



EFFECT OF HIGH STRENGTH CONCRETE COLUMNS ON THE STRUCTURAL BEHAVIOUR OF BUILDING FRAMES

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ABSTRACT

High strength concrete has been used in the lower story columns of high rise buildings owing to its qualities over normal strength concrete - in many countries. But, the full structural qualities of the HSC were unable to be used because of insufficient information regarding the structural behaviour of the material and its properties were not adequately addressed in building codes including EBCS. Analytical study was conducted at structure level to investigate the effect of using HSC column on the structural behaviour of regular models of medium to high rise frame buildings under seismic lateral load in addition to gravity loads. Concrete strength variations of C30 to C90MPa were applied on the columns of the frame models. The proposed properties of the HSC class were incorporated in the analysis and design of the columns.

1.0 INTRODUCTION:

In developing countries, the increasing reliance of employment on economic and social considerations is one of the reasons that lead to increasing rural-to-urban migration which in turn lead to increased demand on land use in large cities like Addis Ababa. Following this, higher rise structures are being constructed now than in the past. On the other hand, for the developed countries, the engineering challenge where by the two targets of boasting the longest bridge and the highest building have become serious considerations in the conceptual design of landmark projects is another stimulus for construction of high rise buildings. Thus, the need for higher buildings naturally leads to the conclusion that high strength construction materials will be increasingly used in the future. The

following three performance criteria lend weight to the argument for the use of high strength concrete (HSC) for such high rise buildings. Firstly, column sizes should be kept at manageable dimensions in order to make more effective use of floor areas, especially in the lower stories of high rise structures strength concrete economics rather appealing

1.1 DEFINITION AND DEVELOPMENT OF HSC:

Although high-strength concrete is often considered a relatively new material, its development has been gradual over many years. As the development continued, the definition of high-strength concrete has changed with time and geographical location due to lack of a standard criterion for the strength that is required to qualify as a high strength concrete. In the 1950s, concrete with a compressive strength of 34 MPa was considered high strength. In the 1960s, concrete with 41 and 52 MPa compressive strengths were used commercially. In the early 1970s, 62 MPa concrete was being produced.

The following typical classifications based on strength are observed in some literatures.

- Normal strength.....20-50MPa
- High strength..... 50-100MPa
- Ultra-high strength..... 100-150MPa
- Special strength >150MPa

1.2. GENERAL OBJECTIVE:

The objective of this thesis is to investigate the structural behaviour of medium to high rise frame building with reinforced HSC columns subjected to seismic lateral load in addition to gravity loads. In light of this, the variation of the different structural responses due to change in columns concrete strength for regular moment resisting building frames will be studied. This will provide data which determines the need for using HSC columns over NSC for medium to high rise buildings and the HSC will be given attention by structural designers. The obtained data which is related to structural responses will act as a supportive document for possible decision to be made on the need for awareness creation in using HSC column and increase confidence that it can be used economically for high rise building frames.

1.3 SCOPE OF THE STUDY:

This study is limited to analysis of moment resisting concrete frame buildings with number of story not less than ten which was believed to represent medium high rise buildings. Sample regular moment resisting frame buildings with rectangular horizontal layout will be modelled using structural analysis program ETABS. The buildings frame will be loaded and analysed based on EBCS 2, 1995, ACI building code and other relevant building code provisions. Concrete class variation will be applied on the columns of the frame. For different concrete strength of the columns, the same building frame will be analysed. Keeping all other design parameters constant except the columns cross section dimension, the effect of alteration in columns concrete strength on structural behaviour of the frames will be investigated. Because higher number of story dictates the use of other lateral load resisting system which is outside the scope of this thesis, the number of story is limited

to not greater than twenty five.. On the other hand, for the developed countries, the engineering challenge where by the two targets of boasting the longest bridge and the highest building have become serious considerations in the conceptual design of landmark projects is another stimulus for construction of high rise buildings. Thus, the need for higher buildings naturally leads to the conclusion that high strength construction materials will be increasingly used in the future. The following three performance criteria lend weight to the argument for the use of high strength concrete (HSC) for such high rise buildings.

1.4 STRUCTURAL DESIGN:

Considerations of HSC High-strength concretes have some characteristics and engineering properties that are different from those of normal strength concretes. The use of higher-strength concretes permits more efficient structural designs, allowing members to span longer distances, be smaller in cross section, and carry larger loads. The HSC members design are more likely to be controlled by serviceability and other practical design considerations instead of strength. As a result, special considerations may be required in the design of high-strength concrete structural members.

