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Comparative Structural Design of a Prototype Villa Unit in Mass Housing Project

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***Abstract*:**

If we think a little about the cost of residential units, we find that the cost of the structural structure is 40-50% of the total cost of the construction phase of the residential unit. This high ratio makes it possible to study economic alternatives in the construction process as necessary and inevitable to reduce the cost of housing in general. Since most projects are constructed with the frame system, it has been taken as the reference system and compared to the cast in situ load bearing walls system and the precast autoclaved aerated concrete panels system (AAC). Comparison was based on the cost, time of construction, and thermal insulation capacity. As thus, it was found that the cast in situ bearing wall system and the precast panel system are much more suitable in house massing projects.

Keywords-(AAC); Autoclaved Aerated Concrete

I. INTRODUCTION

A. *Introduction*

The development of methods of achieving economic housing is one of the most important priorities of the present because it has an important role in achieving satisfaction and adequate shelter, especially for people with limited income.

At present, providing adequate housing that meets the needs of the family is one of the most important priorities for our good government and Vision 2030.

B. *Problem statement*

If we think a little about the cost of residential units, we find that the cost of the structural system is 40-50% of the total cost of the construction phase of the residential unit. This high ratio makes it possible to study economic alternatives in the construction process is necessary and inevitable to reduce the cost of housing in general. Therefore, the most important reasons that encouraged us to choose this subject are the following points:

- The desire to provide a low-cost housing to be affordable for low-income people.
- Create a structural system that reduces the cost of buildings without compromising the durability, safety and function of the building.
- Contribution and scientific participation in finding a solution to one of the national problems.

C. *Research Objectives*

The main objective of this research is to compare between the cost and time for three different structural systems: frame system, bearing walls system and panel precast system; for a residential villa. All systems must provide for the needed thermal isolation weather through the structural units or through the possibility to use external insulation.

This main objective is divide into the following three sub-objectives:

1. Specify the time required for implementation.

2. Determining the cost difference for different structural systems.

3. Investigate provision for thermal insulation.

D. Study significance

The significance of this study is not limited to the chosen studied residential villa, rather, it extends to all other types of buildings by which the study would indicate how to select a preferable type structural design for any building based on cost/economic evaluation, time and through the consideration of different factors.

Furthermore, this study may highlight on the advantages and disadvantage of the utilization of any of the investigated structural systems in terms of their capacity, strength, durability, fire resistance, energy efficiency and the environmental implications as well as its main tenability.

II. LITERATURE REVIEW

Structure refers to a system shaped by the interconnection of basic structural elements built to transfer forces and to securely withstand the loads (live, dead, lateral loads, etc.) applied on it in addition to prevent failures and collapsing of it. A structure supports the building by utilizing of a framed arrangement known as structural members (Shabbar, Noordin, Dawood & Sulieman, 2010). There are two fundamental steps for the construction of a building: structural analysis and structural design. The structural analysis represents a process of prediction and forecasting of the performance of a given structure under specific applied loads and other outside effects, for example, temperature changes and support movements (Ajema & Abeyo, 2017).

III. METHODOLOGY

A. Introduction

This chapter reviews the methods that used to analysis and structural design of a small villa that can be used as a model for a major project. In addition, it provides a guideline to compare the designed structural system include the feasibility evaluation criteria.

B. Research Methodology

Residential villa was chose as a case study, to be utilize in the analytical cost and time comparison between the three previous mentioned structural systems. The villa has a total area of (250) m2 and composed of two floors each of them has an area of (125) m2.

The villa's floors and foundation will be analyze and designed structurally utilizing SAFE program, the columns and walls will be analyze and designed structurally utilizing ETABS program because of their efficiency in obtaining accurate values and easiness of use.

This structural analysis and design are conducted separately for each different structural systems (frame system, bearing walls system "casting in situ" and the precast autoclaved aerated concrete panels system (AAC) in the same seismic zone and on the same Soil class.

C. Design Criteria

1) Applicable Codes

- Saudi Building Code for Loading and Forces SBC-301.
- Saudi Building Code for Soil and Foundations SBC-303.
- Saudi Building Code for Concrete Structures SBC-304.
- Saudi Building Code for Steel Structures SBC-306.
- Guide for Design and Construction with Autoclaved Aerated Concrete Panels ACI 523.4R-09.

2) Analysis and Design Software

Structural Analysis and Design: ETABS 2016, SAFE Programs and EXCEL sheets.

3) Specification of Materials

- Concrete unit weight = $24.5\ KN/m^2$
- Concrete grade (fc`=28 MPa) after 28 days for beams, floors and foundation.

- Concrete grade (fc`=30 MPa) after 28 days for columns & walls.
- Steel used is high strength (Fy =420 MPa)
- (AAC) Products unit weight = $6.5\ KN/m^3$
- (AAC) Elastic Modulus = $1.6\ GPa$

4) Loading

- Dead Loads(D.L) = 3 KN/m2 (from SBC).
- Live Loads(L.L) = 2 KN/m2 (from SBC).
- Lateral Loads as frame and bearing walls systems.

