SEISMIC ANALYSIS OF SOFT STOREY BUILDING

DISSERTATION-II

Submitted by

KRISHNA KANT

In partial fulfillment for the award of the degree of

MASTERS OF TECHNOLOGY

IN

STRUCTURAL ENGINEERING
(CIVIL ENGINEERING)

Under The Guidance of
Miss Sristi Gupta
Assistant Professor

LOVELY PROFESSIONAL UNIVERSITY

Phagwara – 144401, Punjab (India)

LOVELY PROFESSIONAL UNIVERSITY

DECLARATION

I hereby declare that the project work entitled "SEISMIC ANALYSIS OF SOFT STOREY BUILDING" is an authentic record of my work carried out as requirements of Dissertation-II Project for the award of M.Tech. in Structural Engineering from Lovely Professional University, Phagwara, under the guidance of Miss. Sristi Gupta during August to December 2017.

Name of Student: Krishna Kant
Registration Number:11600970

Miss. Sristi Gupta
Department of Civil Engineering

(Signature of Student)

CERTIFICATE

Certified that this project report entitled "**SEISMIC ANALYSIS OF SOFT STOREY BUILDING**" submitted by "**KRISHNA KANT"** registration no 11600970 of Civil Engineering Department, Lovely Professional University, Phagwara, Punjab who carried out this project work under my supervision for the Award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

Head of Department
(Structural Engineering)

Signature of Supervisor
Miss Sristi Gupta
Assistant Professor
Department of Civil Engineering

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ABSTRACT

Parking lot for residential building in inhabited cities become a major draw backs owing to rising population. For that in construction of building use of first open story now widely used. This structure have infill masonry walls at ground floor and for above to ground floor is filled with masonry walls, define as soft story or open grounded story. According to safer design of building plastic hinges developed in column at soft story is not allowable .if the soft story is at higher level so we can eliminated the displacement. For the irregular building, soft story shifted to above level, the effective story drift and displacement will decrease as compare to regular building. And moreover, if we increase the size of the column it reduces the drift but found increased shear force and bending moment in first level. To reduce the effect of stiffness and bending moment, shear wall and cross bracing system is more effective. As researcher found, that soft story is less effective against the strong shaking of ground. So the ultimate solution to this problem by increasing stiffness of first story of building

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1.1 Soft Storey

Population increase since the last decade has been enormous, the automotive parking lot for residential residences in inhabited cities has become a matter of major drawback. Thus constructions of multi-storeyed buildings with open initial floor has become a standard observe within the world. The traditional method has been to utilize the bottom floor of the building itself for parking or reception lobbies within the initial floor. These forms of buildings possessing walls without brick infill ground floor, however entire higher storeys infilled with masonry walls are referred to as "Soft storey" or "Open Ground Storey Building". The poor and destructive response of such buildings in various countries during earthquakes posed challenges for the construction of buildings with soft 1st story. This floor is understood as weak floor as a result of its stiffness is in contrast to higher floors, thus it simply collapses by earthquake. Owing to wrong construction practices and cognitive content for earthquake resistant style of buildings in our country, most of the prevailing buildings are at risk of future earthquakes. So, prime importance ought to run to the earthquake resistant design. According to IS 1893(Part-I): 2002, "a storey of a building is being said soft storey if it has 70 % less stiffness of the above storey or 80% less of the average of above three storey"

Fig 1:-A Soft Storey Building

The higher storeys have wall panels infilled with bricks. Apparently, because of no infill wall panels in the first storey makes most of the buildings to possess first storey as soft storey. The overall dynamic base shear due to earthquake on a building depends on the natural period. The dynamic force distribution on a building depends on it is stiffness and mass distributed over the building height. The buildings having first storey soft, the up storeys having stiffer behaviour show lesser inter storey displacement, while the displacement in the first soft storey is observed to be enormous. It is observed that for every third building the strength in columns in first storey is high which is due to the maximum shear in the first storey. The force distribution in the lateral direction is non uniform on the buildings in which the stiffness in the storeys tend to change suddenly. This has detrimental impact on the response of building during dynamic excitation. These building are needed to be assessed by performing dynamic analysis and should be designed with utmost care. Past earthquakes have proved critical damage aspects with the building having soft storeys such as the Northridge 1994, San Feranando 1971 and Bhuj 2001. The earthquake in Jabalpur proved the lacking of design aspects in the indian building codes with respect to the buildings with soft storey.

2.1 Scope

1. Using the concept of Soft Storey enough spacing can be safely utilized for different purposes.
2. The purpose of durability and ductility of the structure in seismic zone concerned can be achieved.
3. After taking the effective measures soft storey structures can be used in highly seismic zone.

2.2 Objective

1. Analyse the behaviour of building in case of dynamic loading.
2. Remedial measure to decrease the seismic vulnerability of building.

1. **Suchita Hirde and Ganga Tepugade(2014),** Discussed the performance of a building with soft storey at different levels along with ground level. The past earthquakes have manifested that if in a building there are concentration of forces and deformation due to discontinuity in the stiffness and mass may cause the failure of structural members which eventually may cause the collapse of the building. The nonlinear static pushover analysis is carried out. They have observed that in the columns of the ground level soft storey the plastic hinges were developed which is not considered safe for the design of the building. It has been observed that the displacement reduces when the soft storey is provided at higher level. They concluded that after the provision of shear walls to the building in consideration there was no formation of hinges in the columns and the lateral displacement was also reduced.