TABLE 1.1 STRUCTURAL DETAILS

| CONCRETE GRADES F_{cs} (MPA) | EQUIVALENT CYLINDRICAL STRENGTH OF CONCRETE F_c (MPA) | MOULUS OF ELSTICITY E_c (MPA) | MODULUS OF RUPTURE F_r (MPA) |
|--------------------------------|---------------------------------------------------------|---------------------------------|--------------------------------|
| 30 | 24 | 23,164.6 | 4.605 |
| 50 | 40 | 27,897.5 | 5.945 |
| 70 | 56 | 31,744.6 | 7.034 |
| 90 | 75 | 35652.043 | 8.141 |
| 100 | 83.33 | 37,207.254 | 8.581 |

1.5 HIGH RISE BUILDINGS:

The increasing reliance of employment on financial services is one of the reasons that lead to increasing rural-to-urban migration which in turn lead to increased demand on land use in large cities. Whereas in 1950 there were only 7 urban areas in the world with more than 5 million inhabitants, this number rose to 34 in 1980 and is expected to rise further to 60 by the year 2000.1 Consequently, more high rise structures are being constructed now than a decade or two ago. A secondary stimulus for construction of high rise buildings is that of production challenge, whereby the two targets of boasting the longest bridge and the highest building have become serious considerations in the conceptual design of landmark projects. The need for higher buildings naturally leads to the conclusion that high strength construction materials will be increasingly used in the future, in order to keep column sizes at manageable dimensions and to make more effective use of floor areas, especially in the lower storeys of high rise structures. Two other performance criteria lend weight to the argument for the use of high strength concrete (HSC). Increased wind and traffic vibration susceptibility dictates that the modulus of elasticity of the material should be as high as possible in order to limit small amplitude elastic displacements. Moreover, the need for rapid construction requires early age strength gain, a feature that may be offered readily by high strength concrete. The combined effect of the three abovementioned requirements renders high strength concrete economics rather appealing.

1.6 CHARACTERISTICS OF HIGH STRENGTH CONCRETE AND STEEL

The main economic advantages of high strength concrete are its higher strength per

unit cost, strength per unit weight and stiffness per unit cost. The unit price of concrete increases relatively less than the increase in available strength. This gives high strength concrete an economic edge in terms of strength per unit cost. Moreover, the unit weight of concrete only increases slightly with increasing compressive strength. This gives significant advantage in seismic areas, since earthquake forces are directly proportional to the weight of the structure. Additional stiffness due to the increase in modulus of elasticity leads to higher stiffness per unit weight and per unit cost for high strength concrete. Tests on the material level have indicated that unconfined high strength concrete has a near-linear ascending branch and a steep linear descending branch, as indicated.

non-ductile shape for the constitutive model representing the available high yield steel.

2. LITERATURE REVIEW

[1] ZARNIC AND TOMAZEVIC (1984)

He summarised the results of their experimental and analytical investigations into the seismic behaviour of masonry infilled RC frames. It was found that the infill began to crack at a lateral drift of approximately 0.2% and the system exhibited satisfactory behaviour up to a 2% drift. Small amounts of horizontal reinforcement of the infill were found to have little effect. Subsequently, experimental tests on seismic retrofit methods suitable for RC frames with masonry infill were performed. The repair methods consisted of epoxy grouting of cracks in the concrete frame and masonry infill elements plus strengthening of the masonry infill by reinforced concrete jacketing of the infill panel discussed.

[2] ACHINTYA ET AL (1991)

He presented the behaviour for brick in-filled reinforced concrete frames subjected to lateral load, through an experimental approach. The strength of mortar is found to have considerable influence on the lateral stiffness and strength of the in-filled frames. Frames tested with reinforced brick panel have shown insignificant improvement in failure strength. The stiffness of the in-filled frame decreases very rapidly after the initiation of cracks.

[3] YAW-JENG CHIOU ET AL (1999)

He has experimentally and analytically studied masonry in-filled frames with short column effects. The structural behaviour of the framed masonry wall subjected to in-plane monotonic loading showed that the partial filled masonry wall induces a short column effect and leads to a severe failure of the column.

