Performance of High Rise Concrete Building With And Without Flat Slab Against Fire

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Abstract- *Because of the freedom to design space, quicker construction time, architectural –functional and financial features, flat-slab building structures have significant benefits over typical slab-beam-column constructions. Flat-slab structural systems are substantially more flexible for lateral movement due to the lack of deep beams and shear walls. As a result, the system is more sensitive to seismic occurrences than a typical RC frame system. The results of the study for a few different types of building systems provided in the paper demonstrate that flat construction systems are the most efficient.*

With certain changes (beam design around the perimeter of the structure and/or RC walls), a slab system can be used. The research presented in this paper analytically examines the fire performance of flat plate buildings

Keywords- Flat-Slab, Fire Load

I. INTRODUCTION

Flat-slab systems possess many advantages in terms of architectural flexibility, use of space, easier formwork and shorter construction time. However the structural efficiency of the flat-slabs construction is hindered by its poor performance under earthquake loading. This undesirable behavior has originated from the insufficient lateral resistance due to the absence of deep beams or shear walls in the system. This gives rise to excessive deformations that cause damage in non-structural members even when subjected to earthquakes of moderate intensity. Flat plate slabs are economical since they have no beams and hence can reduce the floor height by 10-15%. Further the formwork is simpler and structure is elegant. Hence flat plate slab construction has been in practice in the west for a long time. However, the technology has seen large-scale use only in the last decade and is one of the rapidly developing technologies in the Indian building industry today. Material advances in concrete quality available for construction, improvement in quality of construction; easier design and numerical techniques has contributed to the rapid growth of the technology in India.

It is widely known that the slab-column connection is a critical component in the slab-column frame system as shown in Figure1. This is the region of slab immediately adjacent to the column that has to transmit large torsion, shear and bending moments between slab and column and is therefore susceptible to punching shear failure

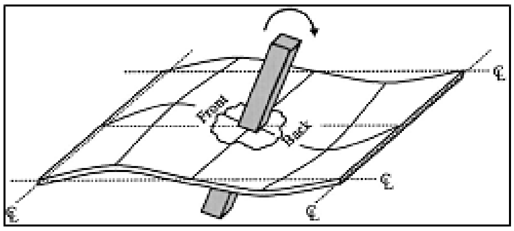


Fig 1: Behavior of Slab-Column Connection in Flat Slab Structure

1.1 Necessity

Flat slab construction is not a new concept in the Indian environment, but its widespread use especially with Post Tension (PT) application is fairly recent especially in high earthquake zones of the country. Since no comprehensive Indian standards exist, Structural Engineers working in high zones have been eyeing this type of design and construction with skepticism. There is an argument that the basis of flat slab design assumes an "equivalent frame" in orthogonal directions of the building so it may be considered as a frame for earthquake purposes too.

FIRE LOAD

- Classification - Fire load is the amount of heat in kilocalories which is liberated per square metre of floor area of a compartment by the combustion of the contents of the building and any combustible parts of the building itself. This amount of heat is used as the basis for classification of occupancies.
- The fire load is determined by multiplying the weight of all combustible materials by their calorific values and dividing the figure by the floor area under consideration.
- Different materials having the same weight and same calorific value may present different hazards on account

of their other properties, such as ease of ignition, speed of burning, and liberation of heat and fumes. Thus, some 'inateirals are more readily ignited than others, 1 again, some burn more rapidly than others, some materials when heated on fire liberate dangerous fumes, and some may readily cause ignition of other materials.

- The content of a building are rarely distributed uniformly over the whole floor area. ,From the fire protection point, it would be undesirable to have all combustible material concentrated on a fraction of the floor area, as the average taken over the whole area would not give a true representation of the actual conditions, and the resulting effects on the structure immediately surrounding would be out of all proportion to these expected on the basis of average fire load.

FIRE ZONES

Demarcation –

The city or area should, for the purpose of the code, be demarcated into, distinct zones, based on fire hazard inherent in the buildings and structures according to occupancy, which should be called the 'Fire Zones'.

Overlapping Fire Zones

- When any building is so situated that it extends to more than one fire zone, it should be deemed to be in the fire zone in which the major portion of the building or structure is situated.
- When any building is SO situated that it extends equally to more than one fire zone, it should be deemed to be in the fire zone having more hazardous occupancy buildings.