2. **Hiten l. Kheni and Anuj K. Chandiwala(2014),** They have suggested a weak beam and strong column for the earthquake resistant design of structures because it has been observed in the past earthquakes that the buildings that collapsed were mostly consisted of the opposite characteristics in which the columns yielded prior to beams and lead to collapse of the structure. They have observed that the displacement according to the lateral load patterns with codal provisions are smaller for the upper stories and the displacement patterns of the considered building is independent of the no of stories. They have observed that the displacement is more accurate with the first model lateral load pattern but simultaneously they have observed that as the number of stories increased the deviation in the results of the lateral load patterns decreases.

3. **Rakshit Gowda K.R. and Bhavani Shankar(2014),** They compared the behaviour of multi storeyed RC frame regular building and vertically irregular building(stepped building). They have proided the soft storeys at various levels of building for different load combinations. They have analysed all the building models in seismic zone V and have analysed them for static and dynamic earthquake loading. They have compared the result of the frame with infill, bare frame and the building with different position of soft storey. They have observed that the dynamic behaviour of the building with infill improves compared to soft storey provided. They have concluded that the building with complete infill exhibits minimum displacement subjected to both static and dynamic loading, while the bare frame exhibit maximum displacement subjected to similar nature of loading. In vertically irregular structure it was observed that the inter storey drift was maximum compared to that of regular structure. The base shear in the frsme with complete infill was observed to be more compared to that of bare frame model in both X and Y direction. If the soft storey is provided in the 5th floor in case the building can not be provided with complete infill, it has been observed to be sustainable compared to that when the soft storey

is provided in the 10th floor as the displacement is more in this case. For the time period mode-1, it is observed that the displacement is more in the irregular building compare to regular building.

4. **Miss Desai Pallavi T. and Prof. Mrs A. Ranjan(2013),** They have worked on the effect of soft storey on RC structures. They change in lateral stiffness and ductility of buildings having soft storey poses the structural vulnerability to dynamic loading. Hence the assumption of effective stiffness during RC frame member modelling is significant for seismic design as it directly effects the period and dynamic response of the building. The soft storey tends to increase the seismic horizontal load and induced moment in the columns. Moreover it increases the axial force in certain columns which creates complicated column behaviour. In the study four models have been considered in which Model 1 includes RCC column with 3m Storey height, Model 2 includes composite column with 3m height ground storey, Model 3 includes composite column of 3m height at ground and 1st storey and Model 4 includes composite column with 4m height ground storey. They have concluded that the stiffness in Model 2 is higher than Model 1. Also it has been observed that the stiffness of the storey above the ground storey is less comparatively. Model 2 and Model 4 analysis indicate having higher stiffness compared to Model 3.

5. **Amit S. Gawande (2013),** has studied the seismic response of ground soft storey of a building. He has investigated the seismic response of a building with ground soft storey under dynamic excitation along with design of masonry infill RC structure. The objective of the study has been to analyse the response of RC frame with respect to its storey stiffness, storey drift, fundamental natural period moment and shear with the help of equivalent static and dynamic analysis using ETABS.

6. **Nikhil Agrawal, et. al (2013),** They discussed about masonry infill with opening and without openings in RC frame buildings to increase the stiffness and the strength of RC frame structures. They have taken a G+5 storey college building in seismic zone III. The stiffness of infilled frames have been calculated by modelling the infill using "Equivalent diagonal strut method". They have analysed the models including bare frame, strut frame, and strut frame with centre and corner openings in proportion to 15% by using STAAD-Pro. They observed the stiffness of the structure has increased with infill panels. Maximum deflection is found more while providing openings in centre compare to the openings at corners. It has also been observed that the deflection in infilled frame is less compared to that of bare frame. In case of frame infilled panel with centre opening the axial load carrying capacity of column increases. With the increase proportion of openings the stiffness decreases. From the analysis the result indicates that the deflection drastically reduces in case of infill frame with opening as compare to bare frame. However the deflection is found more in the top storey because the effect of seismic force is more on this storey.