3. METHODOLOGY:

3.1 DESIGN WIND SPEED (V_d)

The basic wind speed (V_b) for any site shall be obtained from and shall be modified to include the following effects to get design wind velocity at any height (V_d) for the chosen structure:

- Risk level;
- Terrain roughness, height and size of structure; and Local topography.

3.2 HEIGHT AND STRUCTURE SIZE FACTOR (K_s, FACTOR)

Terrain - Selection of terrain categories shall be made with due regard to the effect of obstructions which constitute the ground surface roughness. The terrain category used in the design of a structure may vary depending on the direction of wind under consideration. Wherever sufficient meteorological information is available about the nature of wind direction, the

orientation of any building or structure may be suitably planned.

3.3 WIND PRESSURES AND FORCES ON BUILDINGS/STRUCTURES:

The wind load on a building shall be calculated for:

- The building as a whole,
- Individual structural elements as roofs and walls, and
- Individual cladding units including glazing and their fixings.

Where,

A_h = horizontal acceleration spectrum

W = seismic weight of all the floors

3.4 DISTRIBUTION OF DESIGN FORCE

Vertical Distribution of Base Shear to Different Floor Level

The design base shear (V) shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^n W_j h_j^2}$$

3.5 MATERIALS QUANTITY AND COST ESTIMATION:

The quantity and cost comparison involves only the three main materials that are needed for reinforced concrete construction; concrete, reinforcing steel and formwork. On the premise that relatively less unit price than the increase in compressive strength of concrete, only comparison in terms of quantity has been done for columns concrete but for longitudinal reinforcing steel and columns concrete formwork, cost estimation were included. Concerning the cost, unit cost for the HSC is difficult to obtain since the use of HSC in building projects was not practiced in Ethiopia.

RESULT:

4.1 CONCRETE COLUMNS OF R C FRAME ANALYSIS

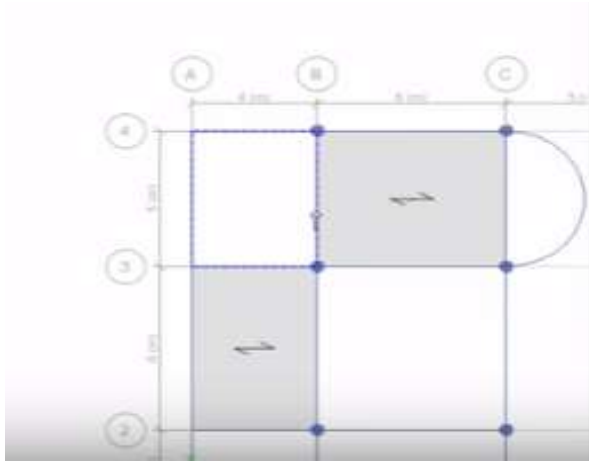


Fig 4.1 Plane view of the rc frame building



THE FIG 4.3 SHOWS THAT TORSIONAL MODE OF Y-DIRECTION IN RC BUILDING

TABLE 4.1 X- COORDINATE SYSTEM GRIDE DATA:

| Gride Id | X-Coordinate | Variable | Double loc |
|----------|--------------|----------|------------|
| A | 0 | yes | end |
| B | 8 | yes | end |

| | | | |
|---|----|-----|-----|
| C | 16 | yes | end |
| D | 24 | yes | end |

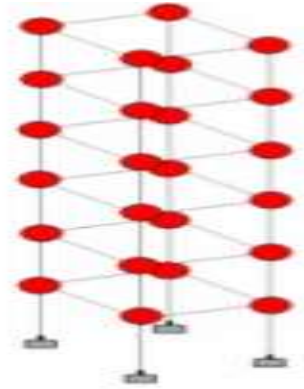
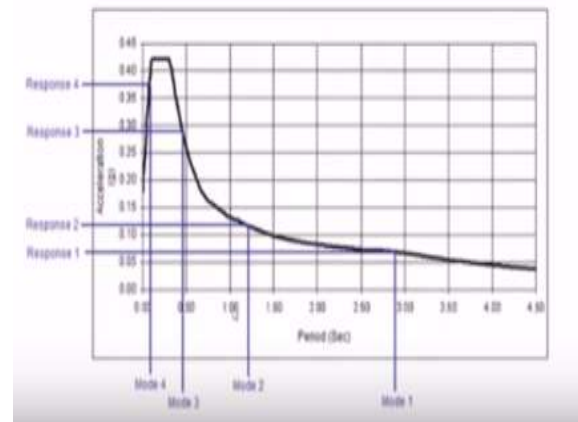