5) Load Combinations

All Possible Load combinations were used in accordance to SBC.

IV. MODELING, ANALYSIS AND DESIGN PROCEDURES

A. Introduction

Modeling is a very important process. It is not easy process. It needs high accuracy to be applied as required to get a more accurate result.

In this chapter, we will model and design all structural systems on Safe and Etabs programs.

B. Architectural drawings

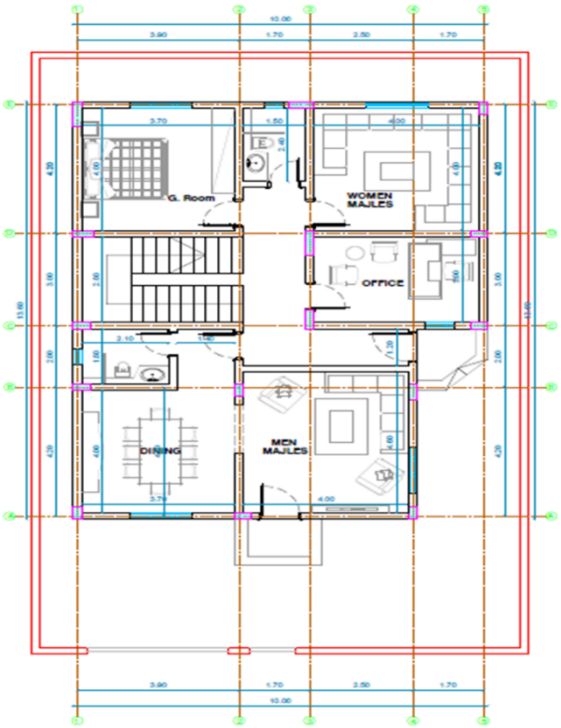


Fig. 1 1st floor plan

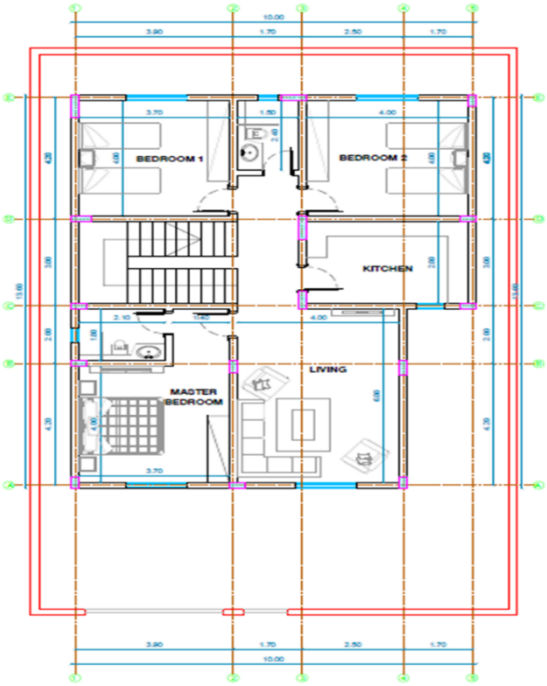


Fig. 2. 2nd floor plan

C. Modeling, Analysis and Design

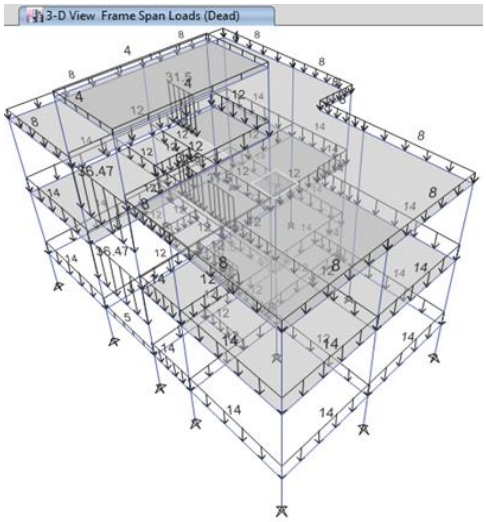


Fig. 3. Frame system.

