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Earthquake Resistant Design of Building - A Case Study on Modification of Terminal Building at Silchar Airport

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Abstract: Aseismic or earthquake resisting building designs are essential from the seismology point of view. While both linear as well as nonlinear analysis are require for analytical modeling with special care because such loads are unpredictable the magnitude, direction and time occurrence manner. Shear, moments and torque, horizontal and vertical forces occurs due to earthquake in building whereas these are highly dependable on material's weight and stiffness, structural system and its configuration, time period of vibration of building, soil conditions, seismic zone and its behavior.

Calculation of earthquake loads has done through various method as per India standards code for seismic resistant design of structures. A field survey was conducted to evaluate the expected seismic load on a particular building. Evaluation of developed construction materials and technology, along with comprehend seismic loads and building response certainly gives positively to minimize earthquake vulnerability and prevent collapse of buildings and losses of lives, property as well as environmental degradation. This paper provides an overview of design approach to seismic analysis of a particular plan of terminal building (G+3) at Silchar Airport, to ensure that the building is safe or not as per I.S: 1893 (Part-1)-2016 provision.

Keywords- Soil-structure interaction, structural ductility, base isolation, load transfer mechanism, seismic response, earthquake resistant designs, seismic coefficient method.

I. INTRODUCTION

Aseismic structures are designed to prevent from structural collapse due to seismic force. One of the Earth's most destructive forces recorded by earthquake which can demolish buildings, lives, even mountain and financial losses and repair. According to history, the world's largest earthquake occurred on 1960 in southern Chile. Earthquake in Assam, India on 1950 which grievous blow in both Assam and Tibet having 4800 peoples death with destroyed 70 villages. In this case with other seismic cases, losses of lives due to the collapse of buildings and people was inside them. In India, earthquake zone of falling almost by 59% of the geographical area.

Almost by 59% of the geographical area.

Figure-1:Bridge collapse (at Lakhimpur, Assam), Road damaged, Buildings collapse due to Earthquake

In past decades, new designs and construction materials has developed through Engineers to build earthquake resistant structures. To design such structures , it is required to reinforce structures which counteract with seismic forces. Since, earthquake release energy results pushing a building from one direction & strategy required to push the building in opposite direction for prevention of collapse. Few technique are using for building withstand earthquake such as steel plate walls systems, earthquake resisting materials, pendulum powers, shield building from vibrations, counter force with damping system, etc.

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II. ANALYTICAL METHODS

There are few analytical approach has developed by many countries. In India, as per IS: 1893 (Part-1)-2016, analysis and design are carried out by- equivalent static analysis, non-linear static analysis, linear dynamic analysis, non-linear dynamic analysis, seismic coefficient method, response spectrum method, time-history analysis. In this paper, all calculation has done through seismic coefficient method.