Temporary Buildings

- Temporary buildings should be permitted only in Fire Zones No. 1 and 2 as the case may be, according to the purpose for which these are to be used, by special permit from the authority for a limited period and subject to such conditions as may be imposed in the permit.
- Such buildings should be completely removed on the expiry of the period specified in the permit.

1.2 Objective

The present work consists of analysis of reinforced concrete building systems. The main focus is to compare the behavior and cost of two types of multistoried buildings, one is conventional building against fire i.e. slab, beam & column the other one is flat slab building. Example building of different number of storey's is analyzed and a comparative analysis is carried out. Difference between Flat Slab & Conventional Slab-Beam System

1.3 Outline of project

To accomplish the stated objectives, the report is presented in five chapters. Chapter 2 provides a comprehensive review of literature related to area of response of flat slab structure. In chapter 3 system development part is covered. In this model study, methods of analysis are discussed.

Fig 2 Shuttering of flat slab

Initial framing system formulation provides a detailed geometric description of the column spacing and overhang. Even though the architect provides this part of the design, the engineer should emphasize on the following

- Three continuous spans in each direction or have an overhang at least one-forth times adjacent span length in case of only two continuous spans. Typical panel must be rectangular
- The spans must be similar in length i.e. adjacent span in each direction must not differ in length by one-third

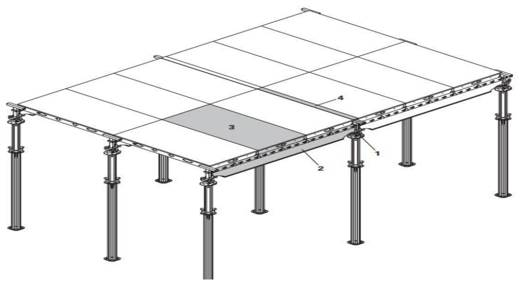


Fig 3 Flat slab

1.4 Main components

- Drophead SFK
- Main Beam SLT 225
- Panel SDP

- Cover Strip SAL

1.5 Factors Affecting Fire Resistance of RCC

Total of 2,500 citizens in India die per year as a result of fire-building occurrences. Fire causes thousands of deaths and loss of property. The fire incidents across the world have been seen which results in the large amount of damage to reinforced cement concrete framed structures. Column being one of the most important loads bearing member, the whole structure fails due to the failure of the columns. Any of the world's worst fire incidents

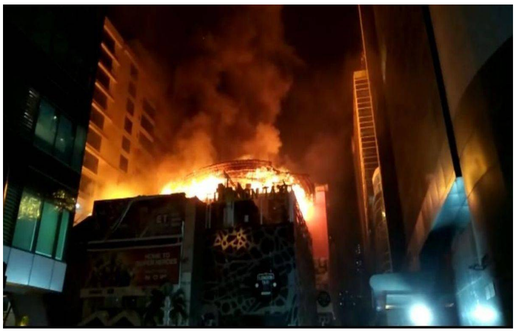


Fig 4 Mumbai's Kamala Mills fire (Dec 29, 2017)

II. REVIEW OF LITERATURE

2.1 General

The various literatures have been referred from journals, proceedings, books, websites etc. to understand the present status of project undertaken. From this literature, present work is formulated. These are explained in following section.

2.2 Literature Review

2.2.1 Earthquake Response of Flat Slab Building

Thomas et al. [1] studied the use of flat plate floor systems consisting of a conventional or post tensioned reinforced concrete slab-column system incorporating shear reinforcement within the slab-column connection region has become increasingly popular as lateral-force resisting systems in intermediate seismic zones and gravity systems in high seismic zones. Relatively sparse experimental data, however, are available to assess the dynamic responses of such systems, particularly for post-tensioned systems. To address these gaps, shake table tests of a conventional reinforced-concrete slab-column frame (RC specimen) and a post-tensioned slab-column frame (PT specimen) were conducted.

Ahmad J. Durrani [2] discussed system identification, three-dimensional linear dynamic analysis, and code-specified conventional equivalent static techniques used to evaluate the response of a nine-storey fiat-slab building during the Loma Prieta, California, earthquake of 1989. Four different models are used in the finite-element-based dynamic and static analyses.

