



## **The use of modern materials in Light weighting buildings and its effects on seismic behavior**

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### **ABSTRACT**

With the advancement of technology and entry into the era of new materials production, using them has widely increased in construction industry and today, using modern materials is customary in most places of the world. One of the advantages of modern materials is their light weight compared to traditional materials. Reducing the overall weight of the building affects the weight and dimensions of structural members and accordingly, it will influence the seismic behavior of building. This study is aimed to investigate the effects of using such materials in light weighting buildings and its seismic behavior. For this, two buildings with the same and regular plan and different number of floors (5 and 10 floors) and seismic system (moment frame and braced frame) were modeled and analyzed by ETABS V.13 software and finally the results were compared and the effects of using modern materials on structural parameters of building were examined.

**Key words:** modern materials, light weighting, improvement, lightweight roof

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### **INTRODUCTION**

Iran plateau is one of the seismic areas in the world and in the last half century, major earthquakes have occurred in Iran and most of the damages have been related to the buildings which were constructed through unprincipled method. The results of field studies show that the most important factors causing damages are unfamiliarity with the correct construction culture and their financial weakness in proper implementation. Using thick walls and roof and increased mass caused by it will result in financial threats and casualties during moderate earthquakes (Taregh, 2002).

In general, many factors such as site conditions, designing, construction quality, execution, maintenance and repair conditions impact on the performance of structure during earthquake. If high quality materials are used and technical notes are observed in execution, vulnerability to natural disasters such as earthquakes will be less. Such buildings can be repaired spending not so much cost and exploited again. So, to provide the useful life of structures at the predicted time, observing the issues of designing, execution and selecting standard material are inevitable. In terms of construction materials, physical and mechanical properties of used materials, compatibility with the environment and quality of execution are the most important factors affecting the behavior of materials during earthquake. In terms of construction materials, Weaknesses and failures of buildings are caused by mentioned factors and unfortunately, these shortcomings can be seen in the majority of conventional constructions in Iran.

#### **2- Materials and seismic performance of buildings**

Earthquake force increases with building mass and thus, it leads to designing more resistant buildings with larger dimensions of members with a higher cost. So, one of the most effective ways to reduce the cost of construction is to reduce the mass and as a result, the forces (gravity and lateral) exerted on building (Razaghi, 1999).

In an overview, it can be said that lowering the weight of building includes dead loads on all structural and non-structural elements. In Iran, in conventional buildings, the weight of non-structural elements such as the weight of flooring and finishing coat of roof and exterior and interior walls is more than the weight of structural elements such as the weight of beam and columns and roof coatings (Khaloo, 2002).

3- The properties of modelled building

1-3- Plan: in this study, the structures are steel. They are similar in terms of plan and they are regular in terms of regulations. The numbers of floors are considered 5 and 10. The plan is considered 12\*20 and the height of ground floors is 2.50 m and the height of other floors is 3.20 m.

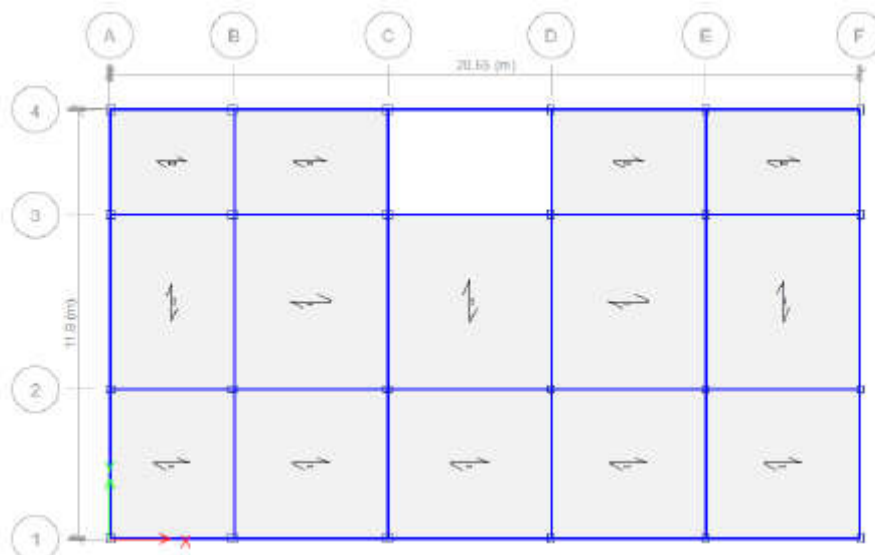


Figure 1. Dimensions considered for studied buildings

2-3- Loading: in order to examine the effects of using modern materials in lightweighting building and to compare them with traditional and conventional materials. Two different loadings are used: one of them for the base model with conventional materials and another one with modern materials. Their values are listed in Tables 1 and 2 in related part. It should be noted that living load of floors in all models is considered 200 kg/m<sup>3</sup> and in roof, it is considered 150 kg/m<sup>3</sup>. Also, the weight of partitions is widely applied on bed load and the load of side walls is directly applied on beams.