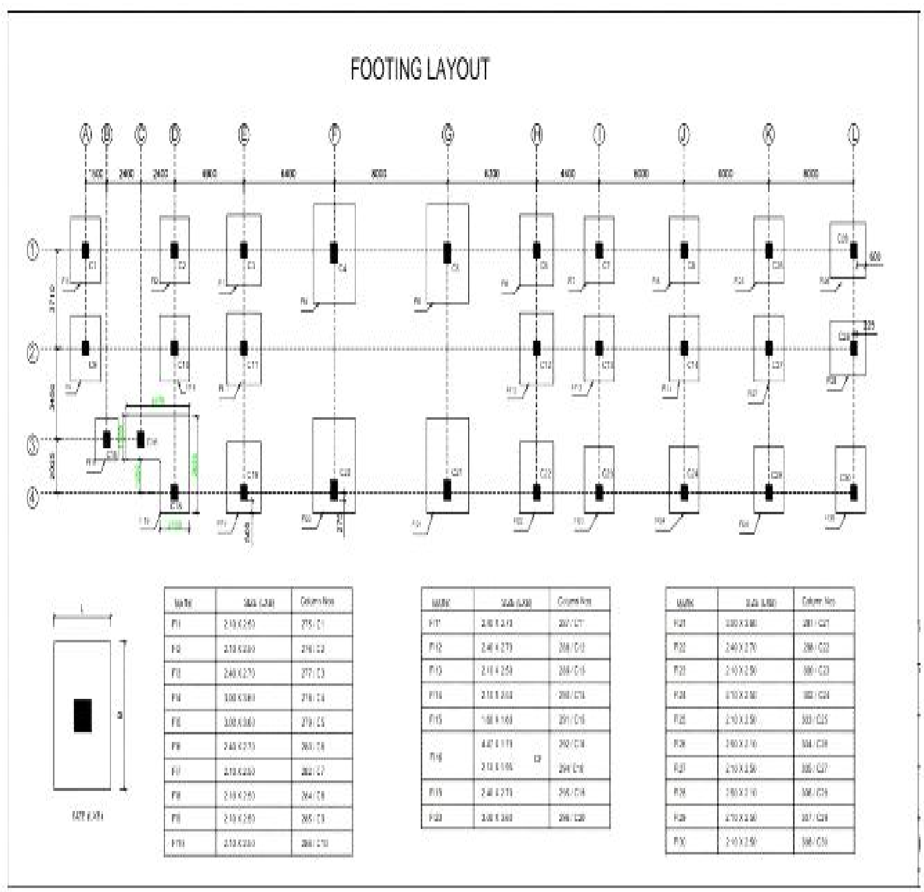
A. *Seismic Coefficient Method*

It is one of the static procedure where the horizontal and vertical forces are calculated as seismic coefficient for consideration of seismic action caused through earthquake. The assumption for this method are such-

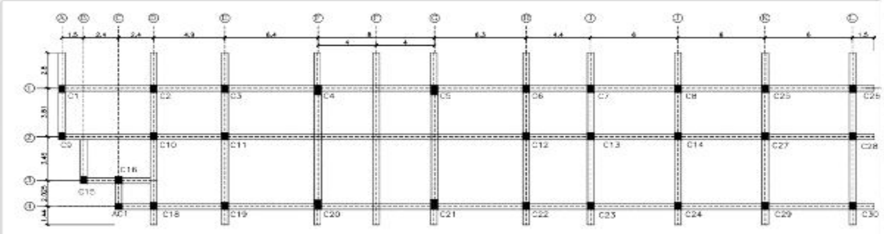
1) Design should be carried out as per IS: 1893(Part-1)-2016 provisions.
2) Assume, the structure is rigid
3) There is perfect flexibility between super structure & foundation, i.e. integral system of action.
4) Building should not be heavily mass weighted and beam-column having equal in width.
5) While on earthquake pressure on ground, every point on the building behaves same accelerations.
6) Effect of seismic force is equivalent to Horizontal forces over the height.
7) Determine total horizontal force, i.e. Base Shear-where is depends upon on several factors such as natural period, damping, subsoil condition, model shapes, types of structure & its location, importance of building, reduction factor, etc

In this case study, a part of (G+3) building plan from expansion of terminal building at Silchar Airport has carried out where 735.6 sq.m area constructed with details given below-

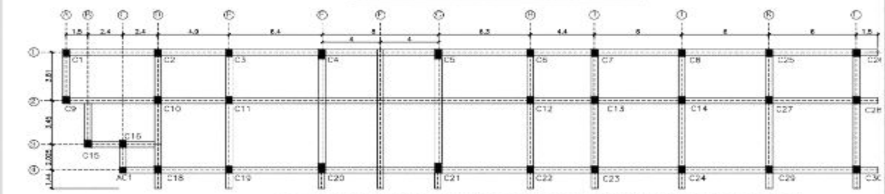
III. ANALYSIS AND DESIGN



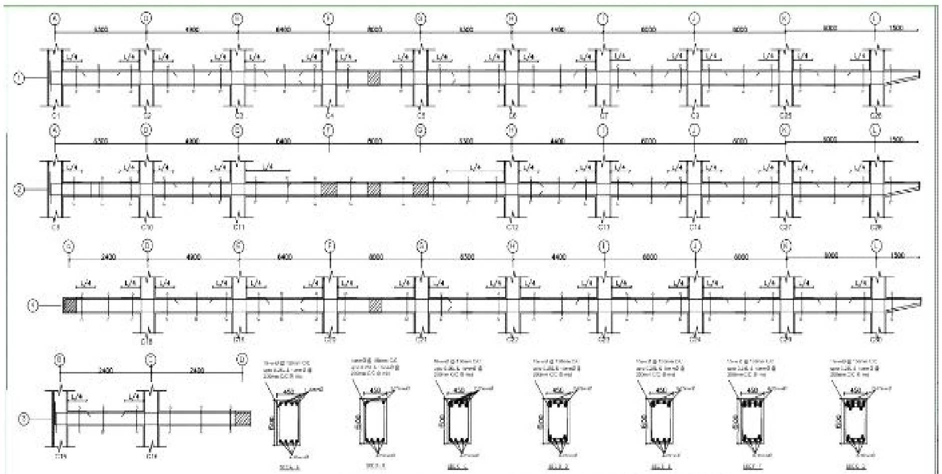
Plan:1- Footing Layout, AAI/Modi/T.B/TXS



