

# Comparison of Seismic Behaviour of an RC Frame with Ordinary Brick and Fly-Ash Brick for Shear Wall and Base Isolation

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**Abstract-** Earthquake is the most important factor in design and construction of a structure as it produces collapse of structure, loss of life, property. From every past Earthquake it is clearly evident that they bring greater damage to all structures from residential buildings to tall structures, industrial buildings, power plants, etc and even has an effect to collapse them. So it is very important to clearly understand the seismic behaviour of structure to effectively design it. Even though the amount seismic load that can be occurring in a structure cannot be judged correctly in life time they have to be designed accordingly to withstand the load which has the most probability of occurring in its lifetime. Mainly all structures are of Reinforced Concrete construction and they are also heavily affected seismic loading. This thesis is an design and analysis of an RC framed structure with ordinary brick and fly ash brick for shear wall and base isolation for the purpose of an comparison of them. When compared to an steel building an RC structure will be more vulnerable to seismic forces. So an RC frame has been taken with ordinary brick and fly ash brick for shear wall and base isolation. RC frame with all said conditions are analysed and designed, which will give an comparison of each in seismic loading. Due to which the behaviour can be found.

**Keywords-** Earthquake, seismic behaviour, RC frame, fly ash brick, shear wall and base isolation.

## I. INTRODUCTION

Vibrations which are caused under the earth's surface generate waves which disturb the earth's surface, termed as earthquakes. It is known that earthquakes will not kill human but structures which are not constructed in considering the earthquake forces do. 60% of India lying in earthquake prone zone at which there is a need of increase of understanding the behaviour of earthquake, constructing and developing earthquake resistant structures.

All civil engineering structures are designed generally for dead, live, wind, seismic loads. Other loads are considered in special cases for special structures of the entire loads said seismic load is the main factor deciding the design of the structure. Seismic load will be acting on a lower probability case in entire life time of structure where as all other loads act throughout the life time of the structure.

Even though there is less probability it is the major factor. And generally the structure is not designed for maximum seismic force which will lead to very uneconomical sections. So they are designed in such a way that the structure will be damaged to a certain limit but will not collapse. So in every structures design the main thing is that it must be able to withstand the seismic loading acting on it. The main seismic provisions given in a structure are sheared wall, base isolation and reduction in self- weight.

So in this project the shear wall and base isolation for ordinary brick and fly-ash brick are analyzed for an RC frame.

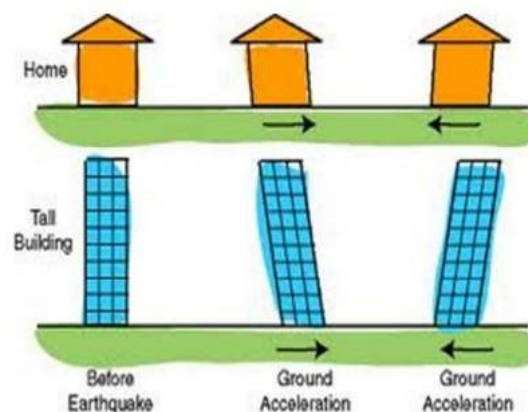


Fig 1. Flow chart of cluster based routing.

## II. SCOPE AND OBJECTIVE

An RC frame is taken here because almost all structure are made of Reinforced Concrete and Steel structures are constructed in less amount when compared to former. And another aspect is that the RC frames will be more vulnerable when compared to Steel Structures because: - Steel is eight times stronger in shear and tension than concrete and no quality control problem is there. Steel is

resilient and uniform in molecular level. So the RC frame is taken and analysed for dead, live, wind, seismic loading. And their seismic response is found. The structures are modelled, designed and analysed using STAAD.Pro software package. The seismic response mentioned above is natural time period, natural frequency, mode shapes of the structure. The above said are based on seismic behaviour of a structure 4 so they can be used to represent an behaviour for comparing different configurations taken into considerations. And all the structural members (beam, column, slab, and footing) are analysed and designed according to respective codes.

### III. RELATED WORKS

#### 1. Role of Fly-Ash Bricks in Construction: K. Srikanth Reddy:

Fly ash is a fused residue of clay minerals present in coal. The high temperature generated when coal burns in thermal power plants, transforms the clay minerals in coal powder into a variety of fused fine particles of mainly aluminium silicate composition. Pulverized fuel ash commonly known as fly ash. It is a useful byproduct from thermal power stations using pulverized coal as fuel and has considerable pozzolonic activity. This national resource has been gainfully utilized for manufacture of fly ash-lime bricks as a supplement to common burnt clay buildings bricks leading to the conservation of natural resources and improvement in environment quality.

Fly ash-lime bricks are obtained from materials consisting of pulverized fly ash in major quantity, lime and an accelerator acting as a catalyst. Fly ash-lime bricks are generally manufactured by inter grading blending various raw materials are then moulded into bricks and subjected to curing cycles at different temperatures and pressures. On occasion as and when required, crushed bottom fuel ash or sand is also used in the composition of the raw material. Crushed bottom fuel ash or sand is also used in the composition as a coarser material to control water absorption in the final product. Fly ash reacts with lime in presence of moisture from a calcium hydrate which is a binder material. Thus fly ash – lime in presence of moisture form calcium – silicate hydrates which is binder material. Thus fly ash – lime brick is a chemically ended bricks.

#### 2. Strength Characteristic Study of Fly Ash: Manas Kumar Sahoo:

Nearly about 67% of the total energy consumption in the country is fulfilled by coal as it is one of the primary sources of energy. India has one of the largest reserves of coal in the world. Indian coal has high ash content and low calorific value. The reserves are likely to last over another 100 years as the rate of coal extraction is increasing. The energy derived 11 from coal in India is about twice that of energy derived from oil, as against the world, where energy derived from coal is about 30% lower than energy

derived from oil. Most of the country's total installed power generation capacity is thermal. Coal-based generation is 90%. Thermal power stations, besides several captive power plants use coal and produce large quantities of fly ash. High ash content (30% - 50%) coal contributes to these large volumes of fly ash. The country's dependence on coal for power generation is increasing and so the production of fly ash will be more. Fly ash causes air, water and soil pollution when it is exposed to environment.

This project report is an attempt to find a suitable utilization for a particular fly ash sample depending upon its Geo-technical properties. The area required for disposing fly ash will be minimized and so damage to the environment will be minimum. In this project various geotechnical experiments were carried out on fly ash samples. Some of them are Tensile strength study, Unconfined compressive strength study etc. Based on the results obtained from these experiments, a suitable use for the fly ash is ascertained. Fly ash composite material (FCMs) was developed from captive power plant of NALCO, Angul, and Odisha, India. The main constituents of the composite are: fly-ash and lime.

### III. MATERIALS

#### 1. Brick Properties:

As said above the main objective regarding brick is to find the amount of variation in seismic behaviour of a structure due to usage of Ordinary Engineers brick and Aerated Fly-Ash bricks. The two bricks have distinct properties which may influence the selection of it.

