wall core placed at the center of the tall building in question. A parametrical comparison of the cost of the reinforced concrete part of the structural system leads to useful conclusions.**

Keywords—parametrical; cost; comparison; tall; reinforced concrete

I. INTRODUCTION

Most of the flat buildings constructed around the world are buildings which have an average height of 4-5 storeys. However, there are special occasions that really tall buildings need to be constructed, e.g. in the case of office buildings for multinational companies, multi-storey flat buildings, etc.. In these cases, a typical structural system which is widely used along the world is the type of a braced shear wall core system. This system is chosen by many consultant engineers because of the great advantages which possesses. One of the most important advantages of this kind of system is its inherent ability to resist horizontal loads due to seismic action or wind pressure loads. This inherent ability of the structural system in question is owed to the fact that this system has increased stiffness and rigidity compared to other typical systems like outrigger-megacolumn system. The high level of stiffness and rigidity leading to an almost excellent behavior against lateral forces is owed basically to the placement of a shear wall core usually at the center of such a structural system. Reinforced concrete shear walls and shear wall cores are well-known for their aforementioned abilities and their large capacities against both horizontal and vertical loads [1-14]. Preliminary design is very useful in these cases because it can quickly estimate a first number for the cost of such a system. Final and detailed design gives a more accurate approach to the final construction cost of the shear wall core but it requires more analysis and design time.

The work herein analyzes the tall building in question for both design methods; preliminary and final method. Afterwards, it estimates the final construction cost for the main member of this type of system, which is the central shear wall core. As it is obvious, because of the fact that the construction material of this core is reinforced concrete, the construction cost calculation takes place for the reinforced concrete material. This calculation has basically to do for the concrete part which is more expensive compared to the reinforcement bars, not essentially because of the net prices of these two materials but because of the quantities used in the construction of the central core. Needless to say, that the quantity used for the concrete is much higher than the steel reinforcement bars themselves. Finally, a comparison for the construction cost of the shear wall for both design methods takes place. It becomes obvious from the present research that the quantity of concrete is one crucial cost parameter influencing the total building construction cost. Useful conclusions derive given in the final part of this work.

II. GENERAL CHARACTERISTICS OF THE STRUCTURAL SYSTEM

A. *Specifications*

General specifications of the building in question are the following:

- $200\ \text{m} \le \text{Height} \le 220\ \text{m}$
- $\text{Volume} \le 400{,}000\ \text{m}^3$
- Increased storey height only for the ground floor
- Equal storey height for the rest of the floors

B. *Elevation Geometrical Characteristics*

Two more specifications are chosen for the storey height:

- Increased ground floor height
- Equal typical floor height

Thus, the chosen storey heights are:

- 6m (Ground floor)
- 4.45m (Typical floor)

Thus, the total building height is:

$$\text{Building height} = 6 + 48\text{x}4.45 = \underline{219.60\ \text{m}}$$

C. *Plan Geometrical Characteristics*

The building area is:

$$\left.\begin{array}{l}\text{Volume} \le 400{,}000\text{m}^3 \\ \text{Volume} = \text{Height} \times \text{Area}\end{array}\right\} \Rightarrow 219.6 \times \text{Area} \le 400000 \Rightarrow$$

$$\Rightarrow \text{Area} \le 1821\ \text{m}^2$$

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A plan area of 42×42 m is chosen:

$A = 42 \times 42 = 1764\ m^2 \leq 1821\ m^2 \rightarrow$ OK

D. Dimensions for the Shear Wall Core

The plan dimensions of the central shear wall core are chosen in such way in order to occupy 20% of the total plan area of the building. Thus, the plan dimensions of the shear wall core are:

$A_{core} = 18 \times 18\ m = 324\ m^2 \geq 20\% \times A = 0.20 \cdot (42 \cdot 42) = 352.8\ m^2$

III. DESCRIPTION OF THE BRACED SHEAR WALL CORE SYSTEM

A. General

The braced shear wall core system is constituted basically by: (a) The shear wall core at its center, (b) The columns at the perimeter and (c) The beams (primary or secondary). The materials for its type of member are given in Table 1.

TABLE I. IIITYPE AND MATERIAL OF STRUCTURAL SYSTEM'S MEMBERS

TYPE AND MATERIALS OF STRUCTURAL SYSTEM MEMBERS			
	Shear wall core	Columns	Beams
Type	Reinforced concrete	Composite	Composite
Material	High-strength concrete (C90/105)	Normal weight concrete (C50/60)	Lightweight concrete (C40/50)

B. Load path

As it has been previously stated, the braced shear wall core system is based mainly on the shear wall core to carry the horizontal loads due to wind or seismic actions. The contribution of other members, like the perimetrical columns, to the resistance of the lateral loads is minimal. Vertical loads are carried typically by the composite beams (primary or secondary) and brought down to the foundation and eventually to the ground through the composite columns and the shear wall core.