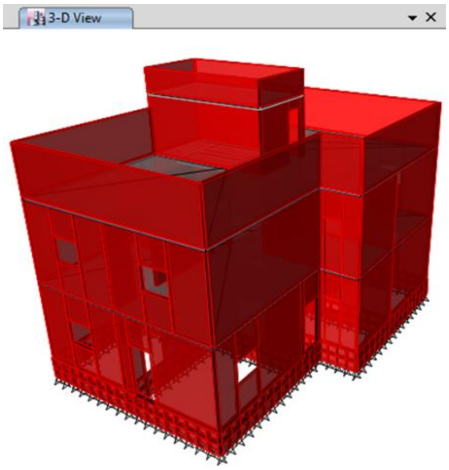


Fig. 4. Bearing wall system

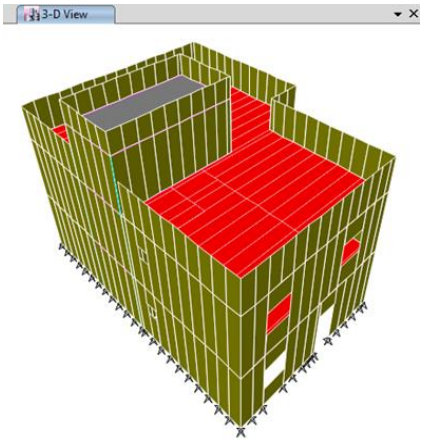


Fig. 5. Precast panel system

V. RESULT AND DISCUSSION

The table below explains the cost and time for housing project divided to units, 25 units, 50 units, 100 units and 200 units. In addition, shows the thermal resistance (R-value), thermal conductivity (U-value) and reduction rate of air conditioning system consumption.

TABLE I. EXPLAIN THE COST, THE TIME AND U-VALUE

Structural System	Units	Price of m^2	Estimated cost (SR)	Estimated Time (Days)	R-value m^2k/W	U-value W/m^2k	Reduction rate of air conditioning system consumption
Frame System	25	1040	7,020,000	235	3.28	0.30	72%
	50	1000	13,500,000	270			
	100	960	25,920,000	325			
	200	920	49,680,000	442			
Bearing Wall System "casting in situ"	25	1600	10,800,000	90	3.15	0.32	71%
	50	1200	16,200,000	115			
	100	1000	27,000,000	160			
	200	950	51,300,000	273			
Precast Wall Panel System (AAC)	25	950	6,412,500	60	2.95	0.34	70%
	50	900	12,150,000	85			
	100	870	23,490,000	130			
	200	830	44,820,000	236			

- The cost includes skeleton stage for villa 270 m^2 consisting of two floors.
- The cost also includes external plaster works and external paints for external wall and roof finishing.

- The prices are approximate and may vary from place to place and from contractor to another.

- $R_T = R_{si} + R + R_{se}$, $U = 1/R_T$, $R = d/\lambda$
- Frame system:

  $(R_T = 0.13 + \frac{0.2}{0.8} + \frac{0.1}{.035} + 0.04 = 3.28\ m^2k/W)$,

  $(U = \frac{1}{3.28} = 0.30\ W/m^2k)$.
- Bearing wall system " casting in situ":

  $(R_T = 0.13 + \frac{0.12}{1.6} + \frac{0.1}{.035} + 0.04 = 3.15\ m^2k/W)$,

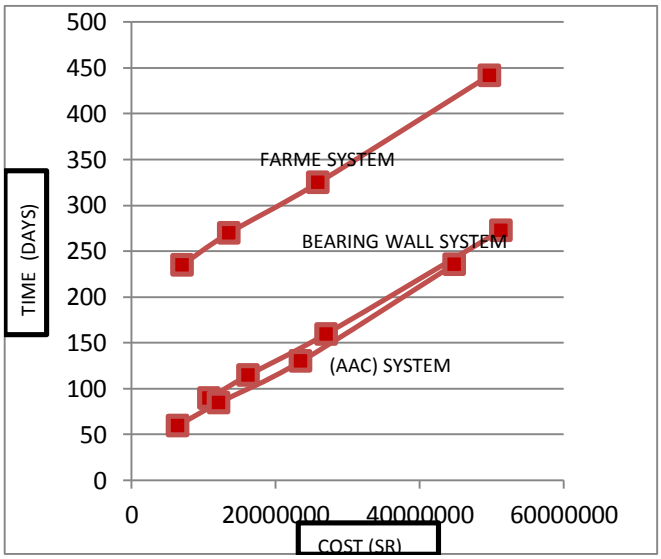
  $(U = \frac{1}{3.15} = 0.32\ W/m^2k)$
- Precast wall panel system(AAC):

  $(R_T = 0.13 + \frac{0.3}{0.108} + 0.04 = 2.95\ m^2k/W)$,

  $(U = \frac{1}{2.95} = 0.34\ W/m^2k)$

The graph below shows the results the relationship between all the systems presented in the research, when the points refer to divided units 25 units,50 units,100 units and 200 units.

Fig. 6. The relationship between cost & time



VI. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The cost of structural elements comprimise of approximatly 50% of the construction total cost at reseedntial buildings .

In this research project, a comparison was based on the cost, time of construction, and thermal insulation capacity for three selected structural systems.

As thus, it was found that the cast in situ bearing wall system and the precast panel system (AAC) are much more suitable in house massing projects.

B. Recommendations

We recommend using the cast in situ bearing wall system and the precast panel system (AAC) for a prototype villa unit in mass housing project.

VII. REFERENCES

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