The Ordinary Engineers bricks of class A have the following properties:

- Used where strength, low water porosity or acid (flue gas) resistance are needed.
- They have good thermal resistance
- Failure pattern area is less due to loading
- Used mostly due to availability and ease of construction
- Unit weight taken here is 20 kn/m<sup>3</sup> in accordance with code

On the other hand the Aerated Fly-Ash brick uses fly-ash in preparation of it. Fly ash brick is a building material, specifically masonry units, containing class C fly ash and costs 20% less than traditional clay brick manufacturing. They are being used nowadays.

They are commercially available. The main properties of it are:

- They have good compressive strength when compared to Engineers brick and their unit weight is also low.
- The unit weight of it is 15 KN/m<sup>3</sup>
- Apart from being more strength and less self weight they are less thermal resistance is low and their failure pattern area is high when compared to Engineers bricks.

The two bricks have many other basic properties which define the behaviour of it but on point of view of this project the self weight are taken mainly where other properties are not taken. Though the neglected properties will be having effect on behaviour of structure in all means including seismic effects but will be in smaller amount. So neglecting them will not bring a greater difference in seismic behaviour of structure.

As said above the weight of bricks used alone comprises of 30-40 % of total weight. So for an building with same configuration if the two bricks are used and seismic analysis are done then their responses can be found, which will lead to a conclusion on brick usage alone as all others are same. And all other things are done according to respective code books. The code book IS 1893 (part-I): 2002 specifies standards for a seismic behaviour of a building and these are followed to obtain generalized results regarding the seismic behaviour of the structure.



Fig 2. Ordinary Engineers Bricks.



Fig 3. Fly-Ash Brick.

### 2. Concrete and Steel:

The concrete considered is of grade M25 concrete. The mix ratio is 1:1:2 taken according to code. Coarse aggregates, fine aggregates and water content are taken accordingly. The grade of steel to be used is taken as Fe415 grade. The reinforcement bars are obtained according to design said below. Plastering and all other things are assumed accordingly.

### 3. Shear Wall and Base Isolator:

The shear wall will have reinforcements as shown below, a typical one. But position of shear wall is to be decided based on plan and requirement. And an typical isolator will be as shown below.

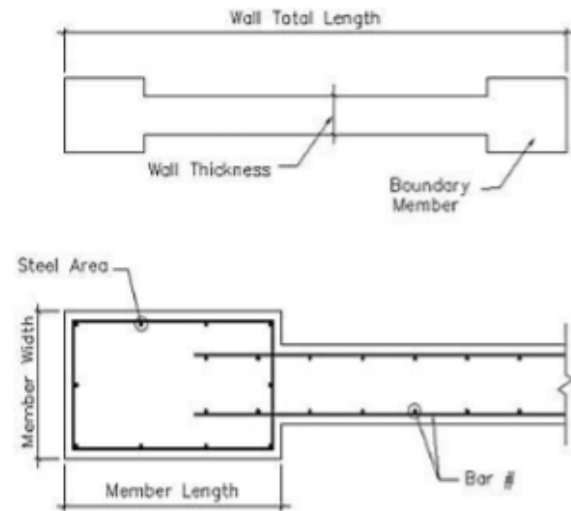


Fig 4. Typical Shear Wall Detail.

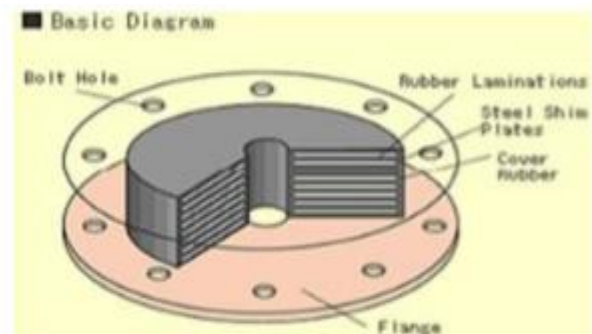


Fig 5. Typical Base Isolator used in Base Isolation.

## IV. STRUCTURE DETAILS AND MODELLING

### 1. Structure Details:

An three storey structure consisting of floor height 3m and each bay dimension 2m is taken as shown below. As we are dealing with seismic response the building is considered to be an important building say hospital structure.



Fig 6. Plan of the structure.

The structure consists of beam, column, slab, footing a typical RC Framed structure. The structure configurations of above said components will be varying in sizes for both bricks because of less self weight of bricks which will be clearly dealt in design part. The structure is modelled in STAAD.Pro software. The plan and elevation are same for both bricks types and in its components only change comes. And they gave below. 3-D view is shown from which the beam, column, slab, footing layout can be seen clearly.

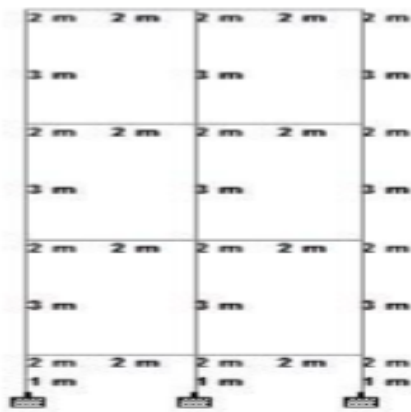


Fig 7. Elevation of the structure.

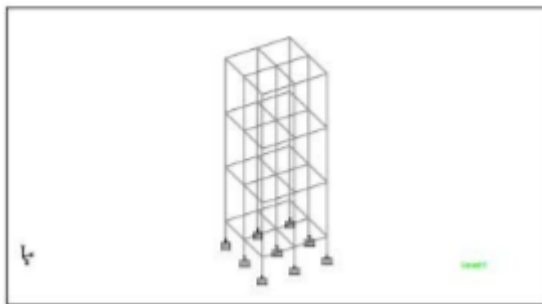


Fig 8. 3-D View of structure.

## 2. Modelling For Engineers Brick:

The plan and elevation are given above are used for Engineers bricks model. The beam and column sizes are assumed first for structure as

**Beam size = 0.380 m\*0.380 m**  
**Column size = 0.460 m\*0.460 m**

The beam and column size with concrete & steel grades are used to model the structure in software. The Young's modulus, Poisson's ratio, density of concrete and damping ratio are given. They are:

**Young's modulus = 25000 N / mm<sup>2</sup>**  
**Poisson's ratio = 0.17**  
**Density of concrete = 25 KN / m<sup>3</sup>**  
**Damping ratio = 0.05 %**

The above said things are given for modelling in software.

## 3. Modelling for Fly-Ash Brick:

For aerated fly-ash brick the concrete & steel grades, Young's modulus, Poisson's ratio, Damping ratio, Density are same. The size of beam and column are reduced due to self weight and they are taken as:

**Beam size = 0.280 m\*0.280 m**  
**Column size = 0.360 m\*0.360 m**

The above said things are given for modelling in software.