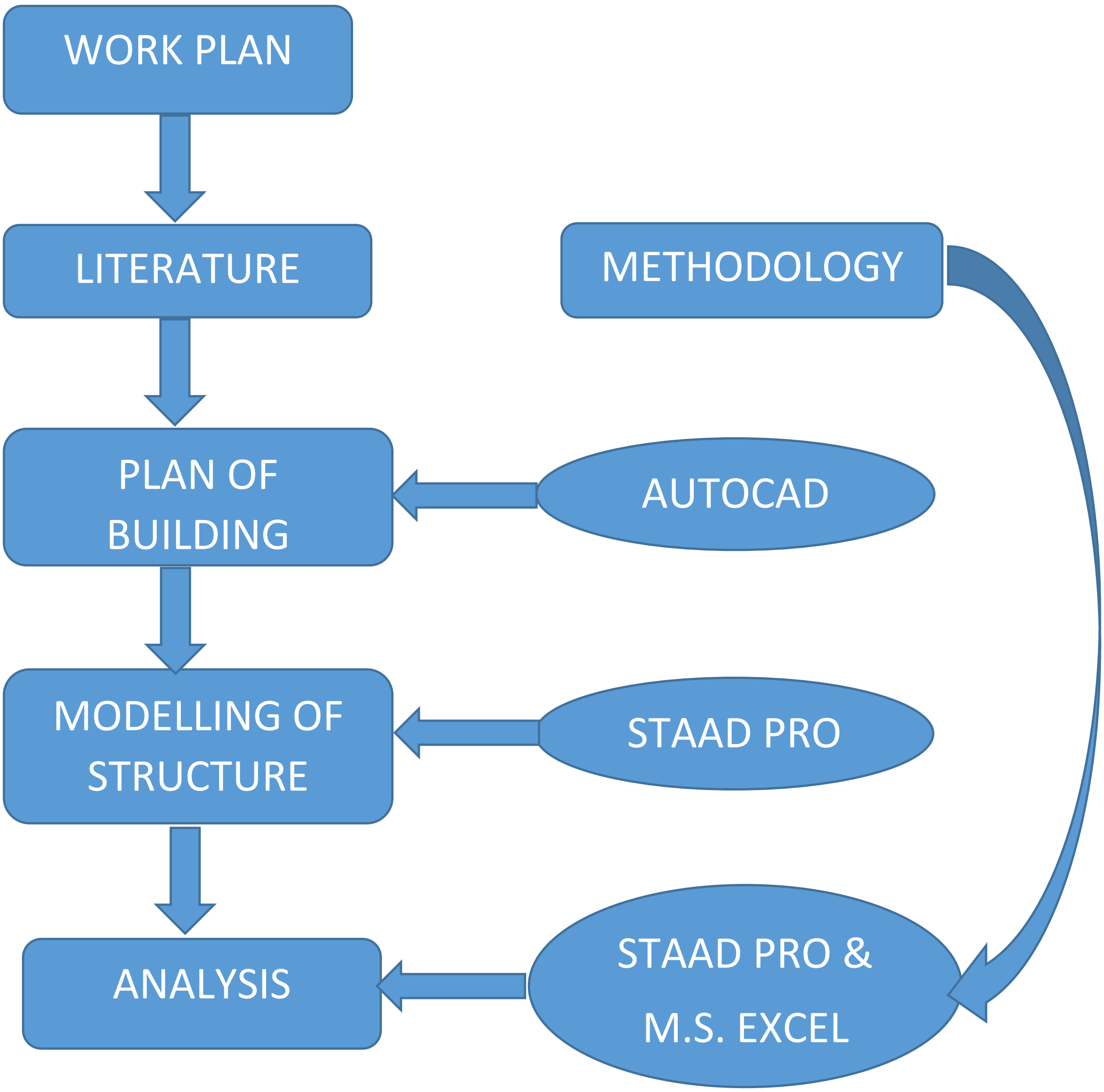
7. **Dande P.S. and Kodag P.B.(2013),** They discuss about that we can improve the strength of the soft storey and they give two ways for it; (a) By provision of more stiffness to the column and (b) By provision of infill wall panel in the building frame at each corner. The modified soft storey provision has been compared with respect to the complete infill wall frame and bare frame models. They have concluded that the columns of the first storey in a building with soft ground storey are subjected to larger Shear Force and Bending Moment. However after providing the infill wall panels to the soft ground storey, the strength of columns in the first storey is seen to be improved and the Shear Force and Bending Moment reduced. It has been that the fundamental time period of a bare frame model is more as compared to the fundamental time period provided by the code. This indicates that the analysis of a bare frame model is inappropriate. It is observed that when lateral load applied to bare frame model each floor's mass acts independently and each floor is observed to drift with respect to adjacent floor. Due to this action the building behaves in a ductile manner and shear force is distributed to each floor. But when infill is provided the mass of each floor acts as single mass the drift of each floor is reduced and the magnitude of lateral force is seen to act as a base shear to a large extent and the shear in the columns of the ground storey is observed to increase.

8. **Narendra Pokar, et al.,** In this paper they discussed about the effect of soft storey with small scale model. It is essential for testing a scale model for optimal analytical model and the provision of special design for those structures. They have taken 2 bay G+4 stories RC frame model for behaviour of soft storey by using SAP software.
   They have taken 5 models;
   1. Full Scale RC model without infill in all floors. (M1)
   2. Full Scale RC model with infill in 1^{st}, 2nd, 3rd and 4^{th} floor. (M2)
   3. Full Scale RC model with infill in 1^{st}, 2nd, 3rd, 4th floor and bracing at ground floor. (M3)
   4. Small Scale RC model with 1/16.66 scale without infill at ground floor. (M4)
   5. Small Scale Steel model with 1/16.66 scale without infill at ground floor. (M5)