1-2-3- The materials used in the base model

Conventional materials often used in constructions are used for the base model. Block joist system with concrete blocks is used for roof, rock materials are used for flooring, plaster and soil, stucco and mosaics are used for finishing coat. Waterproof is used for insulating the roof. Clay bricks and conventional finishing coat details are used for interior walls and clay bricks are used for side walls and the facades is stonework. The amounts of loading details are listed in table 1.

Table1. Details of loading and loads applied on the structure using material for the base model

No.	Item	Description	Dead load (kg/m <sup>3</sup> )
1	Ceiling of roof	Block joist-structural concrete-flooring with rock materials-finishing (plaster and soil)- waterproof	50
2	Ceiling of floor	Block joist-structural concrete-flooring with rock materials-finishing (plaster and soil)- mosaic	600
3	Interior partition	Clay brick with sand-cement mortar- plaster and soil- 20 cm stucco	260
4	Side walls	Clay brick with sand-cement mortar- stone façade- plaster and soil- stucco	260-325

2-2-3- Modern materials used in research model

For research model, modern materials which have recently used in constructions, are used. Kermit joist system and polystyrene blocks are used for roof. Foam concrete is used for flooring. Plaster is used for false ceiling and flooring is used for floor. 3D panel with conventional finishing details are used for interior wall. Composite plates are used for side walls. The amounts of loading details are listed in Table2.

Table2. Details of loading and loads applied on the structure using modern material for the research model

No.	Item	Description	Dead load (kg/m <sup>3</sup> )
1	Ceiling of roof	Block joist-structural concrete-flooring with foam	360

		concrete-plaster false ceiling - waterproof	
2	Ceiling of floor	Roofix system-structural concrete-flooring with foam concrete-plaster false ceiling- flooring	330
3	Interior partition	3D panel-stucco	30
4	Side walls	3D panel (armature network, thermal insulation-cement coatings)	110-130

Note: the weight of side walls is calculated as the load per meter according to having or not having openings and having or not having façade and then applied in software. The equivalent unit area load of partition is added to bed load.

3-3- structural system: in this study, for structural system, braced frame system is used in one direction and moment frame system is used in the other direction. This structural system is a common and conventional system used for construction and conventional buildings and it is used in this study to understand the effects of using modern materials better.

#### 4- Analysis and designing

In the study, ETABS V.13 software is used for analysis and designing in 3 dimensions. The members are also designed using this software and based on the results of analysis. Conventional sections which exist in software are used to design the buildings. According to the Code 2800, the data required for seismic design of building is entered into software and finally the weight of steel parts of the models and other required data are extracted from outputs after analyzing and designing. Finally the results of each analysis mode are examined and compared with each other.