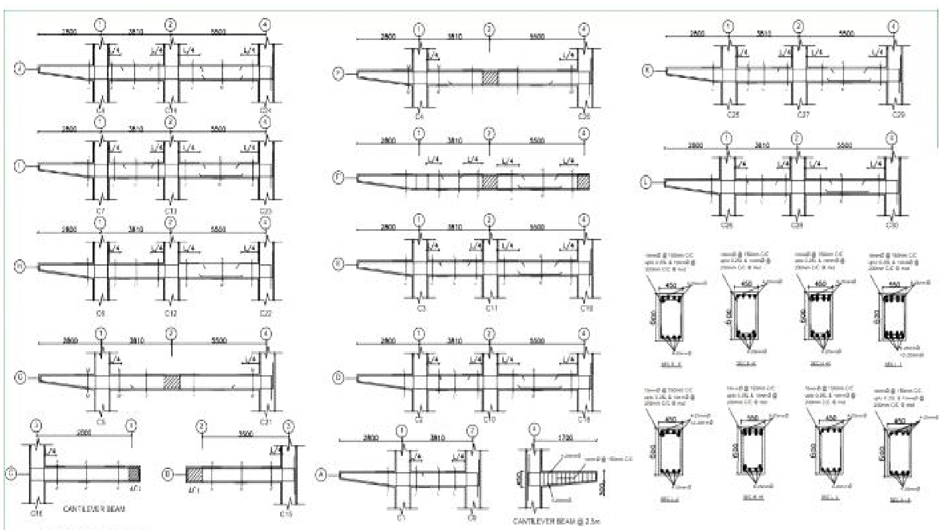
FLOOR BEAM AND COLUMN LAYOUT



PLAN:2: PLINTH BEAM AND COLUMN LAYOUT, AAI/MODI/T.B/IXS



Plan:3: DETAILING OF FLOOR BEAM 1, AAI/ MODI/T.B/IXS



PLAN:4: DETAILING OF FLOOR BEAM 2, AAI/MODI/T.B/IXS

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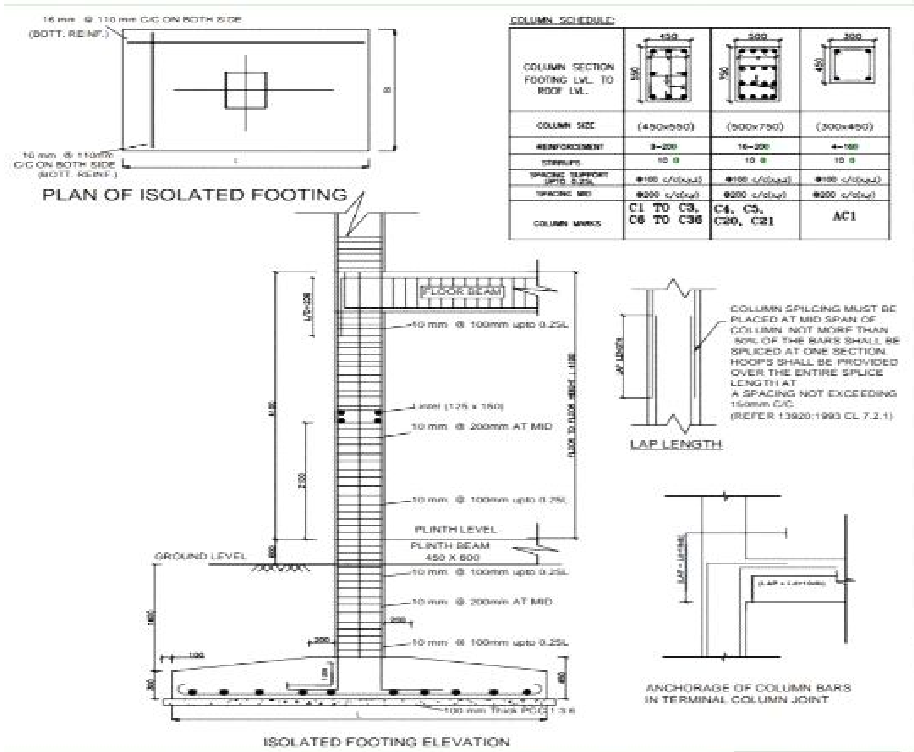