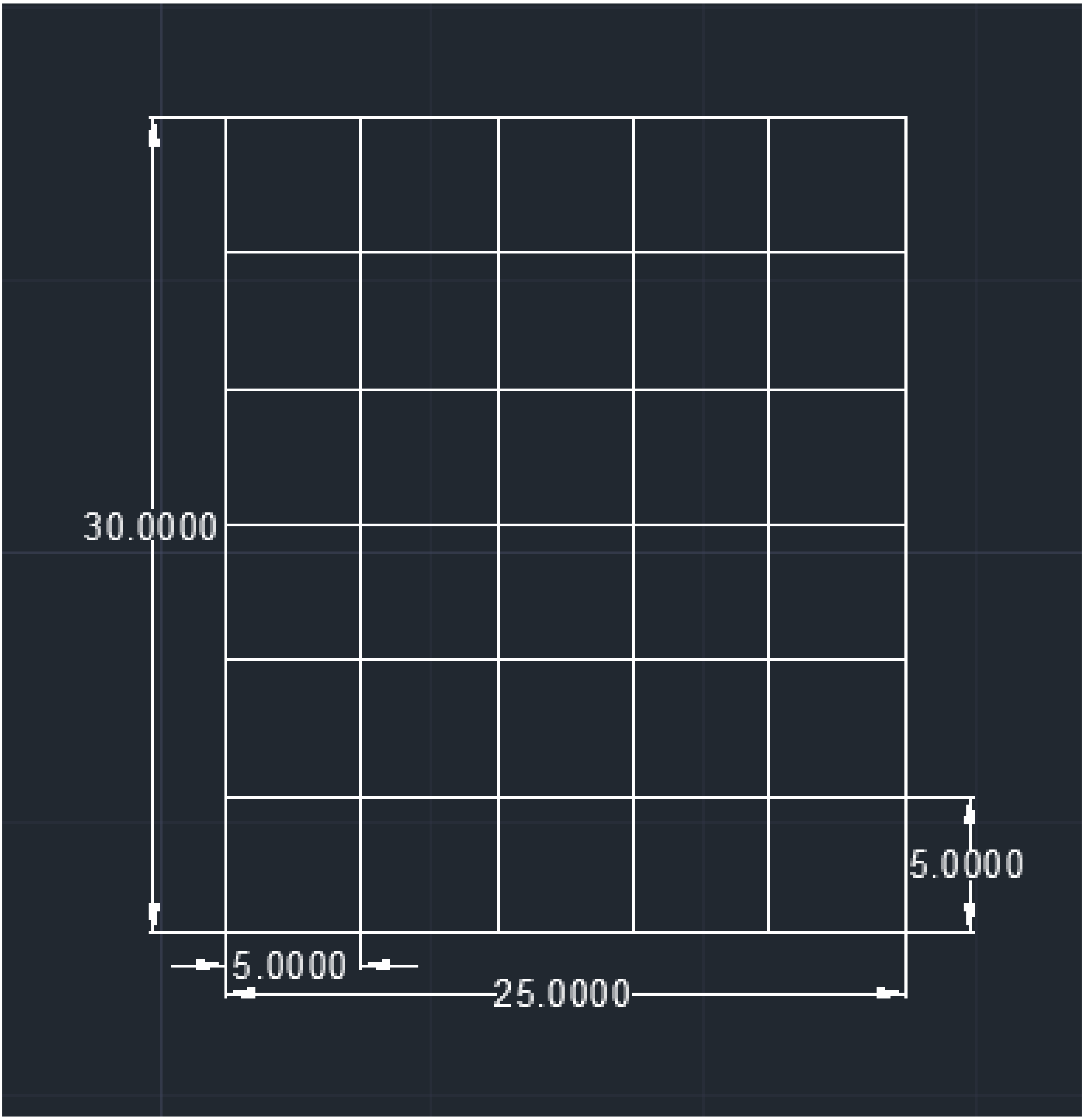
   The data of Bhuj earthquake 2001 has been taken for Time history analysis for Model M1, M2 and M3 at different load combination and Response spectrum analysis also been used for the analysis. Model M4 and M5 are analysed as per similitude rule with scaled time history. It is observed that displacement slope changes in X direction when the upper floors of the building are provided with masonry infill which increases the stiffness of the building. This tends to decrease the strength of the ground story columns which is overcome by increasing the size of the columns at the ground story. Moreover the stiffness of these columns can be increased by providing the masonry infill in the ground storey on all four sides.

9. **P.B. Lamb and Dr R.S. Londhe(2012),** The vertical stiffness irregularity in a building is the main cause for the formation of soft storey in a building. They have taken a multi-storey building with soft ground storey in zone IV and observed the response of building including drift, shear force, bending moment and stiffness by using SAP2000. They observed that the provision of shear walls & cross bracings has proved to decrease the stiffness irregularity and bending moment in columns and the higher column size also helps to decrease the drift but due to the higher size of columns, shear force and bending