EmaCoelho[3] conducted an experiments at the ELSA Laboratory, with the aim of assessing the seismic behaviour of flat-slab structures. The program consisted in pseudo-dynamic tests on a full-scale three storey RC flat-slab building structure, representative of flat-slab buildings in European seismic regions. The paper presents the experimental results obtained from the two tests, performed using Eurocode 8 compatible accelerograms of increasing intensity, together with the comparison with analytical evaluations. Some considerations are drawn regarding the deficiencies of the behaviour of these structures.

AltugErberik [4] studied Flat-slab RC buildings exhibit several advantages over conventional moment-resisting frames. However, the structural effectiveness of flat-slab construction is hindered by its alleged inferior performance under earthquake loading. Although flat-slab systems are widely used in earthquake prone regions of the world, fragility curves for this type of construction are not available in the literature. This study focuses on the derivation of such fragility curves using medium-rise flat-slab buildings with masonry infill walls.

Emad et al. [5] studied an appropriate FE model for determining the dynamic characteristics of a long-span flat concrete floor using natural frequency measurements. The Cardington concrete building was selected for the study because it represents a popular form of concrete construction. The natural frequencies of the floors were measured. Several FE models of the floor are considered and the models are refined based on the comparison between numerical predictions and the frequency measurements. It is concluded that a floor-column model provides the most appropriate representation of the actual structure.

Altug et al. [6] studied loss estimation analysis of flat-slab structures, a reinforced concrete structural form that exhibits behaviour and response patterns distinct from conventional moment frames. The fragility information obtained for flat-slab structures presented in a companion paper is implemented into HAZUS, the loss assessment software of the Federal Emergency Management Agency. The latter program includes many existing structural types, but does not deal with flat-slab structures. For implementation purposes, the fragility curves should be in a format consistent with fragilities already available in HAZUS. The latter objective is achieved by making use of the response statistics and employing the capacity spectrum method. After implementation, the earthquake losses in flat-slab buildings are predicted in comparison with the existing structural types in HAZUS by using different scenario earthquakes for a selected study region. The prediction results are consistent with the seismic response characteristics of the compared structural types.

Thomas et al. [7] In this paper analytical and experimental studies were undertaken to assess and improve modelling techniques for capturing the nonlinear behaviour of flat-plate systems using results from shake table tests of two, approximately one-third scale, two-storey reinforced concrete and post tensioned concrete slab–column frames. The modelling approach selected accounts for slab flexural yielding, slab flexural yielding due to unbalanced moment transfer, and loss of slab-to-column moment transfer capacity due to punching shear failure. For punching shear failure, a limit state model based on gravity shear ratio and lateral interstorey drift was implemented into a computational platform. Comparisons of measured and predicted responses indicate that the proposed model was capable of reproducing the experimental results well for an isolated connection test, as well as the two shake table test specimens

III. SYSTEM DEVELOPMENT

3.1 Introduction

Common practice of design and construction is to support the slabs by beams and support the beams by columns. This may be called as beam-slab construction. The beams reduce the available net clear ceiling height. Hence in warehouses, offices and public halls sometimes beams are avoided and slabs are directly supported by columns. These types of construction are aesthetically appealing also. These slabs which are directly supported by columns are called **Flat Slabs.** Fig. 3.1 shows a typical flat slab.

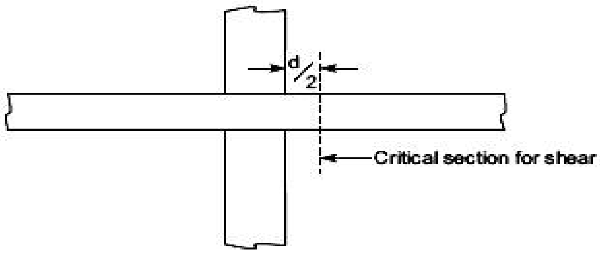


Fig 5 A Typical flat slab (without drop and column head)

The column head is sometimes widened so as to reduce the punching shear in the slab. The widened portions are called column heads. The column heads may be provided with any angle from the consideration of architecture but for the design, concrete in the portion at 45º on either side of vertical only is considered as effective for the design

3.2 Proportioning of Flat Slabs

IS 456-2000 [Clause 31.2] gives the following guidelines for proportioning.