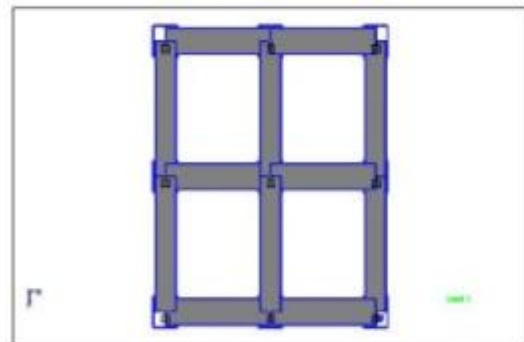


Fig 9. Top view of structure.

In both brick cases the slab is not designed through software because of practical difficulties in it so it is designed manually. As for slab only dead and live load acts so according to that load they are designed manually. To counter act this in software master and slave nodes are given as they will give a slab action in software.

## 4. Loading:

The loading are applied to both modelled structures according to respective codes. Dead, live, wind, seismic loading are given here, all according to respective codes. And they are clearly given below. Temperature load and other loads not considered as they contribute in a very small amount.

**4.1 Dead Load:** Dead load all are given according to IS: 875 (part-1) - 1987. The self-weight of structure is calculated through software by defining the load accordingly. Floor load for each floor is given as 4.5KN / m<sup>2</sup> and for terrace alone 5.5KN / m<sup>2</sup> is given. The loads are calculated based on slab weight and floor finish in floor. They will be said in slab design. An extra 1KN / m<sup>2</sup> is given for terrace according to codal provision. The next load to be given in dead load is wall load acting.

For Engineers brick the wall load is calculated as

$$= (2.620 * 0.230) * 20$$

$$= 12.05 \text{ KN / m}$$

Where 0.230m (assume) is wall thickness and 2.620m is wall height (3m is floor height subtracting half beam size

on both sides  $3-0.382=2.620$  m)  $20\text{KN} / \text{m}^3$  is self weight of ordinary Engineers brick.

The self weight and floor load are same for fly-ash brick. The only change is that the wall load changes due to self weight.

For fly-ash brick the wall load is calculated as

$$= (2.620*0.230)*15$$

$$= 9.03 \text{ KN / m}$$

Where the terms used are said above. And for top floor the wall will be changing due to presence of parapet wall so they must be calculated accordingly,

For Engineers brick the wall load at terrace

$$= (2.620*1)*20$$

$$= 4.6 \text{ KN / m}$$

Where 1m is height of parapet wall taken.

For Fly-ash brick the wall load at terrace

$$= (2.620*1)*15`$$

$$= 3.55 \text{ KN / m}$$

The above loads are applied accordingly in software for both structures comprising of Ordinary Engineers brick and Aerated Fly-ash brick as shown below.

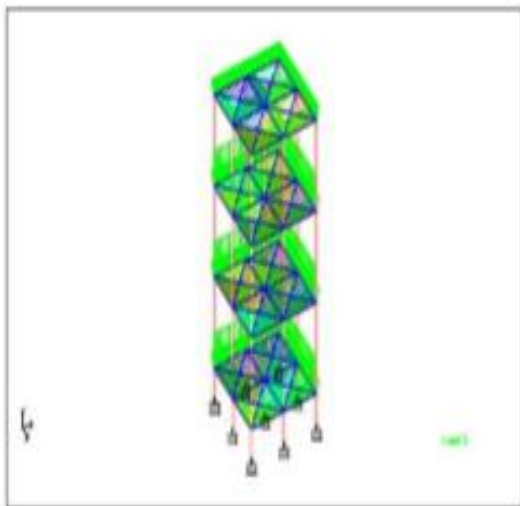


Fig 10. Dead load on structure.

**4.2 Live Load:** Live load is given for building according to IS: 875 (part- 2)-1987. Live load is given as  $3\text{KN}/\text{m}^2$  for all floors except terrace and for terrace  $1.5\text{KN}/\text{m}^2$  is given according to code.

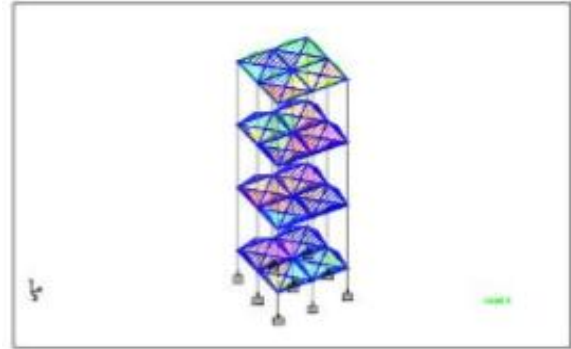


Fig 11. Live load on structure.

**4.3 Wind Load:** Wind load for structure is given according to IS: 875 (part- 3)-1987. Zone taken is v to get maximum wind effect. The basic wind pressure  $V_z$  is  $50$  m/s. And using it according to code wind pressure is calculated.  $K_1, K_2, 3$  are taken according to code based on risk coefficient for  $K_1$ , height & terrain category & class for  $K_2$ , topography for  $K_3$ . The values are used to calculate  $P_d$  pressure.

$$P_d = (K_1 * K_2 * K_3 * V_z)^2 * 0.6 = (1.08 * 0.87 * 1)^2 * 0.6$$

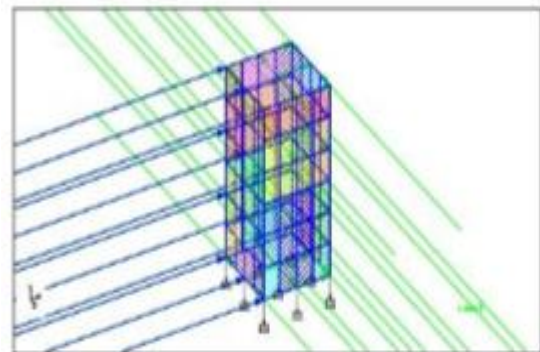


Fig 12. Wind load on X direction.

And wind pressure calculated according to code is  $1.32\text{KN}/\text{m}^2$ . And by code for building dimension external ( $C_{pe}$ ) and internal ( $C_{pi}$ ) wind pressure are calculated. The table based on dimension of structure is used to get wind force for each direction in positive and negative sides. Wind force in x, -x, y, -y are calculated and given in software as shown above.

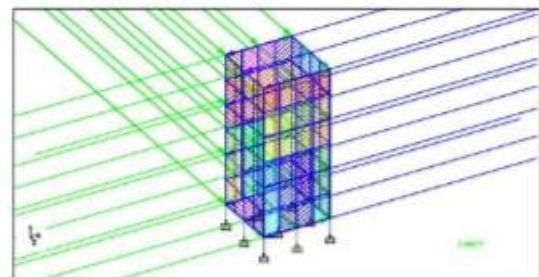


Fig 13. Wind load on Z direction.

The above pictures denote wind load on X and Z directions but there will be load acting + X, -X, +Z, -Z directions and they all are given in software. The below table gives total wind load.

Table 1. Wind load coefficients.

Wind load direction	Coefficient in X		Coefficient in Z	
WL x	1.15	1.45	-0.9	-0.9
WL - x	-1.45	-1.15	-0.9	-0.9
WL z	-0.9	0.9	1.15	1.45
WL -z	-0.9	0.9	-1.45	-1.45

The above are wind load coefficients in each direction. “+” denotes that the wind load acts towards the building in that direction and “-” denotes that the wind load acts away from the building in that direction. All are applied accordingly in software with specifying also the wind pressure all along height of the structure.