TABLE 4.2 Y- COORDINATE SYSTEM GRIDE DATA

| Gride Id | y-Coordinate | Variable | Double loc |
|----------|--------------|----------|------------|
| A | 0 | yes | start |
| B | 8 | yes | start |
| C | 16 | yes | start |
| D | 24 | yes | start |



Graph 4.1 SHOWS THAT SPECTRUM PLANE RESPONSE CURVE

TABLE 4.4 3D SURFACE AND SECTION CURVE DATA

| PORT | P kN | M2 Kn-m | M3 Kn-m |
|------|------------|---------|----------|
| 1 | 3673.4103 | 0 | 0 |
| 2 | 3673.4103 | 0 | 96.9555 |
| 3 | 3673.4103 | 0 | 184.2892 |
| 4 | 3107.2143 | 0 | 260.0866 |
| 5 | 2454.2197 | 0 | 312.2169 |
| 6 | 1726.1325 | 0 | 336.3083 |
| 7 | 1327.9464 | 0 | 364.7702 |
| 8 | 815.8471 | 0 | 364.7702 |
| 9 | 73.7255 | 0 | 249.5798 |
| 10 | -656.563 | 0 | 97.5814 |
| 11 | -1038.8826 | 0 | 0 |

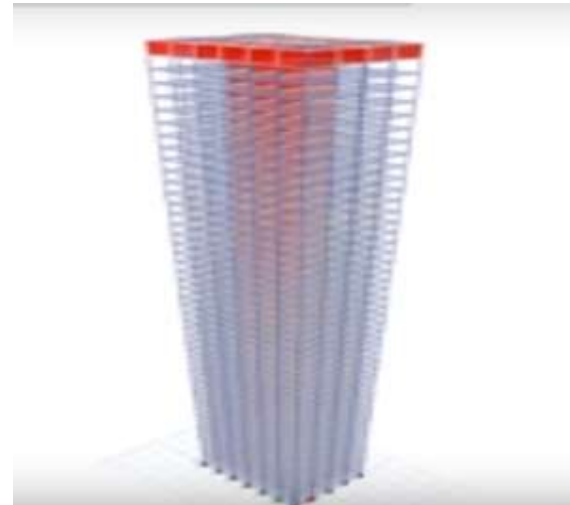
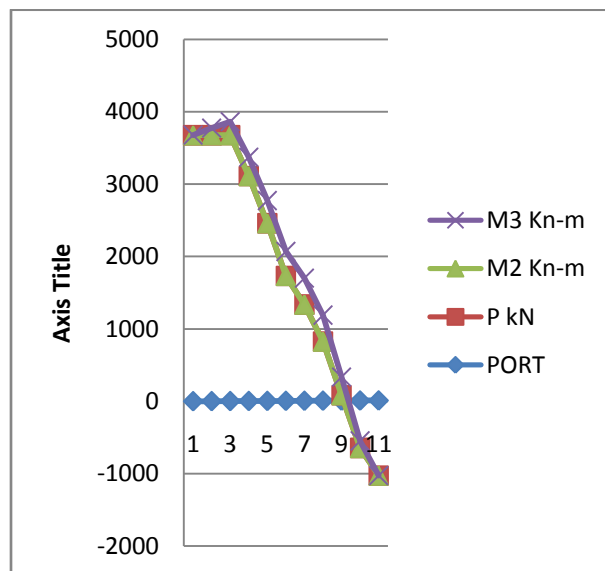


fig 4.3 shows that total displacement of the 3D view

CONCLUSIONS:

This study was conducted to investigate the effect of using HSC column on the structural behaviour of regular rectangular models of medium to high rise frame buildings subjected to seismic lateral load in addition to normal use gravity loads. The structural behaviours; level of ductility and inter-storey drifts were the main focus of the study. To clearly visualize the effect, the numbers of variables were limited to variation in columns concrete strength and optimizing the columns cross sectional dimensions. Columns longitudinal steel; yield strength, ratios and distributions were kept constant for all frame models to minimize their effect. In addition, square column sections were utilized for all the frame models. The properties of the HSC class were incorporated in the analysis and design of the columns based on the proposed equations by ACI and some researchers. The frames analysis was done using ETABS and columns were designed based on the EBCS-2 column design procedures using excel spread sheet.



GRAPH 4.2 3D SURFACE AND SECTION CURVE



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