PLAN:5: FOOTING & COLUMN DETAILING. AAI/MODI/T.B/IXS

The above plans where the grid are c/c distance of structural elements from “A” to ”L”.
From the plan,
Height of each storey = 4.1 m (floor to floor)
Thickness of slab = 130 mm
Size of each type of Beam with calculated length from drawing:
Size-1 type beam (450 mm x 600 mm) with length = 164.175 m
Size-2 type beam (450 mm x 550 mm) with length = 80.705 m
Size-3 type beam (450 mm x 450 mm) with length = 66.655 m
Size-4 type beam (450 mm x 550 mm) with length = 6.4 m
Size of each type of column with total nos.
Size-1 type column (450 mm x 550 mm) in 25 Nos.
Size-2 type column (500 mm x 750 mm) in 4 Nos.
Size-3 type column (450 mm x 300 mm) in 1 No.
Thickness of wall (including plaster) = 250 mm
Building type- (G+3) storey i.e. 3 nos. of floors with 1 no. of roof slab with
live load = 5.75 KN/m^2,
Floor Finish = 1 KN/m^2,
Terrace water proofing factor = 1.5 KN/m^2,
Density of concrete = 25 KN/m^3,
Density of Masonry = 20 KN/m^2,
M25 grade of concrete and FE 500 steel.
So, Maximum length along X direction, L = (1/2)x(.450) +1.5 +2.4+2.4+4.9+6.4+8+6.3+4.4+6+6+6+1.5 = 56.025 m
Maximum length along Y direction, B = 2.8+3.81+3.45+2.025+1.44 = 13.525 m
From drawing, size of slab = building covered area = (L X B) – small uncovered portion
= (56.025 x 13.525) – [{1.5 x (3.45+2.025+1.44)} + {2.4 x (2.025+1.44)} + (2.4 x 1.44)}]
= 757.7381 – 10.3725 – 8.316 – 3.456 = 735.6 sq.m

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A. Load Parameters

1) Dead Load

a) Dead load of each Slab = (L x B) x thickness of slab x density of concrete
= 735.6 x 0.13 x 25 = 2390.7 KN.

b) Dead load of each Roof = D.L of slab + Floor finish + Terrace water proofing factor
= 2390.7 + (735.6 x 1 KN/m^2) + (735.6 x 1.5 KN/m^2)= 4229.47 KN

c) Dead Load on each Floor = D.L of slab + Floor finish = 2390.7 + (735.6 x 1) = 3126.3 KN.

d) Dead Load of a Beams in each floor-

Volume for beam type-

Beam-1, V_1 = .45 x .60x 164.175 = 44.327 m^3

Beam-2, V_2 = .45 x .55x 80.705 = 19.975 m^3

Beam-3, V_3 = .45 x .45 x 66.655 = 13.498 m^3

Beam-4, V_4 = .45 x .40x 6.4 = 1.152 m^3

Total volume of beams = Volume of all beams in each floor - Avg. beam column junction area = (44.327+19.975+13.498+1.152) – (30 x .45 x .60 x .55) = 74.497 m^3

Total dead load on each floor beam = 74.497 x 25 = 1862.425 KN.

e) Dead load of wall per meter Height-

From above plan, avg. total length of wall = 232.125 m

Self weight of wall per meter height = Length x Thickness x Density of masonry
= 232.125 x 0.25 x 20 = 1160.625 KN/m

f) Self weight of Columns per meter Length-

Dead load of size-1 type column = Nos. of column x size x Density of concrete
= 25 x 0.45 x 0.55 x 25 = 154.69 KN/m

Similarly, D.L of size-2 type column = 4 x 0.50 x 0.75 x 25 = 37.5 KN/m

And, D.L of size-3 type column = 1 x 0.45 x 0.30 x 25 = 3.375 KN/m

Total self weight of each floor Columns per meter length = **195.57 KN/m**

2) Live Load: For seismic weight of building having with Live Load, whereas L.L. are considers only some amount of percentage of actual live load acting on the load.

Live load on Roof = 0, According to IS: 1893 (Part-1)-2016, Table-8,

IS 1893 (Part 1) : 2002

Table 8 Percentage of Imposed Load to be Considered in Seismic Weight Calculation

(*Clause* 7.3.1)

Imposed Uniformity Distributed Floor Loads (kN/ m^2)	Percentage of Imposed Load
(1)	(2)
Upto and including 3.0	25
Above 3.0	50

Live load on Floor = 50% of total live load to be consider, when L.L > 3 KN/m^2

So, here L.L = 50% of 5.75 KN/m^2 = 2.875 KN/m^2 on the floor

So, total Live Load on each floor = size of plan x L.L = 735.6 x 2.875 = 2114.85 KN.