**4.4 Seismic Load:** The seismic loading to the structure is applied according to code book IS 1893 (part-I):2002. The seismic loading coding is first selected in software. Then to generate loads the zone factor, importance factor, response reduction factor, damping value (5% for RCC) are given. Zone V, Importance factor I=1.5 are given as we have taken an important structure.

Response reduction factor of “3” is adopted as we are taking Ordinary moment resisting frame. And along with it seismic weight and horizontal seismic coefficient are also given in software so that software will be able to generate the seismic load acting on structure according to code. Hard soil is assumed. Generally seismic weight is sum of Dead load acting + % of Live load and it is given accordingly in software.

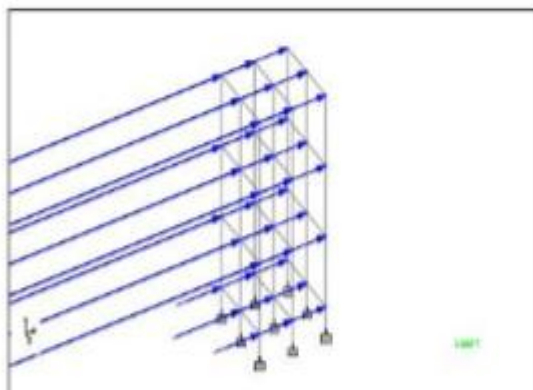


Fig 14. Seismic loading in X direction.

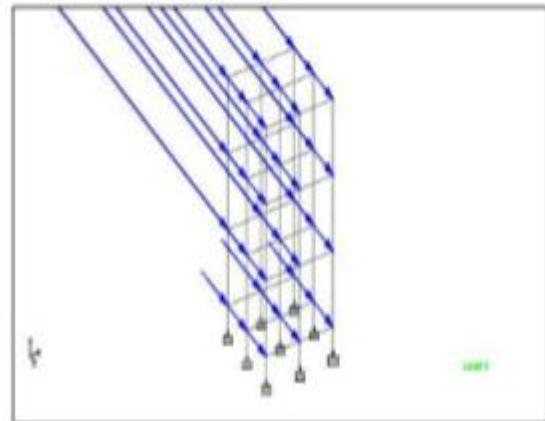


Fig 15. Seismic loading in Z direction.

### 5. Support Condition:

The support condition is selected as fixed supports in software. The foundation to be used is isolated footing. So to incorporate that in software fixed supports are given. And they are given in all node points on foundation as shown below.

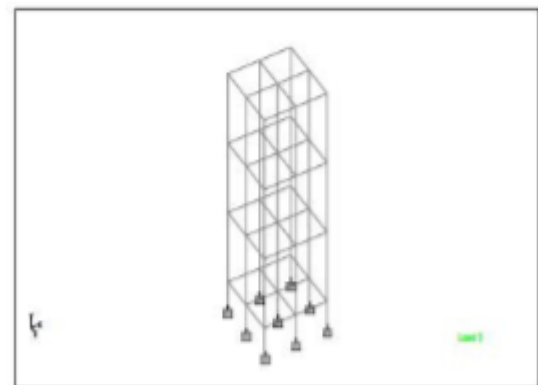


Fig 16. Support Condition.

Now all load conditions, properties, support conditions are given so next step is to analyse the structure.

### 6. Load Combinations:

The above said loads are calculated accordingly and in software these loads must be given in combinations according to code IS 456:2000. The combinations given here along with partial safety factors are:

$$- 1.5 \text{ DL} + 1.5 \text{ LL} - 1.5 \text{ DL} + 1.5 \text{ WL}_x - 1.5 \text{ DL} + 1.5 \text{ WL-x}$$

$$- 1.5 \text{ DL} + 1.5 \text{ WL}_z - 1.5 \text{ DL} + 1.5 \text{ WL-z} - 1.5 \text{ DL} + 1.5 \text{ SL}_x$$

$$- 1.5 \text{ DL} + 1.5 \text{ SL-x} - 1.5 \text{ DL} + 1.5 \text{ WL}_z - 1.5 \text{ DL} + 1.5 \text{ SL-z}$$

$$- 1.2 \text{ DL} + 1.2 \text{ LL} + 1.2 \text{ WL}_x - 1.2 \text{ DL} + 1.2 \text{ LL} + 1.2 \text{ WL-x}$$

$$- 1.2 \text{ DL} + 1.2 \text{ LL} + 1.2 \text{ WL}_z - 1.2 \text{ DL} + 1.2 \text{ LL} + 1.2 \text{ WL-z}$$

$$- 1.2 \text{ DL} + 1.2 \text{ LL} + 1.2 \text{ SL}_x - 1.2 \text{ DL} + 1.2 \text{ LL} + 1.2 \text{ SL-x}$$

$$- 1.2 \text{ DL} + 1.2 \text{ LL} + 1.2 \text{ SL}_z - 1.2 \text{ DL} + 1.2 \text{ LL} + 1.2 \text{ SL-z}$$

$$- 0.9 \text{ DL} + 1.5 \text{ WL}_x - 0.9 \text{ DL} + 1.5 \text{ WL-x} - 0.9 \text{ DL} + 1.5 \text{ WL}_z$$

$$- 0.9 \text{ DL} + 1.5 \text{ WL-z} - 0.9 \text{ DL} + 1.5 \text{ SL}_x - 0.9 \text{ DL} + 1.5 \text{ SL-x}$$

$$- 0.9 \text{ DL} + 1.5 \text{ SL}_z - 0.9 \text{ DL} + 1.5 \text{ SL-z}$$

Where DL = Dead load

LL = Live load

WL<sub>x</sub>, WL<sub>-x</sub>, WL<sub>z</sub>, WL<sub>-z</sub> = Wind load in x, -x, z, -z directions

SL<sub>x</sub>, SL<sub>-x</sub>, SL<sub>z</sub>, SL<sub>-z</sub> = Seismic load in x, -x, z, -z directions

Partial safety factors are taken from code book

## V. ANALYSIS AND DESIGN

### 1. Analysis:

The above modelled structures for Engineers brick and Fly-ash brick are next to be analysed. All possible combination along with safety factors are taken into consideration. And for the worst case of load combination the results are obtained. Adopt a clear cover 40 mm for all members.

Four face equal reinforcement and reinforcement are given for all members in software. And analysis is done for given load combinations and results are obtained. The other analysis is to be done is dynamic analysis according to code. Because the above said analysis will give results for load combinations i.e. bending moments, shear force, deflection, etc are only obtained and not the seismic response. So to obtain this seismic response the dynamic analysis. To do this analysis the response spectrum method is taken here and they are done according to code. The response spectrum is given in software. First code is selected as Indian Codes. Next step is to define combination method here SRSS (Square Root of Sum of Squares ) method is adopted.