IV. STRUCTURAL SYSTEM ANALYSIS AND DESIGN

A. General

Preliminary design is done using hand calculations [15]. Final design of the structural system takes place using personal computer static and dynamic analysis software (SAP 2000). Eurocodes [16-20] and other codes [21-22] are used for the design of the building.

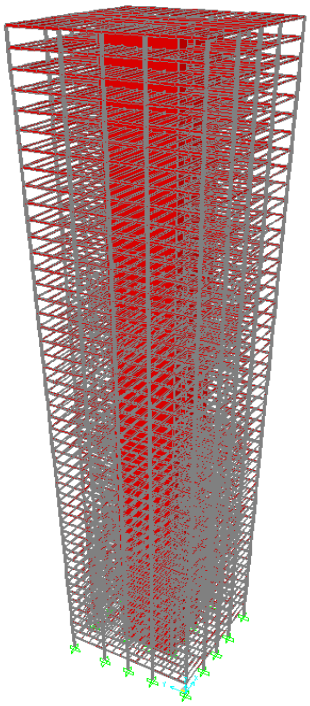

Fig. 1. 3D Model of the building.

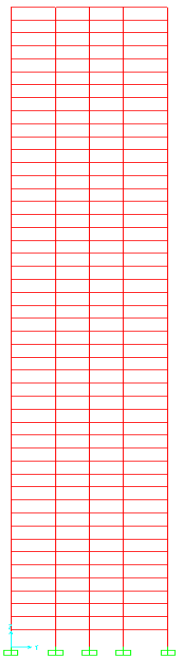

Fig. 2. Side view of the building.

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V. COST CALCULATION AND COMPARISON

It has to be noted the fact that cost calculations are given in terms of weight. This is done because any price given or used would be definitely indicative. It is well-known that prices change from place to place depending on the time of construction. Weights are something objective world-wide and they definitely do not change based on place or time. Table 2 shows the construction cost calculation which, as it has been previously stated and for the reasons given, it takes place for the concrete material of the shear wall core. Cost comparisons between the two design methods (preliminary and detailed) are given in the same Table. Section members have resulted from the design of the building either preliminary or final.

A. Concrete Construction Cost of Shear Wall Core

B. Model

The three dimensional model of the building used for the detailed design is shown in Figures 1 and 2.

TABLE II. CONCRETE VCOST OF SHEAR WALL CORE

CONCRETE COST CALCULATION OF SHEAR WALL		
Design type	**Type**	Volume (m^3)
Preliminary	High-strength concrete C90/105	10046.70
Final	High-strength concrete C90/105	7434.96

Thus, the difference of the shear wall concrete cost for the two design methods (preliminary and final) is:

$$\text{Difference}=\frac{W_{\text{Final}}-W_{\text{Preliminary}}}{W_{\text{Final}}}=\frac{7434.96-10046.70}{7434.96}\Rightarrow$$

$$\Rightarrow \text{Difference}=-35.13\%$$

VI. ANALYSIS OF RESULTS

Analysis of the cost comparison results and investigation of their parameters gives the following:

- Preliminary design of the braced shear wall core system overestimates the concrete construction cost of the shear wall core by almost 35%.
- It can be easily understood that a difference of such size is a considerable difference since it is a difference higher than 10%. In other words, it cannot be considered an acceptable, even in terms of preliminary design.
- Investigating the cost influential parameters, someone can notice that the concrete cost is a significant cost. Especially, if someone considers the whole concrete cost of the whole building (meaning concrete cost of composite beams, composite columns and composite slabs).
- Of course, it is considered necessary the continuation of the present research to other parameters, too.

VII. CONCLUSIONS

Parametrical comparison of the concrete construction cost for the shear wall core and analysis results result to the following conclusions:

1. As far as the concrete cost of the shear wall is concerned, preliminary results overestimate it.
2. Nevertheless, the usefulness of preliminary design remains in terms of a quick estimation of cost or member sections without the need for a time-consuming modelization or computer analysis of a building.
3. Certainly, concrete cost is not a negligible or trivial cost in buildings of such size even if they possess steel elements, too.
4. Tall constructions demand high costs and preliminary design can be very helpful for consultant engineers in order to be able to reduce them.
5. More research is needed and more parameters in other cases need to be studied in order for final and more concise conclusions to be stated.

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