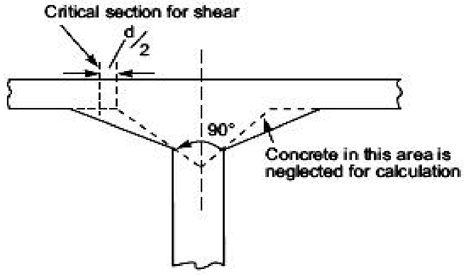


Fig 6 Slab without Drop and Column with Column Head

3.3 Analysis and Design of Flat Slab

design lateral force is based on the provisions of Indian Standard IS 1893 (Criteria for Earthquake Resistant Design of Structure), however due to non-clarity of IS1893 designer, in addition may have to use, other codes like UBC-2000 (Uniform Building Code) to design an effective lateral system. Based on these codes a common practice is to determine lateral force by either using static or a dynamic procedure.

Even though the slabs and columns are not required to share the lateral forces, these deform with rest of the structure. Under force, the concern is that under such deformations, the slab-column system should not lose its vertical load capacity.

3.4 Methods of Analysis of Building

Earthquakes are nature’s greatest hazards to life on this planet. The hazards imposed by earthquakes are unique in many respects, and consequently planning to mitigate earthquake hazards requires a unique engineering approach. An important distinction of the earthquake problem is that the hazard to life is associated almost entirely with manmade structure expect for earthquake triggered landslides, the only earthquake effect that causes extensive loss of life are collapse of bridges, buildings, dams, and other works of man

IV. PERFORMANCE ANALYSIS

4.1 General

The main objective of the analysis is to study the behavior of flat slab structure under seismic loading and compare the behavior with a conventional beam-column structure. The analysis is carried out in STAAD Pro 2007 software. To achieve the objective conventional R.C.C. structure and flat slab structure of different heights are modeled and analyzed for the different combinations of static loading. The comparison is made between the conventional R.C.C. structure ad flat slab structure situated in seismic zone IV & V.

4.2 Modeling of Building

For the study, two types of hypothetical RCC buildings are considered without infill. Mass of infill and slab is considered on beam element as uniformly applied load and floor load respectively. Stiffness of infill and slab is not considered.

The buildings which are used in this report is (G+5).The total dimension of building is 20m x 20m.The above building are analyzed for firstly with beam-column structure, and then these buildings are analyzed as flat slab buildings. Following are the designation of the six models used in this study.

Model 1 A 5 storey conventional R.C.C. structure (CS 5)
Model 2 A 5 storey flat slab R.C.C. structure (FS 5)

In this study, Slab is modeled by finite element approach using 441 elements. The Table 4.1 shows total number of nodes and line element used in all buildings for modeling. It clearly shows there is less number of elements in flat slab building due absence of beam but total number of nodes are same in both buildings.

Table 1:No. of Nodes and Line Element in Building

Structure	Nodes	Line Element
CS 5	1098	250
FS 5	1098	128

Above data and models are used for analysis of structure subjected to earthquake forces. Parameters like period, acceleration, displacement, base shear, deflection are studied for comparison purpose

Table 2: Geometrical Characteristics of the Analyzed Structural Systems

Type Of Structural System	Slab(mm)	Column (mm)	Beam(mm)
CS 2	150	230 x 750	290 x 600
FS 2	180	230 x 750	231 x 450

Table 3: Earthquake Force Data for Response Spectrum Analysis

Zone	IV,V
Response Reduction factor	5
Importance factor	1.5
Damping Ratio	0.05

For generating the earthquake forces in the analysis, joint weight has been provided as per appropriate column load at appropriate joints. Software for the analysis generates effective seismic forces as per the various factors defined above