There is also Complete Quadratic Combination (CQC) and other methods available which can be used. Here SRSS is used. Hard soil is selected. For both X and Z directions the response spectrum is defined so that for both results can be obtained. And analysis is done as above said ways. The

results are obtained and they give clear idea about the seismic response of the building. And they are given in results.



Fig 17. Bending of Structure.

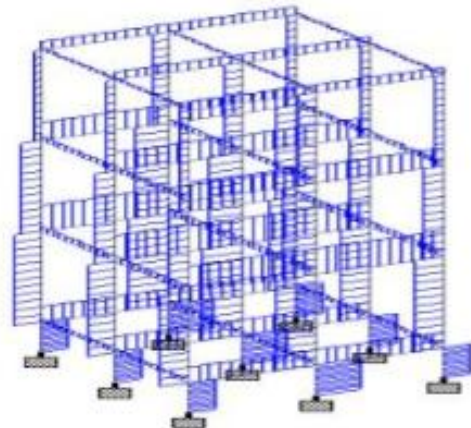


Fig 18. Shear stress in structure.

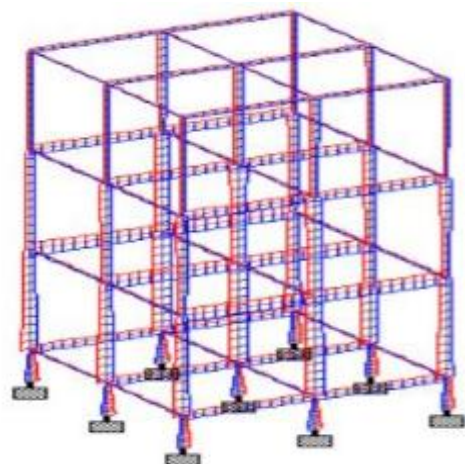


Fig 19. Beam stresses.

### 2. Design of Elements:

The analysis is done and forces acting on elements are found. The beam column forces and design are given below for both bricks. The grades of concrete and steel are M20 and Fe415.

### 2.1 Beam Design: Engineers Brick:

The forces obtained from analysis for beams are:  
 $M_Z = 157.9 \text{ KNm}$     $F_Y = 168.7 \text{ KN}$   
 $M_Y = 1.52 \text{ KNm}$     $F_Z = 1.42 \text{ KN}$

Size =  $0.380 \text{ m} \times 0.380 \text{ m}$   
 $L = 2 \text{ m}$   
 Cover  $D = 40 \text{ mm}$   
 $d = 38 \text{ mm}$

The design is done according to code,

$$\frac{M_u}{bd^2} = \frac{157.9}{(0.380 \times 0.380^2)}$$

=  $2.924 \text{ N/mm}^2$

Assume  $P\% = 0.967$ ,

$$\frac{M_u \text{ lim}}{bd^2} = 3.45 \text{ N/mm}^2$$

$M_u \text{ lim} = 3.45 \times 380 \times 380 = 189.3 \text{ KN m} > 157.9 \text{ KN m}$

Depth check,

$$D = \sqrt{\frac{M}{Q_8}} = \sqrt{\frac{157.9 \times 100000}{3.449 \times 380}} = 337.2 \text{ mm} < 380 \text{ mm} \text{ (Q value obtained from code book)}$$

Hence safe and can be designed as under reinforced section

$$A_{st} = \frac{0.967 \times 380 \times 380}{100} = 1396.3 \text{ mm}^2$$

So provide 25 mm dia bars @ 100 c/c spacing

Use 10 mm dia 2 legged bars @ 98 mm c/c spacing as vertical reinforcement.

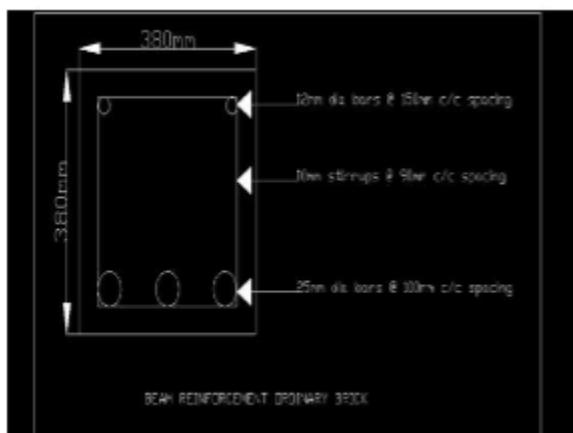


Fig 20. Engineers brick Beam Reinforcement.

### 2.2 Beam Design: Fly-Ash Brick:

The forces obtained from analysis for beams are:  
 $M_Z = 148.3 \text{ KNm}$     $F_Y = 156.7 \text{ KN}$   
 $M_Y = 0.15 \text{ KNm}$     $F_Z = 0.41 \text{ KN}$

Size =  $0.280 \text{ m} \times 0.280 \text{ m}$   
 $L = 2 \text{ m}$   
 Cover  $D = 40 \text{ mm}$   
 $d = 38 \text{ mm}$

The design is done according to code,

$$\frac{M_u}{bd^2} = \frac{148.3}{(0.280 \times 0.280^2)}$$

=  $2.924 \text{ N/mm}^2$

Assume  $P\% = 0.764$ ,

$$\frac{M_u \text{ lim}}{bd^2} = 3.45 \text{ N/mm}^2$$

$M_u \text{ lim} = 3.45 \times 280 \times 280 = 175.73 \text{ KN m} > 148.3 \text{ KN m}$

Depth check,

$$D = \sqrt{\frac{M}{Q_8}} = \sqrt{\frac{148.3 \times 100000}{3.449 \times 280}} = 262.7 \text{ mm} < 280 \text{ mm} \text{ (Q value obtained from code book)}$$

Hence safe and can be designed as under reinforced section

$$A_{st} = \frac{0.764 \times 380 \times 380}{100} = 1120.8 \text{ mm}^2$$

So provide 20 mm dia bars @ 80 c/c spacing

Use 10 mm dia 2 legged bars @ 80 mm c/c spacing as vertical reinforcement.

It is clearly given below as,

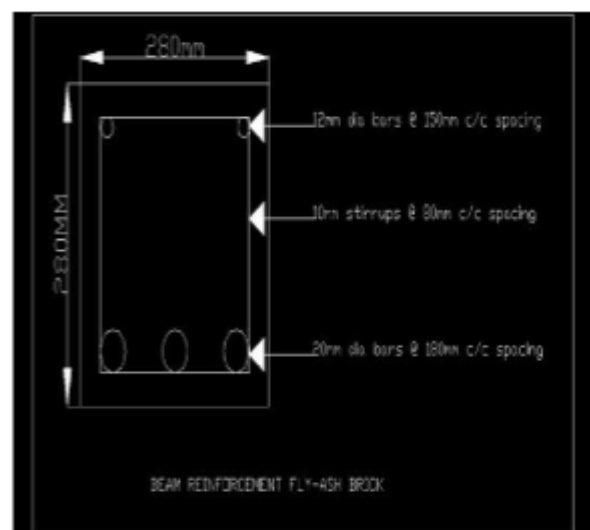


Fig 21. Fly-ash brick Beam Reinforcement.