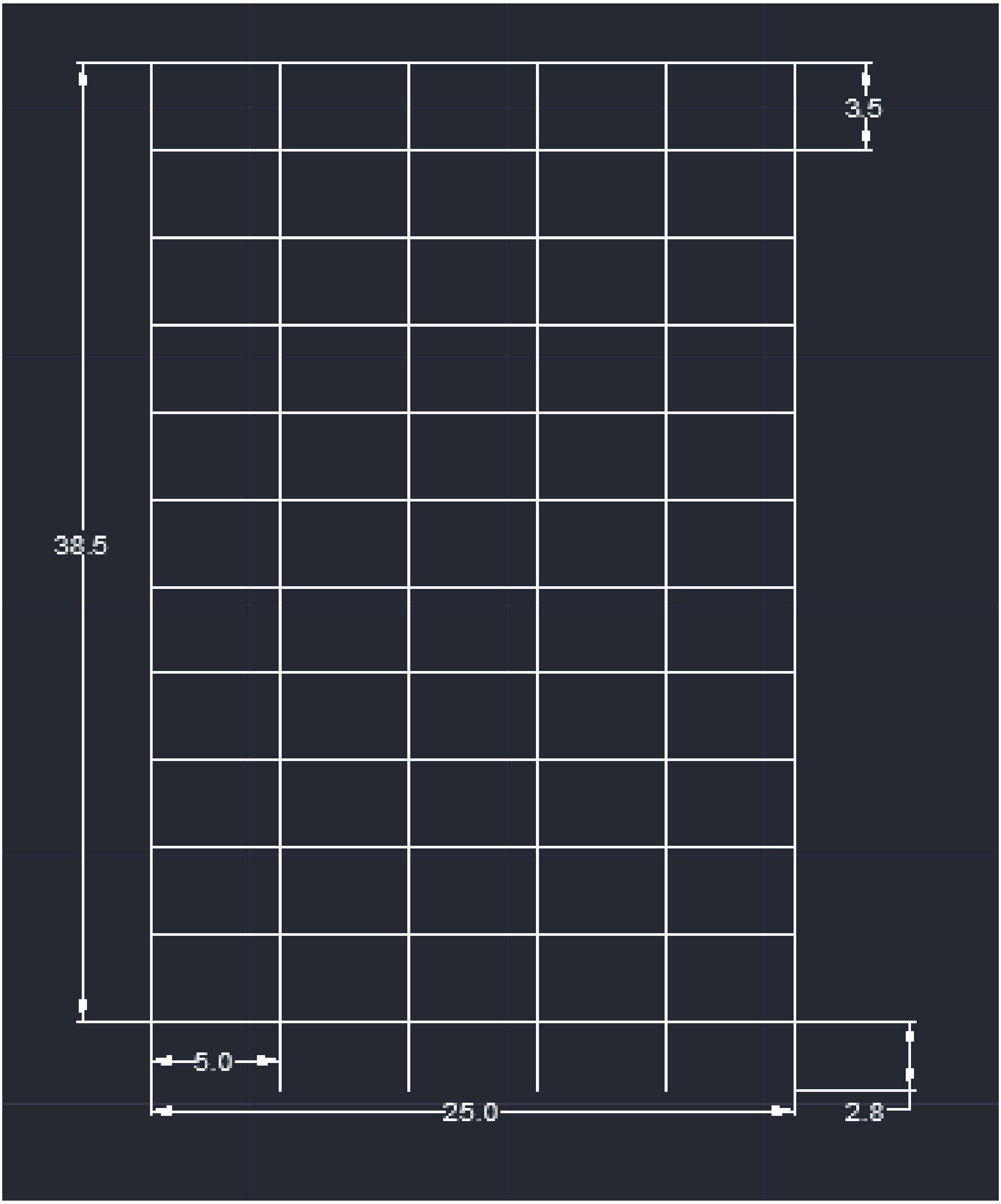
.moment increases in the first storey. It is observed that infill with masonry is not helpful to reduce the demand of strength in first storey columns. However stiffness irregularity reduces to a large extent. The provisions of bracings enhances the stiffness in the first storey. It is observed that the drift profile of the lateral displacement reduces after providing bracings. The provision of shear walls has effectively decrease the drift and stiffness irregularity but simultaneously it has increased the shear force and bending moment in the first storey. They have observed that the light weight masonry infill increases the first storey stiffness and enhances the strength of the columns in the first storey.


WORK PLAN
LITERATURE
METHODOLOGY
PLAN OF BUILDING
AUTOCAD
MODELLING OF STRUCTURE
STAAD PRO
ANALYSIS
STAAD PRO & M.S. EXCEL