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3) *Lump Mass Modeling:* Mass lumping is a careful step in seismic analysis to impose horizontal deformations. It is a Finite Element Method (FEM) related technique that has used for calculation of seismic load of a structure, where it discretion the distribution of mass of elements is lumped at joints or nodes.

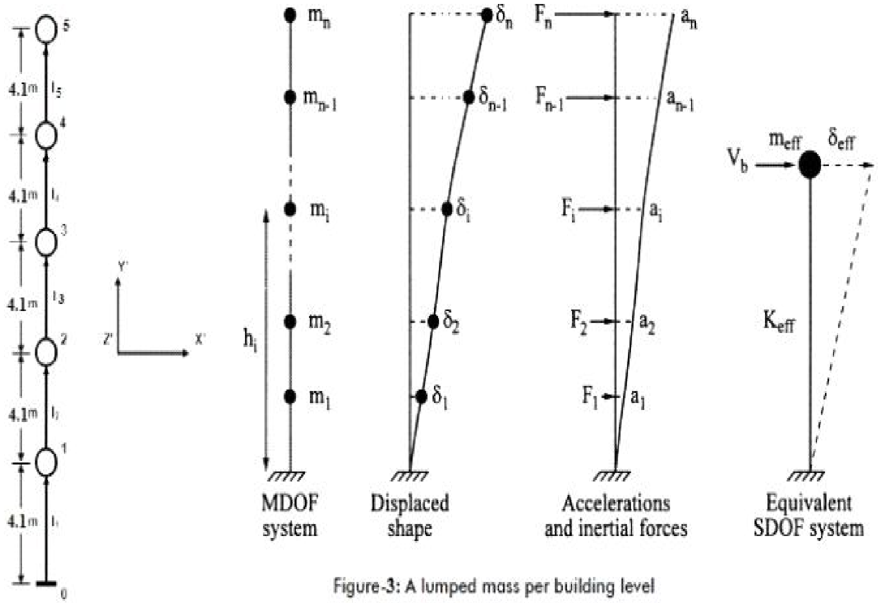

Figure-3: A lumped mass per building level

We have to assume weight of particular storey, which lumped at centre point & converting in this multistory building to single degree of freedom (SDOF) system. That's why we have to consider half of the storey from the upper side and from the bottom side , for each and every floor while calculating storey weight. And the remaining portion will be the half of the Top one, i.e. ROOF. So, for roof structures, we have to consider only half of the storey of upper one portion.