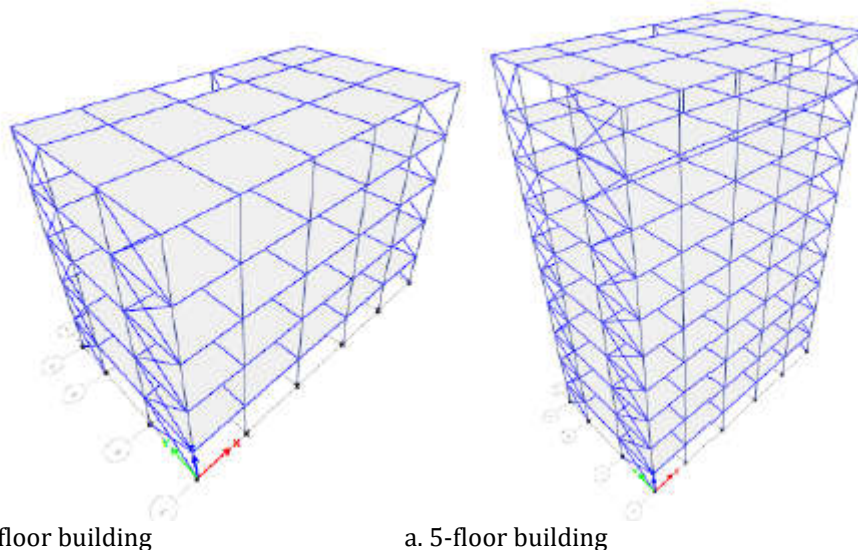


Figure 2. 3D models of studied buildings

#### 5- Data analysis and results

After performing initial calculation and calculating the details required for modelling, the buildings are modelled in the software and after designing and analyzing, desired results such as the total weight of building, the weight of used steel and first mode period of structure are extracted from the outputs which are listed in tables 3 and 4.

Table3. The results of 5-floor building analysis

Description	Base model	Research model	Percentage of difference
Total weight (tons)	1328.39	841.20	36%
Used steel (tons)	94.60	77.54	18.03%
First mode period (sec.)	1.669	1.663	0.35%

Table4. The results of 10-floor building analysis

Description	Base model	Research model	Percentage of difference
Total weight (tons)	2618.08	1713	34.6%

Used steel (tons)	260.20	207.85	20.1%
First mode period (sec.)	2.417	2.343	3.06%

## 6- Discussion

According to the values obtained from the analysis, it can be seen that even limited use of modern and lightweight materials significantly reduces the weight of structure and as a result, this will reduce the amount of used steel. The difference in the amount of used steel can be interesting for client economically in addition to reduction in the force applied on building during earthquake.

In analysis, first mode of structure period was calculated for two base model and the model with modern materials. The values show that given the reduction in the amount of used steel, no significant displacement is observed and it is still in the allowed range. Structure period considered in the models didn't change significantly and this change is 0.20% in 5-floor building and about 3% in 10-floor building. By comparing the results of two modeled 5-floor and 10-floor buildings, it can be observed that the reductions in the amount of steel used in both building are close to each other and in 5-floor building, it is about 18% due to the details of finishing coat and in 10-floor building, it is about 20%. This suggests that with the condition of using similar structural system, there is no relationships between the reduction in the weight of building as a result of using lighter materials and the number of floors and increase in building height and in terms of structure, the amount of required steel depends on the structural system and it is not affected by weight of materials. According to above and in order to compare the results and also in order to conclude on the topic, the valued obtained from research model analysis are shown in Chart 1.



Chart1. Comparison of reductions in different parameters as a result of using modern materials in research model

## CONCLUSION

In the study, the role and use of modern materials in building and their effects were studied. For this purpose, in order to examine the effects of using modern materials in building, two 5-floor and 10-floor buildings with structural system of braced frame in one direction and moment frame in another direction which are used in the majority of conventional buildings were considered. They were regular in terms of plan and height and for each of buildings, loading details with conventional materials and modern materials were considered and finally four models were prepared to be analyzed using software.

- The results of analysis suggest that using modern materials in conventional buildings reduces the total weight of building significantly. In the study and given loading details and structural system, it was about 35% and this reduces the forces exerted on the building in proportion to structure mass during earthquake. The reduction in mass has secondary effect on the reduction in casualties.
- As a result of reduction in structure weight, the amount of steel used in building decreases and this is important economically that according to current conventional market price and cost of implementation and overhead costs, 35000 Rials reduction in costs per one kilogram reduction in steel consumption can be considered and it is economically interesting for client.
- Reduction in steel of structure in the buildings with same structural system was not affected by the number of floors and in the condition of using same structural system, reduction nearly has a specific ratio. In present study, reductions in the amount of steel used in 5- and 10-floor building were equal.
- In buildings with different structural systems, reduction in the amount steel as a result of reduction in building weight will be different.

- Selecting proper structural system according to type and characteristics of building is very effective in maximum reduction in the amount of steel.
- Given the dominance of vertical load in braced frames, using modern and lightweighting materials in buildings with braced frame system can lead in maximum reduction in the amount of steel in both directions.
- According to the results, other parameters such as displacement and structure period are not significantly different in both models.
- Obviously, the approaches of using modern materials are different and depend on client's objectives and given specific conditions and objectives of any project, their role, effectiveness and applications can be different in terms of various aspects such as time of executive operation, efficiency, costs, improvement of structural and functional behavior and etc.

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