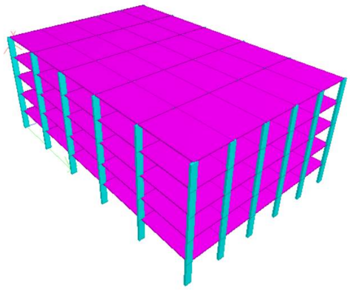


Fig 7 3 D View of 2 Storey Flat Slab Building

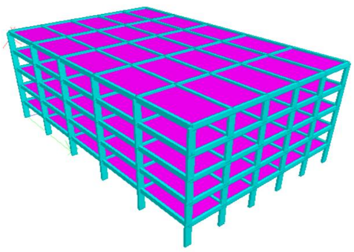


Fig 8 3 D View of 2 Storey Conventional Building

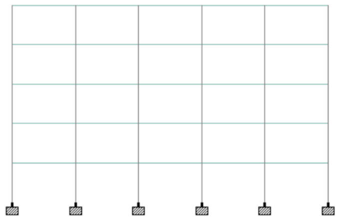
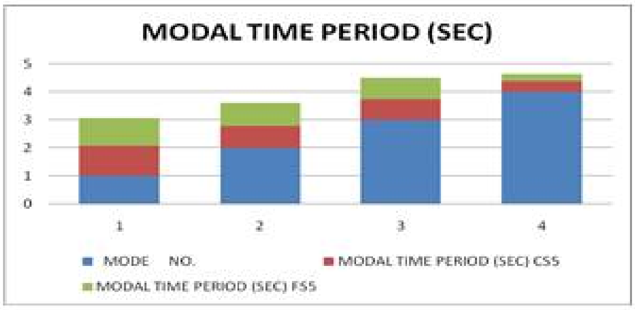


Fig 9 Elevation of G+5 Storey Building

Table 4 Values of Natural Time Period for Different Model

MODE NO.	MODAL TIME PERIOD (SEC)	
	CS5	FS5
1	1.07	0.99
2	0.78	0.84
3	0.73	0.77
4	0.37	0.28

Fig 10 Variation of Time Period for Different Mode



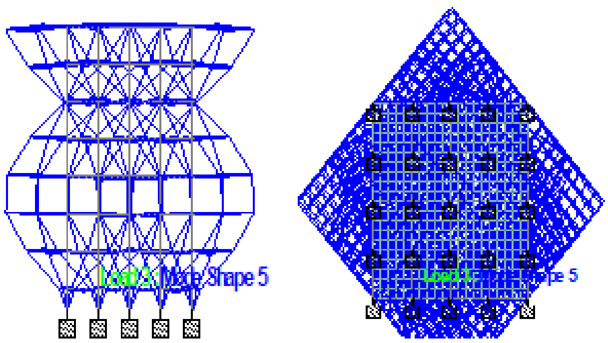


Fig 11 Mode 5 Conventional Building

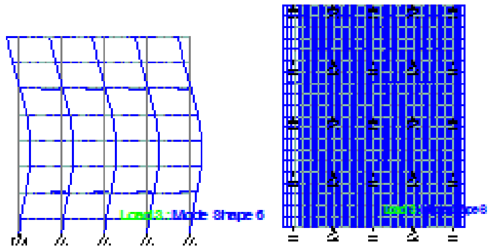


Fig 12 Mode 6 Flat Slab Building

4.3 Result and Discussion of Response Spectrum Analysis

1 Base shear

Two types of buildings are analyzed i.e. conventional beam-column building and building with flat slab for two different zones (IV&V) using code response spectrum. The maximum base shears for different structures by SRSS method are given in Table 6. For all the structures, base shear increases as the height increases. This increase in base shear is gradual up to 7th -storey, thereafter, it increases significantly. It is observed that magnitude of base shear is significantly affected by flat slab structure. This is due to the flexibility of flat slab structure.

Fig 13 Variation of Base Shear with no. of Storey

Table 5: Acceleration Values

Buildings	Without flat slab after fire resistance (m/s^2)	Flat slab Structure after fire resistance (m/s^2)
G+5	0.72345	0.6405

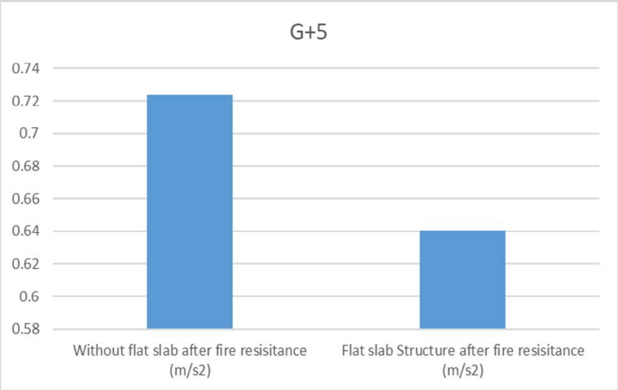
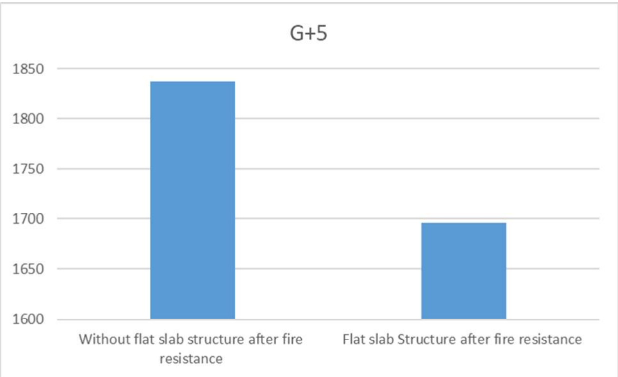