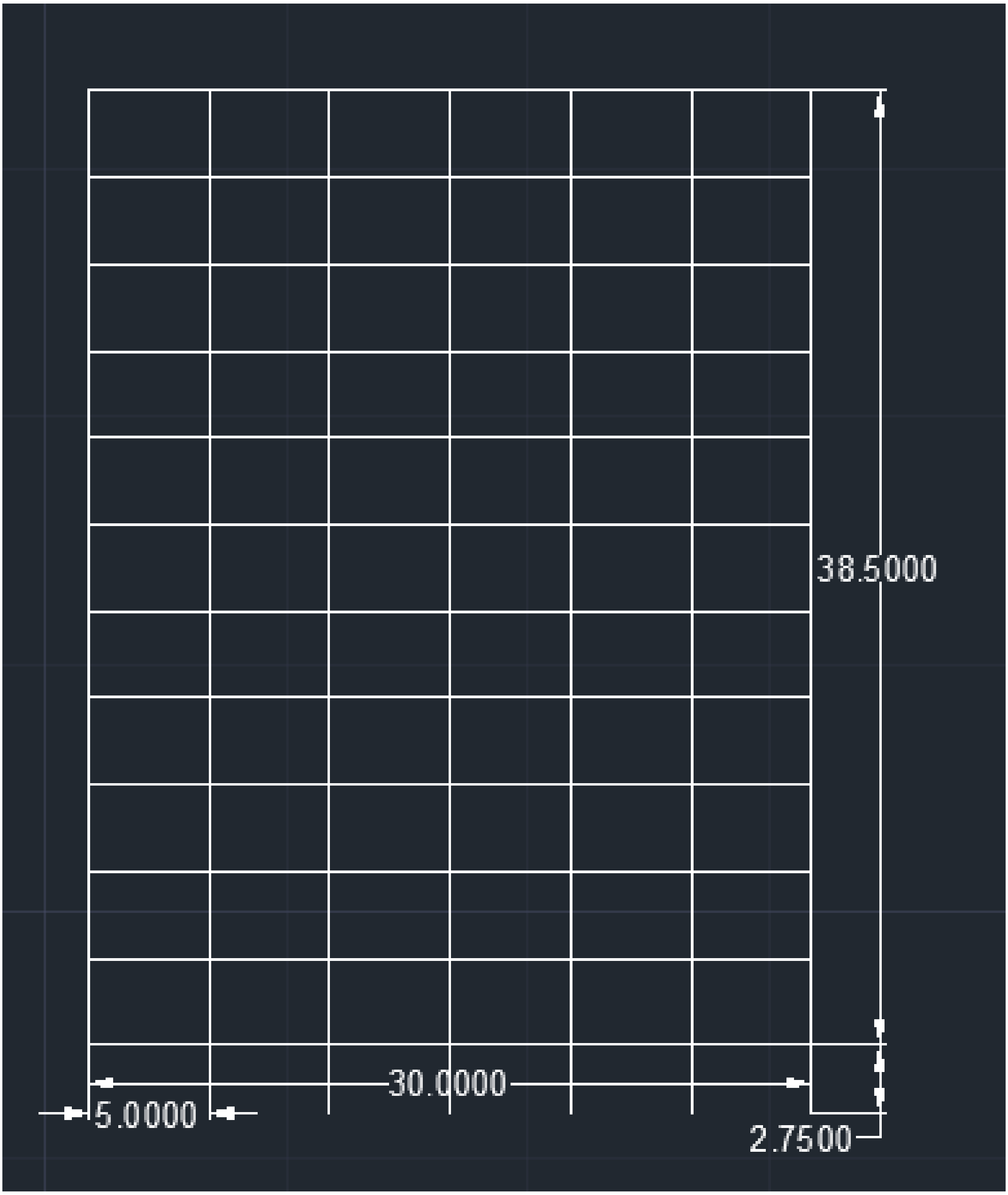
5.1 Plan of Building



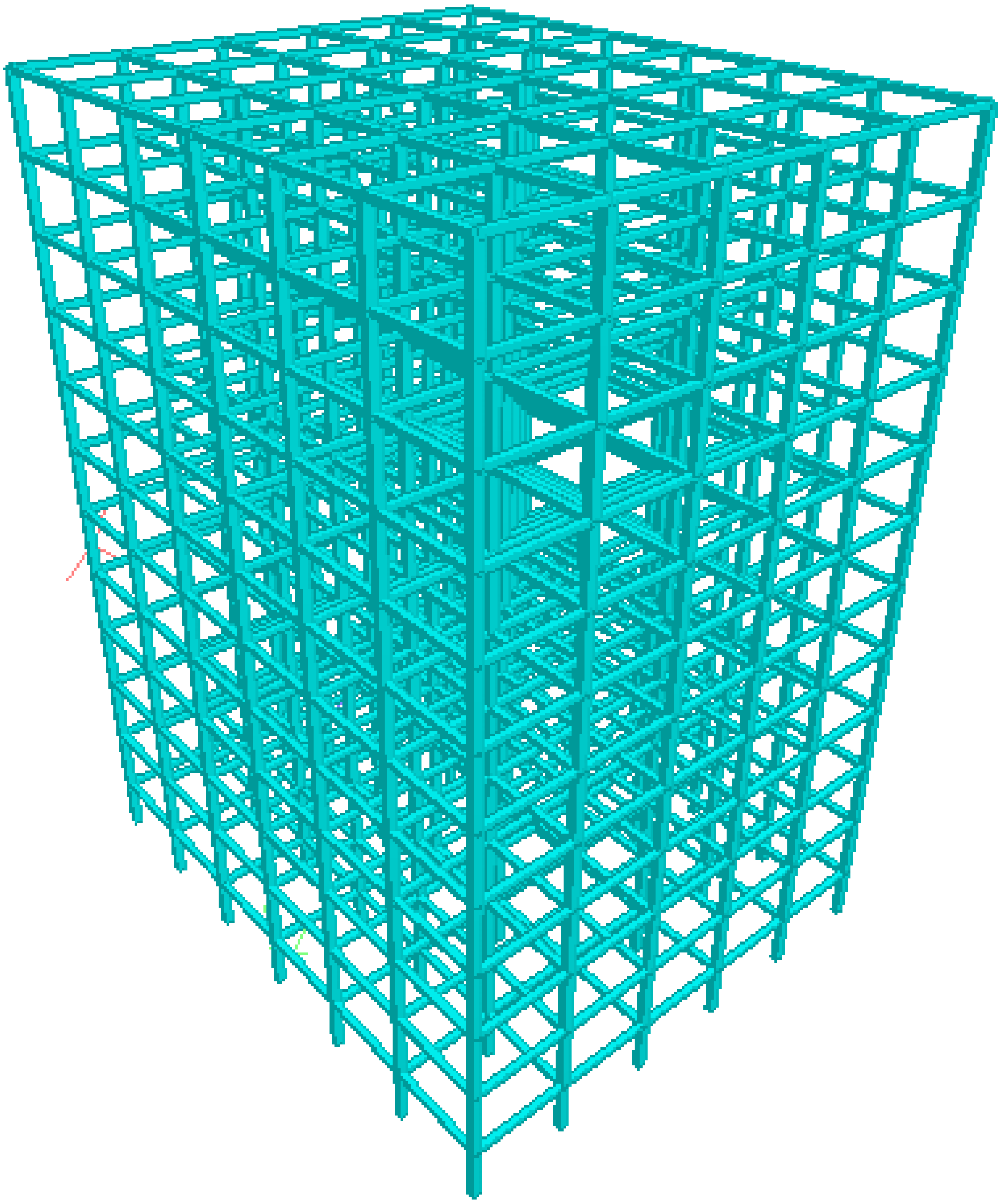
5.2 Front Elevation of Building



5.3 Side Elevation of the Building



5.4 Model of the Building

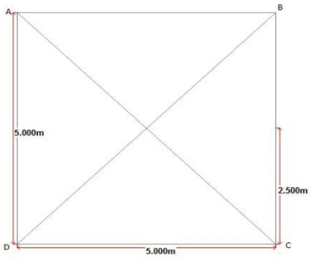


5.5 Design

LOAD CALCULATION

1 **SLAB-**

Lentth,l=	5	m	5000	mm
width,b=	5	m	5000	mm
depth,D=	0.225	m	225	mm
Unit wt of conc. ϒ=	25	kN/m^3		
Load= lxbxDxϒ			5	kN/m^2



2 **BEAM-**

Area of triangle(Δ)= 0.5*b*h — 6.25 m^2
Load on beam, W= Δ*length of adjacent beam — 31.25 kN/m

Load on External beam= 31.25 kN/m
Load on Internal beam= 62.5 kN/m

Reactions or Load on Supports-
For External beams= Wl/2 — 78.125 kN
For Internal beams= Wl/2 — 156.25 kN

The above load will act as U.D.L on beam AB,BC,CD,DA

3 **COLUMN-**

	Exterior(in kN)		**Interior(in kN)**
	Corner	**Intermediate**	
10th Storey	78.125	156.25	312.5
9th Storey	156.25	312.5	625
8th Storey	234.375	468.75	937.5
7th Storey	312.5	625	1250
6th Storey	390.625	781.25	1562.5
5th Storey	468.75	937.5	1875
4th Storey	546.875	1093.75	2187.5
3rd Storey	625	1250	2500
2nd Storey	703.125	1406.25	2812.5
1st Storey	781.25	1562.5	3125
Ground Storey	859.375	1718.75	3437.5

Load for column	Exterior	Corner	859.375
		Intermediate	1718.75
	Interior		3437.5

TWO WAY SLAB DESIGN

Size of Slab	Lx=	5	m	5000	mm	
	Ly=	5	m	5000	mm	
Live Load				3	kN/m2	
Finish Load				1	kN/m2	
Conc Grade	fck			20	N/mm2	
Unit Weight of Conc.				25	kN/m3	
Steel Grade	fy			500	N/mm2	