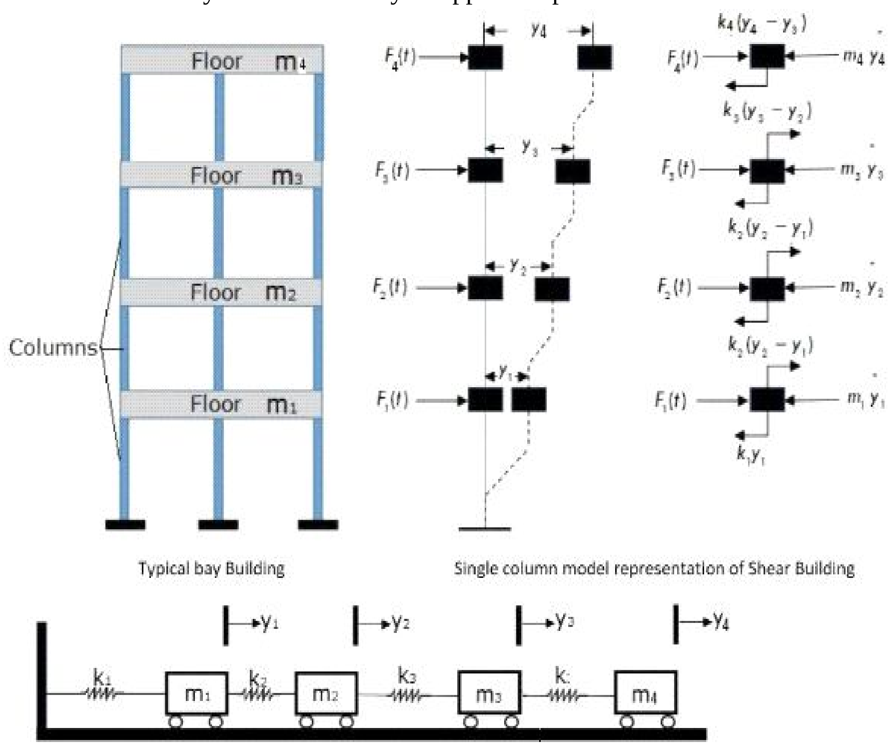

Figure-4: Multimass-spring model for a **four** -story Shear Building

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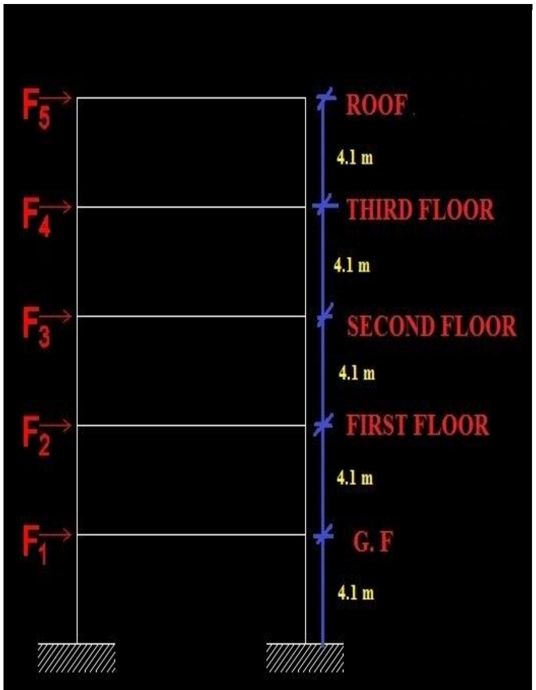

Figure-4.1:Distribution of Seismic Lateral Force, F_x

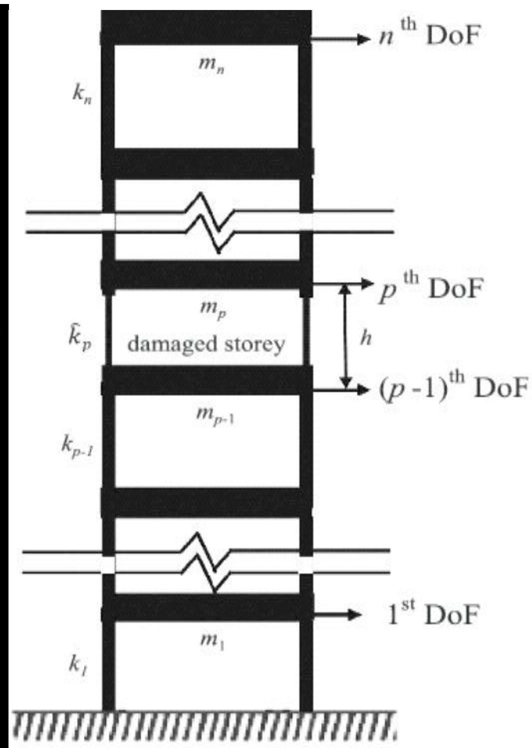

Figure-5: Lump mass modelling

4) *Design Load From Seismic Weight*

a) *Dead Load*

i) *Seismic Load for Roof Floor*

= Total weight of roof in each storey
= D.L + L.L , (since, live load on roof =0)
= D.L =All the self weight for roof
= Roof slab + Beams + Columns + Wall
= (4229.7 KN) + (1862.425 KN) + [(195.57 KN/m) x {(1/2) x (4.1 m)}]
+ [(1160.625 KN/m) x {(1/2) x (4.1 m - 0.6 m)}]
=4229.7 + 1862.425 + 400.918
5 + 2031.09 = 8524 KN
Therefore, seismic Load for ROOF of the structure = 8524 KN

ii) *Seismic Load for Floor*

= Total weight of floor in each storey
= D.L + L.L
Dead load for each floor = Floor slab + Beams + Columns + Walls
= (3126.3 KN)+ (1862.425 KN) + {(195.57 KN/m) X (4.1 m)}
+ { (1160.625 KN/m) (4.1 m – 0.6 m)} = 9852.46 KN
Therefore, Seismic Load on each FLOOR structure = D.L +L.L = 9852.46 + 2114.85
= 11967.31 KN

Seismic Load on Total Building-
= Seismic load on total floor + Seismic load on roof of the structure
= (Dead Load on each floor x No. of floor) + Roof Load= (11967.31 x 3) + 8524
= 44425.93 KN
Therefore, Total seismic weight of the Building, W = 44425.93 KN.