Table 6 : Base Shear Values

Buildings	Without flat slab structure after fire resistance	Flat slab Structure after fire resistance
G+5	1837.5	1695.75



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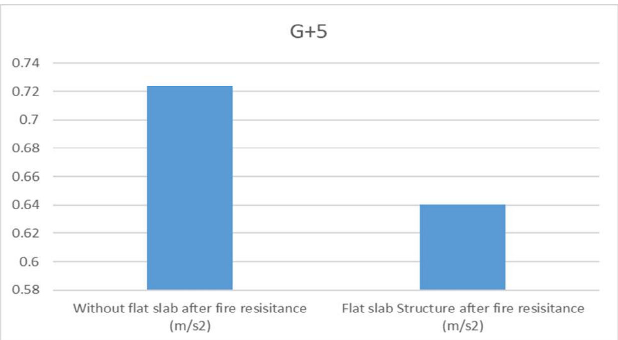

4.4 Axial force, shear force, moments

The maximum Axial Force, shear force & bending moment in all models are shown in Table. The governing load combination for design moment is 1.5[DL+EQX] moreover the governing load combination for design shear force is 1.5[DL+EQZ] .For the bending moment and shear force strength demand are severely higher for flat slab structures as compared to beam-column structure because forces in slab are distributed by beam to column in beam –column structure however in flat slab structure force are carried over from slab to column directly because of absences beam in flat slab structure.

Following observations are made

1) The bending moment is more in flat slab structure than beam-column structure.
2) The bending moment in exterior beams is more as compared to interior beams in beam-column structure.
3) Maximum moment occurs at top interior column for all structure.
4) Axial force is more in flat slab structure than beam-column structure.
5) Axial forces are remains same for both zone IV & V.
6) There is decrease of about 65-80% of shear force in beam-column structure than that in flat slab structure.

Table 5 Maximum Axial Forces for Different Models

		Axial Force (kN)			
Height of building (m)	No. of storey	Zone-IV		Zone-V	
		Conventional Structure	Flat Slab Structure	Conventional Structure	Flat Slab Structure
15	5	2564.21	2687.14	3485.10	3801.45

V. CONCLUSIONS

In this work a comparative study of conventional beam-column building and a flat slab building against fire is carried out. The main objective of study is to understand the behavior of flat slab buildings against fire. Based on this analytical study following conclusion can be drawn:

1. Although the acceleration in flat slab structures are reduced due to its flexibility, the storey drift increases significantly and are many times exceed the permissible limits specified by the code. This may make the flat slab structure unserviceable during earthquakes.
2. The natural time period increases as the height of building (No. of stories) increases, irrespective of type of building viz. conventional structure, flat slab structure.
3. In comparison with the conventional RCC building to flat slab building, the time period is more for flat slab building than conventional building.
4. For all the structure, base shear increases as the height increases.
5. Base shear of conventional RCC building is more than the flat slab building
6. Storey drift in building with flat slab construction is significantly more as compared to conventional RCC building. As result of this, additional moments are developed. Therefore, the column of such building should be designed by considering additional moment caused by the drift.
7. The moment in column of conventional RCC building is less than the flat slab RCC building.
8. The bending moments in the in the conventional RCC building are reduced by 30-60% as compared to the flat slab building.
9. Flat slab deflections do not have a significant reduction after subjected to 200°C and 600°C.
10. High temperatures will result in loss of strength both yield and ultimate strengths.
11. The compressive strength, modulus of elasticity and tensile strength decreased noticeably in all of the specimens with rising temperature.

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