beam thickness		0.15	m	150	mm	
Effective Short Span				5150	mm	
Span to effective depth ratio			1.5*20	30		
depth	d=	171.6667	mm	200	mm	(Take)
Assume						
Clear cover	d'=			25	mm	
Dia of bar				10	mm	
Overall depth	D=Depth+Clear Cover			225	mm	
Effective depth	d=D-Clear Cover-0.5Dia of bar			195	mm	
Effective Span		lex=		5195		
		ley=		5195		
	r=	ley/lex		1		
Loads on Slabs	Self Wt			5.625	kN/m2	
	Finish			1	kN/m2	
	Live			3	kN/m2	
Total load				9.625	kN/m2	
Factored load	p			14.4375	kN/m2	
	αx=	(r^4/(1+r^4))/8		0.0625		
	αy=	(r^2/(1+r^4))/8		0.0625		
Design Moments	Mux=αx*Wu*lex^2			24.35248	kNm	**Shorter Span**
	Muy=αy*Wu*lex^2			24.35248	kNm	**Longer Span**

Design of Reinforcement

Ast = ((1-(1-(4.6Mu/(fckbd^2)))^0.5)bdfck)/2fy

Required Ast	Ast,x=	217.9577	mm^2/m	
	Ast,y=	272.4471	mm^2/m	
Area of one bar	ast=(pi*d^2)/4	78.5	mm^2	

Spacing	X dir			360.1616	mm
	Y dir			288.1293	mm

Maximum spacing for primary reinforcement=300mm

Total No. of bars in X-direction	Nos.,x=Lx*Ast/ast	13.88266	
Total No. of bars in Y-direction	Nos.,y=Ly*Ast/ast	17.35332	

Hence Provided no. of bars

X- DIR		14
Y- DIR		18

Hence Provided Ast

1099	mm^2	219.8	mm2/m
1413	mm^2	282.6	mm2/m

Provided Spacing

X- DIR	357.1429	mm C/C	357	mm C/C
Y- DIR	277.7778	mm C/C	277	mm C/C

Checks-

1	Deflection-		(l/d)max	30	
			(l/d)prov	26.64103	Safe
2	Shear-	τv=	Vu/bd		
		Vu=	wu(0.5ly-d)	33.27844	kN/m
		So, τv=		0.170659	N/mm^2
		Pt=	100Ast,prov/bd	0.112718	%
		τc=		0.250174	N/mm2