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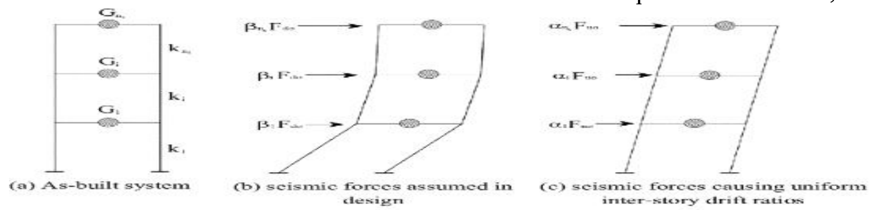
B. Base Shear Calculation

Due to the seismic ground acceleration at the base where the maximum lateral earthquake force occurs, called Base Shear.



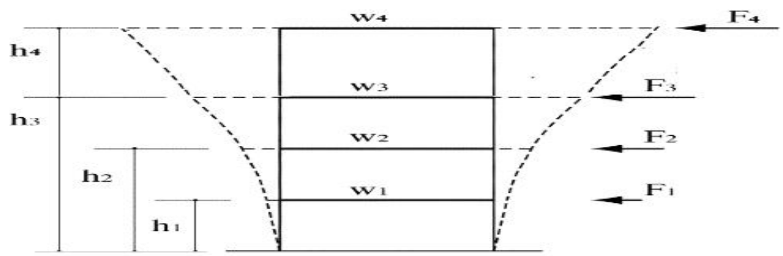


Figure: 6 - Base shear due to earthquake

Base Shear, $V_B = A_h \times W$,…………………………….. eq.1

$A_h = (Z/2) \times (I/R) \times (S_a/g)$,………………………………….. eq.2

Here, Z = Zone factor, depending upon on the location of Area/Zone/City.

Since, Silchar Airport is located under Seismic Zone- V

As per IS: 1893 (Part-1)-2016, Annex-E,

Table 2 Zone Factor, *Z*
(*Clause* 6.4.2)

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

Z = 0.36 (Seismic Zone- V under Guwahati city)

Table 6 Importance Factors, *I*
(*Clause* 6.4.2)

Sl No.	Structure	Importance Factor
(1)	(2)	(3)
i)	Important service and community buildings, such as hospitals; schools; monumental structures; emergency buildings like telephone exchange, television stations, radio stations, railway stations, fire station buildings; large community halls like cinemas, assembly halls and subway stations, power stations	1.5
ii)	All other buildings	1.0

I =1.5 , (since it is a Public building)

R = Response Reduction Factor, depends upon of Type of soil-> OMRF or Ordinary Moment Resisting Frame and SMRF A special Moment Resisting Frame.

Since, this structure is a public building. So, generally provide special moment Resisting Frame (SMRF). R = 5

S_a/g = Depends upon the time period.

Time period, $T = (0.09 \times h)/ (d)^{1/2}$, where h = Total height of the building

= 4.1 x 4 storey = 16.4 m

d = value of dimensions of the building which is along the direction of the earthquake.

Consider, Earthquake comes along the longer direction of the Building.

i.e., d = 56.025 m.

$T = (0.09 \times h)/ (d)^{1/2} = (0.09 \times 16.4)/ (56.025)^{1/2} = 0.197$ sec.

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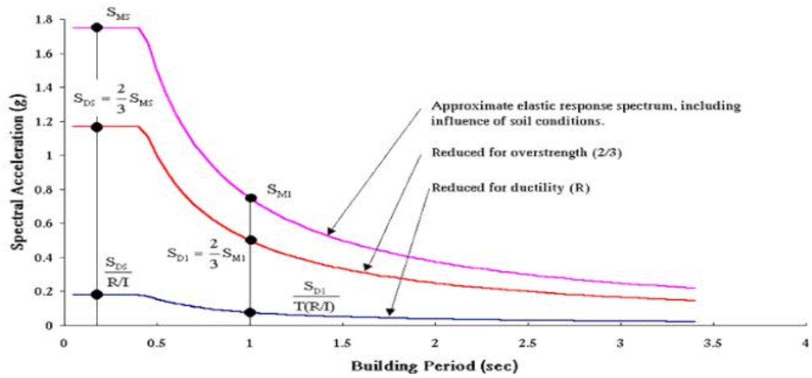