### 2.3 Column Design: Engineers Brick:

The forces acting in column are:

$$P_u = 743.2 \text{ KN}$$

$$M_{uy} = 155.7 \text{ KNm}$$

$$M_{uz} = 156.5 \text{ KNm}$$

$$\text{Column size} = 0.460\text{m} * 0.460\text{m} (b*d)$$

$$L = 3000 \text{ mm}$$

$$\text{Cover } D = 40\text{mm}$$

$$d = 38\text{mm}$$

First to find short or long column,

$$\frac{L_{eff}}{D} = \frac{3000}{460} = 6.52 < 12$$

$$B = D = 460 \text{ mm}$$

Hence it is an short column. Next is to find eccentricity,

$$e_{min} = \frac{L}{500} + \frac{D}{30} \text{ or } 20\text{mm not less than } 0.05 * D$$

$$= 21.33 < 23$$

Hence there is no eccentricity.

The column is designed according to SP 16. Now assume reinforcement longitudinal as 2% and 32 mm dia bars, values are obtained from interaction charts.

$$D=40 \text{ mm } d'=40 + 32/2 = 56 \text{ mm}$$

$$\frac{d'}{D} = \frac{56}{460} = 0.1086$$

$$\frac{p}{f_{ck}} = \frac{2}{25} = 0.08$$

$$\frac{p}{f_{ck} b d} = \frac{743.2 * 1000}{25 * 460 * 460} = 0.1409$$

Assume four side equal distribution of bars and from chart 43,

$$\frac{M_u}{f_{ck} b d} = 0.129$$

From above equation  $M_{ux1} = M_{uy1} = 313.90 \text{ KNm}$

Assume area of steel = 2% of gross area of structure  $P_{uz} = 0.45 f_{ck} A_c + 0.75 f_y A_{sc}$

$$\text{Solving } P_{uz} = 3.6 * 10^6 \text{ N}$$

$$P_u / P_{uz} = 0.2009 \quad \alpha_n = 1.001$$

$$\alpha_n \quad \alpha_n$$

$$\left( \frac{M_{ux}}{M_{ux1}} \right) + \left( \frac{M_{uy}}{M_{uy1}} \right) < 1$$

$$0.92 < 1$$

Hence safe.

$$\text{Area of one bar} = (3.14 * 32^2) / 4 = 804.25 \text{ mm}^2$$

Hence six numbers are required to satisfy reinforcement amount.

$$\text{Now transverse reinforcement dia} = \text{dia of main bar} / 4 = 32/4 = 8 \text{ mm}$$

So provide 8 mm bars @ 300 mm c/c spacing

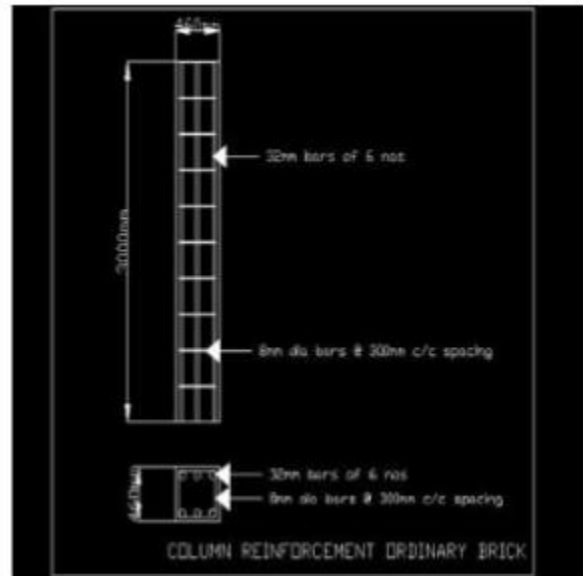


Fig 22. Column reinforcement Engineers brick.

### 2.4 Columns Design: Fly-Ash Brick:

The forces acting in column are:

$$P_u = 650 \text{ KN}$$

$$M_{uy} = 157.2 \text{ KNm } M_{uz} = 157.2 \text{ KNm}$$

$$\text{Column size} = 0.360\text{m} * 0.360\text{m} (b*d)$$

$L = 3000 \text{ mm}$   $\text{Cover } D = 40\text{mm}$   $d = 38\text{mm}$  First to find short or long column,

$$\frac{L_{eff}}{D} = \frac{3000}{360} = 8.3 < 12$$

$$B = D = 360 \text{ mm}$$

Hence it is an short column.

Next is to find eccentricity,

$$e_{min} = \frac{L}{500} + \frac{D}{30} \text{ or } 20\text{mm not less than } 0.05 * D$$

$$= 18 < 23$$

Hence there is no eccentricity.

The column is designed according to SP 16. Now assume reinforcement longitudinal as 2% and 25 mm dia bars, values are obtained from interaction charts.

$$D=40 \text{ mm } d'=40 + 25/2 = 52.5 \text{ mm}$$

$$\frac{d'}{D} = 52.5/360 = 0.101 \qquad \frac{p}{f_{ck}} = 2/25 = 0.08$$

$$\frac{p}{f_{ck}bd} = \frac{650 \cdot 1000}{25 \cdot 360 \cdot 360} = 0.201$$

Assume four side equal distributions of bars and from chart 43,

$$\frac{Mu}{f_{ck}bd} = 0.145$$

From above equation  $M_{ux1} = M_{uy1} = 348.90 \text{ KNm}$   
Assume area of steel = 2% of gross area of structure  $P_{uz} = 0.45 f_{ck} A_c + 0.75 f_y A_{sc}$   
Solving  $P_{uz} = 3.1 \cdot 10^6 \text{ N}$

$$P_u / P_{uz} = 0.245 \quad \alpha_n = 1.001 \quad \alpha_n \alpha_n$$

$$\left( \frac{M_{ux}}{M_{ux1}} \right) + \left( \frac{M_{uy}}{M_{uy1}} \right) < 1$$

$$0.85 < 1$$

Hence safe.

$$\text{Area of one bar} = (3.14 \cdot 25^2) / 4 = 490.87 \text{ mm}^2$$

Hence six numbers are required to satisfy reinforcement amount.

Now for transverse reinforcement provide 10 mm bars @ 300 mm c/c spacing.

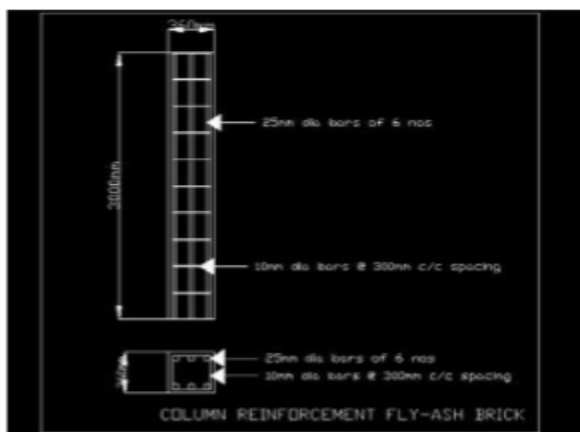


Fig 23. Column Reinforcement Fly-ash brick.