For τc (From Table 19 IS 456			
Pt	**M15**	**M20**	**M25**
0.15	0.28	0.28	0.29
0.25	0.35	0.36	0.36
0.5	0.46	0.48	0.49

BEAM DESIGN

Length of Beam, l		5	m
Load, W		31.25	kN/m
Conc. Grade, fck		35	N/mm^2
Steel Grade, fy		415	N/mm^2
Unit weight of Conc		25	kN/m^3
Dia of bar,ϕ		16	mm
Factored Load	Wu=1.5*W	46.875	kN
Design Moment	Mu=Wu*l^2/8	146.4844	kNm

Xu,max/d= 700/(1100+0.87fy) 0.479107

d/b ratio varies brtween 1.5 to 3

Take d/b= 2

Limiting Moment Mu,lim= Ru*b*d^2

Ru= 0.36fck(Xu,max/d)(1-0.416(Xu,max/d))

Ru= 4.833577

Now equating Mu,lim and Mu we got-

d= (2Mu/Ru)^(1/3) 392.8115 mm

b= d/2 196.4058 mm

For Ast-

Ast = ((1-(1-(4.6Mu/(fckbd^2)))^0.5)bdfck)/2fy

Ast= 1288.551 mm^2

Provide 10 mm dia bar

ast= 3.14*ϕ^2/4 200.96 mm^2

No of bars Ast/ast 6

TABLE- Value of R_u.lim For balance section			
Grade concrete	Reinforcement		
	Fe 250,lim = 0.1489 *fck*	Fe 415,lim = 0.1381 *fck*	Fe 500,lim = 0.1330 *fck*
M15	2.333	2.071	1.995
M20	2.978	2.761	2.66
M25	3.722	3.452	3.325
M30	4.467	4.142	3.99
M35	5.211	4.833	4.655
M40	5.956	5.523	5.32

Design of Long Column

Axial Load	Pu =		859.375	kN
Effective Length-	lex=	5 m	5000	mm
	ley=	5 m	5000	mm
	b=	0.5 m	500	mm
	D=	0.5 m	500	mm
Unsupported Length-	lx=	5.5 m	5500	mm
	ly=	5.5 m	5500	mm
Concrete Grade	fck=		20	N/mm^2
Steel Grade	fy=		415	N/mm^2
	M1x=		15	kNm
	M2x=		60	kNm
	M1y=		10	kNm
	M2y=		55	kNm
Slenderness Ratio-	lex/D=		10	
	ley/b=		10	

Hence Long Column/Short Column

Minimum eccentricity-	ex=(lx/500)+(D/30)	27.66667	mm	
	ey=(ly/500)+(b/30)	27.66667	mm	
Moment due to minimum eccentricity	Mx=Pu X ex	23.77604	kNm	
	My=Pu X ey	23.77604	kNm	
Initial Moment-	Muix=(0.6M2X-0.4M1x)	42	kNm	Major Axis
	Muiy=(0.6M2y-0.4M1y)	37	kNm	Minor Axis
Additional eccentricity-	eax=D/2000(lex/D)^2			
	eay=b/2000(ley/b)^2			
Moment due to additional eccentricity	Max=Pu*eax*Ka	110	kNm	
	May=Pu*eay*Ka	55	kNm	
Compare Initial Moment and Moment due to minimum eccentricity	Mux,min=	42	kNm	
	Muy,min=	37	kNm	
Final Design Moment	MDX=Mux,min+Max	152	kNm	
	MDY=Muy,min+May	92	kNm	

5.6 Analysis of Model

Model analysed for-

Zone- V
Soil Type – Medium Soil
S.M.R.F.
Importance Factor= 1
Size of beam =200mm X 400mm
Size of Column= 500mm X 500mm

1. Base shear = Ah X w

   Ah= (Z/2) X (I/R) X (Sa/g)

   Sa/g= inv(0.075 h^0.75)= (0.075 X 38.5^0.75)^-1 = 0.86

   So, Ah= (0.36/2) X (1/5) X (0.86) = 0.031

   So Now Base Shear (Calculated) = 0.031 X 95859.89 = 2971.66 kN

   Base Shear (Analytical) = 977.6 kN

   Base Shear analytical should be less than calculated, hence safe.

2. Storey drift(Ground Soft Storey)= 0.2605 (Analytical)

   Storey drift (Ground Soft Storey)=0.004X3.5=0.014 (As per IS 1893 2002)

   Analytical Ground Soft Storey drift is greater than the drift as per IS 1893 2002, hence ground soft storey displacement is not appropriate and needs to be strengthened.

1. If soft storey is shifted to above storey the storey drift and displacement will decrease and it is also found more in irregular structure comparatively regular structures.

2. The displacements due to lateral loads as per codal provisions are less in the storey near the ground and more on the stories away from the ground level.

3. The higher size of columns is effective in reducing the drift, but it increases the shear force and bending moment in the first storey. Shear wall and cross bracings are found to be very effective in reducing the stiffness irregularity and bending moment in the columns.

4. Soft Storey buildings exhibit poor performance during a strong shaking. The solution to this problem is in increasing the stiffness of the first storey.

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