Figure-7: Response Spectrum

Therefore, natural time period, T = 0.197 sec. , i.e., $0 < T < 0.4$ sec.
So, as per IS:1893 (Part-1)-2016,

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.00 \end{cases}$$

For soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.67 \\ 1.67/T & 0.67 \le T \le 4.00 \end{cases}$$

Therefore, $(S_a/g) = 2.5$
Putting the values on eq.2, results-
$A_h = (Z/2)\,x(I/R)\ x\ (S_a/g) = (0.36/2)\,x(1.5/5)\ x\ (2.5) = 0.135$
Finally, from eq.1, Base Shear, $V_B = A_h \times W = 0.135 \times 44425.93 = 5997.5$ KN
Base Shear, $V_B = 5997.5$ KN

C. Distribution Of Design Force

Vertical distribution of base shear to different floor levels-> The design shear ($\mathbf{V_B}$) computed shall be distributed along the height of the building as per the following expression-

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

where

Q_i = **Design lateral force at floor *i*,**
W_i = **Seismic weight of floor *i*,**
h_i = **Height of floor *i* measured from base, and**
n = **Number of storeys in the building is the number of levels at which the masses are located.**

Floor	W_i (KN)	H_i (m)	$W_i H_i^2$ (KN)	$(W_i H_i^2)$ / sum$(W_i H_i^2)$(KN)	Q_i (KN)	V_i (KN)
4	8524	16.4	2292615.04	0.44874	2691.318	2691.314
3	11967.31	12.3	1810534.33	0.35438	2125.394	4816.712
2	11967.31	8.2	804681.9244	0.1575	944.61	5716.322
1	11967.31	4.1	201170.4811	0.03937	236.1216	5997.45

So, from the table, final $V_i = 5997.5$ KN
Therefore, maximum shear at the Building = 5997.5 KN.

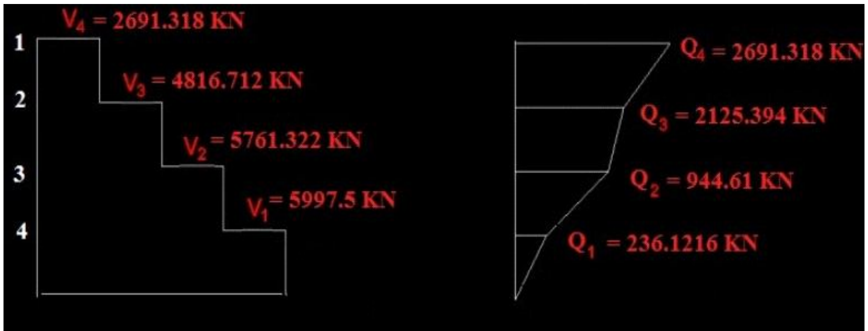

Figure-8: Distribution of Shear, V_x Distribution of Overturning Moment, M_x

IV. CONCLUSION

The present study was undertaken to evaluating seismic analysis and design aspects to ensure that the building is safe from earthquake collapse. On the view of earthquake resistant building, it can be bear the seismic load without failure of structures resulting to save loss of live, money and structural health. Proper earthquake resistant structures gives much advantages to structure from unwanted extra loads and money. Not only the designing of building but also quality of materials with advanced techniques gives a wide positivity against structural failure.

V. ACKNOWLEDGEMENT

Abdul Aziz was born in 1994 at Nilambazar, Karimganj district of Assam. He pursed his bachelor degree in Civil Engineering from Holy Mary Institute of Technology, Hyderabad under J.N.T. University Hyderabad in 2017 and join in Master of Technology in Civil Engineering with specialisation in Structural Engineering and Construction Management from Golden Valley Integrated Campus, previously B.E.S Group of Institution, Angallu, Chittor district of Andhra Pradesh under J.N.T University Ananatapur. He has join at Airports Authority of India as an Graduate Apprentice Trainee (GAT) and completed one year of Training Service at Silchar Airport. He is also connected with many Civil and Structural Engineering societies and Associations as Associate Member in Indian Association of Structural Engineers (IASTRUCTE), Professional Member of Institute for Engineering Research and Publication(IFERP), Student Member of International Association for Bridge and Structural Engineering (IABSE). He has published research paper entitled 'Analysis on mix design of M25 grade of Concrete- A case study on modification of terminal building at Silchar Airport'. His research interest on Concrete Technology, Analysis and Design of various structure, Construction Material science and Management. His thesis entitled 'A case study on modification of terminal building at Silchar Airport'.

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