### 3. Slabs:

The slabs are designed only for dead and live loads acting on structure as only these loads acts mainly in the structure. So for both bricks the slab are designed as, the taken depth

$$d = 125 \text{ mm}$$

$$\text{Slab size} = 2 \text{ m} \cdot 2 \text{ m wall thickness} = 230 \text{ mm}$$

The grades of concrete and steel are M20 and Fe415.

$$\frac{L}{B} = 2/2 = 1 \quad \text{so it is an two way slab .}$$

So effective span =  $2 + 0.125 = 2.125 \text{ m}$  Load calculation:  
Self weight =  $0.125 \cdot 25 = 3.125 \text{ KN / m}^2$  Weight of weathering course =  $1 \text{ KN / m}^2$  Live load acting =  $3 \text{ KN / m}^2$

Take other loads as  $1 \text{ KN / m}^2$  Factored total load =  $12.2 \text{ KN / m}^2$

$$\frac{l_x}{l_y} = 1$$

The  $\alpha$  for x and z directions according to code are 0.062. Now consider 1m width of slab

BM along main span,

$$M_x = \alpha \cdot w \cdot l_x^2 = 0.062 \cdot 12.2 \cdot 2.125^2 = 3.41 \text{ KNm}$$

For  $M_y$  also the same value as  $M_x$  is obtained. So maximum BM is  $3.41 \text{ KNm}$ .

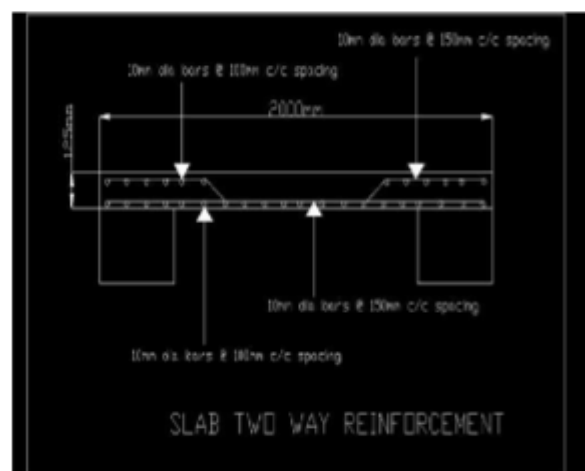


Fig 24. Slab reinforcement.

$$d = \sqrt{\frac{M}{qB}} = 42.42 \text{ mm} < 100 \text{ mm}$$

$$d = 125 - 20 - 10/2 = 100 \text{ mm, take cover as 20 mm.}$$

$A_{st} = 243.2 \text{ mm}^2$  For x and y direction above is reinforcement,

So provide 10 mm dia bars @ 150 c/c spacing for X and -X direction.

Provide 10 mm dia bars @ 100 mm c/c spacing for Z and -Z directions

#### 4. Footing:

The reactions from foundations nodes are taken from STAAD.Pro and they are used

$$\begin{aligned} F_y &= 751.34 \text{ KN} \\ F_z &= -199.76 \text{ KN} \\ M_x &= 109.62 \text{ KNm}, -109.62 \text{ KNm} \\ M_z &= 109.62 \text{ KNm}, -109.62 \text{ KNm} \end{aligned}$$

to design the footing.

$$F_y = 751.34 \text{ KN} \quad F_z = -199.76 \text{ KN} \quad M_x = 109.62 \text{ KNm}, -109.62 \text{ KNm} \quad M_z = 109.62 \text{ KNm}, -109.62 \text{ KNm}$$

Design an isolated square footing,

Assume self weight of footing as 10% of column load so total load =  $751.34 + 75.13 = 827 \text{ KN}$

Factored load =  $1.5 * 827 = 1240 \text{ KN}$  SBC =  $200 \text{ KN} / \text{m}^2$   
Area of footing =  $1240 / 200 = 6.20 \text{ m}^2$  Side =  $\sqrt{6.20} = 2.5$   
provide  $3 \text{ m} * 3 \text{ m}$  size.  
Net upward design pressure at base =  $1240 / (3 * 3) = 137.77 \text{ KN} / \text{m}^2$

$BM = 137.77 * 3 * 1.3 * (1.3/2) = 350 * 106 \text{ Nmm}$  ( 1.3m is distance of column from footing when it is placed on footing )

$$D_{req} = \sqrt{\frac{M}{QB}} = \sqrt{\frac{350 * 1000000}{3.449 * 3000}} = 183.9 \text{ mm}$$

The depth is provided as 560 mm considering effect of shear from top layers of bars. Now assume 26 mm dia bars with clear cover of 52 mm. Total thickness =  $560 + 13 + 26 + 52 = 645 \text{ mm}$

$$M = 0.87 f_y A_{st} \left(1 - \frac{A_{st} f_y}{b d d}\right)$$

On solving for  $A_{st} = 3010.02 \text{ mm}^2$ , Provide 26 mm dia bars in each direction.

$$\text{Development length } L_d = \frac{26 * 0.87 * 415}{4 * 460 + 460 * 1.2} = 960 \text{ mm} < 1300 \text{ mm projection of column}$$

Hence ok.

Transverse shear check:

The critical section of transverse shear is at a distance of 560 mm from face of the column. Length of footing beyond critical section at 560 mm,

$$V_y = 250 * 3 * 0.69 = 517.52 \text{ KN}$$

$$\text{Nominal shear} = \frac{517.50 * 1000}{300 * 560} = 0.308 \text{ N} / \text{mm}^2 > 0.36 \text{ N} / \text{mm}^2 \text{ from IS 456-2000}$$

Hence safe.

Punching shear check:

Its acts at a distance of 280 mm ( $0.5 * \text{effective depth}$ ) around face of the column.

Side of section =  $460 + (2 * 280) = 1020 \text{ mm}$  Punching shear  $V_z = 250(3 * 3 - 1.02) = 1995 \text{ KN}$

$$\text{Nominal shear} = \frac{1995 * 1000}{4 * 560 * 1020} = 0.836 \text{ N} / \text{mm}^2$$

Allowable shear =  $0.25 \sqrt{25} = 1.2 \text{ N} / \text{mm}^2$  ( $f_{ck} = 25 \text{ N} / \text{mm}^2$ )

Hence safe.

Check for safe bearing capacity of soil:

Self weight of footing =  $3 * 3 * 25 * 0.645 = 145.125 \text{ KN}$   
Column load =  $1240 \text{ KN}$   
Total load =  $1240 + 145.125 = 1385 \text{ KN}$

$$\text{Pressure on soil} = \frac{1385}{3 * 3} = 153.07 \text{ KN} / \text{m}^2 < 200 \text{ KN} / \text{m}^2 \text{ Hence safe}$$

The same above said procedure is used for Fli-ash brick and footing is designed. The loads

acting are

$$\begin{aligned} F_y &= 638.7 \text{ KN} \\ F_z &= -249.5 \text{ KN} \\ M_x &= 118.7 \text{ KNm}, -118.7 \text{ KNm} \\ M_z &= 118.7 \text{ KNm}, -118.7 \text{ KNm} \end{aligned}$$

And the reinforcement are obtained as above manner as shown in figures.

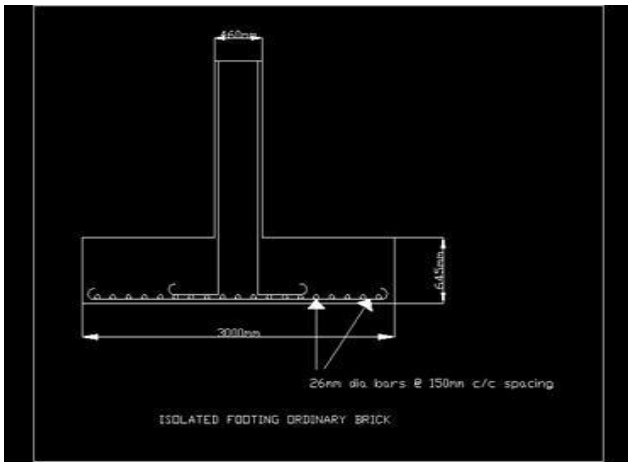


Fig 25. Footing for Engineers brick.

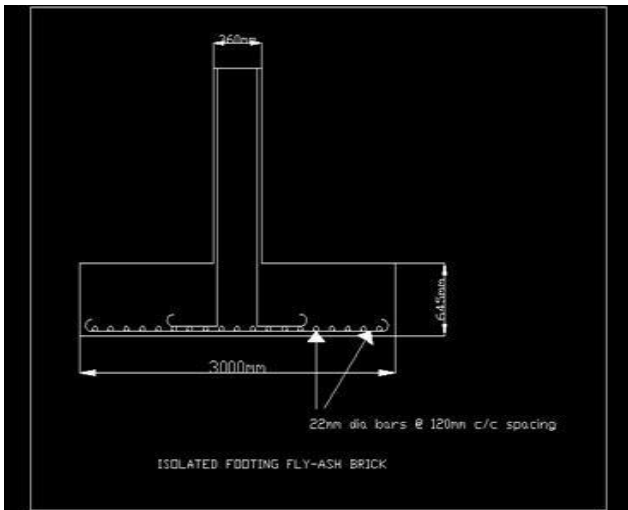


Fig 26. Footing for Fly-ash brick.

## VI. RESULTS

The elements are analysed and designed as said above. In that forces acting are less for Fly-ash brick when compared to the Engineers brick so even this will lead to economy and better performance of the structure underloading. The seismic response will be obtained in Response Spectrum analysis. And they are:

Natural frequency and time period for Ordinary Engineers brick:

Mode:	Frequency(c/s):	Period(s)
1	3.477	0.28758
2	3.477	0.28758
3	4.470	0.22369
4	11.163	0.08958
5	11.163	0.08958

Storey shear:	X( KN)	Z(KN)
5	155.89	153.85
4	344.79	340.26
3	449.45	433.55
2	464.01	457.92
1	464.01	457.92

Natural frequency and time period for Fly-ash brick:

Mode:	Frequency(c/s):	Period(s):
1	1.978	0.5210
2	1.978	0.5210
3	2.458	0.4069
4	6.230	0.1605
5	6.230	0.1605

Storey shear:	X(KN)	Z(KN)
5	124.55	122.96
4	264.94	261.55
3	346.91	341.60
2	353.22	348.99
1	353.22	348.99

The mode shapes for fundamental mode for both bricks are:

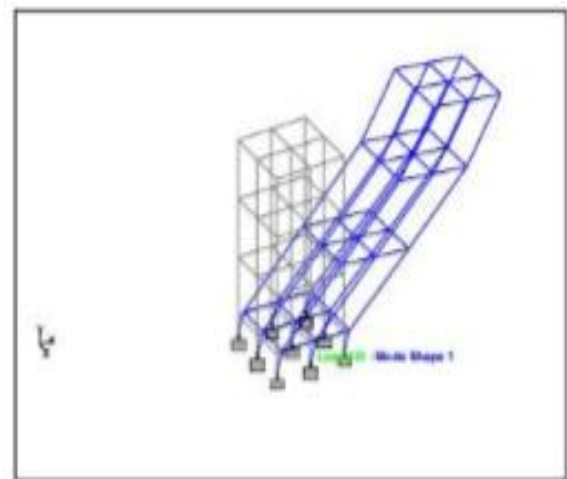


Fig 27. Fundamental mode shape for Engineers brick.

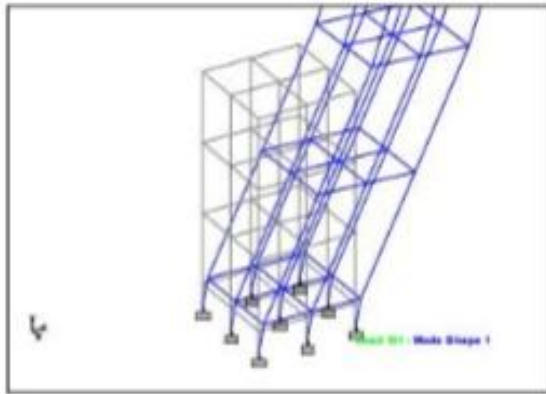


Fig 28. Fundamental mode shapes for Fly-ash brick.

## VII. CONCLUSION

From above results it is clearly seen that the storey shear acting on each floor and natural frequency are reduced. And the natural time period is increased. So this will ensure that the resonance will not be occurring, so even when earthquake strikes resonance effect will be reduced.

This is because the fact that the earthquake will be having low natural period and if the structures natural period is low resonance will be occurring. So when natural period is increased resonance effect will be reduced largely and it will be affected less. The mode shapes are also given and it is seen that the mode shape effect will be less for Fly-ash bricks than Engineers brick. So the usage of Fly-ash brick alone has greater effect in seismic performance of the structure.

## VIII. FUTURE INVESTIGATIONS

Analysing of structure for seismic response with shear modelled as show below for Engineers brick and Fly-ash brick

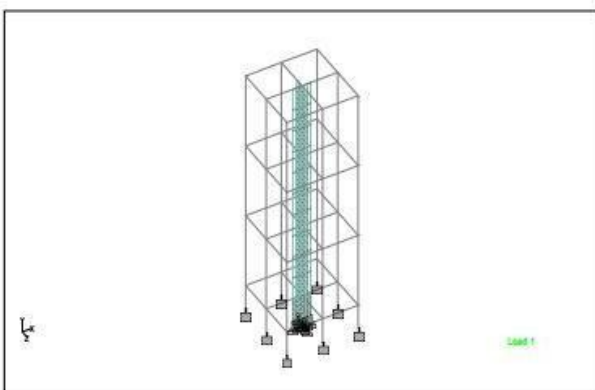


Fig 29. Shear wall modelled for structure.

The structure with both bricks has same all design except the shear wall to be placed. So that the effect of shear wall alone can be obtained for both bricks configurations.

The shear wall is modelled using surface meshing technique in STAAD.Pro software. The base isolator has to be designed and placed in structure. The seismic response is found through analysis. And at last all results are compared to get an effective one.

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