SEISMIC STRENGTHENING ANALYSIS & DESIGN (RETROFITTING) OF EDUCATIONAL BUILDING AT NEPAL

Abstract

Although the timing of a seismic event can be anticipated, it is a given that the damage it causes will be severe. The danger of earthquakes is substantially higher in Nepal than in many other metropolitan centres in developing nations. Uncontrolled development, subpar design, and poor building techniques have all contributed to the seismic risk. In the event of a significant earthquake, there will be significant property damage and loss of life. In order to minimise structural damage and lower mortality in the event of a major earthquake, it is strongly advised that buildings in cities like Kathmandu be designed and built with adequate care for the seismic load. Due to this, the design and construction of the structure have been prone to seismic zone.

Keywords: Retrofiting, Strengthening, SAP, Seismic

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I. INTRODUCTION

One of the most feared natural calamities is an earthquake. earthquakes are waves that vibrate the earth's surface as a result of disturbances deep within the planet. It is a natural occurrence that depends on a number of variables. When it impacts an ever-increasing concentration of material goods and people, it becomes extremely destructive. Nepal experiences earthquakes frequently. This is so because Nepal is located in the Himalayan range, where tectonic plate collisions force the Indian and Eurasian plates to subduct. As a result, there has been an enormous buildup of strain energy, which has led to rapid breakdown of rock masses along the faults, which in turn leads to earthquakes. There have already been significant earthquakes in Nepal that have left a huge human and material toll.

II. RETROFITING DESIGN – BACKGROUND

The result of an earth shake manisfests incredible pulverization because of unpredicted seismic movement striking broad harm to incalculable structures of changing degree i.e either full or halfway or sligth. This harm to Designs in its turn cause a hopeless loss of the existence with countless setbacks. Subsequently scared tenants might decline to enter the structures except if guaranteed of the security of the structures. from future seismic tremors. It has been seen that greater part of such tremor harmed structures might be securely reused, on the off chance that they are changed over into seismically safe designs by utilizing a couple retrofitting measures. This ends up being a superior choice taking care of the financial contemplations and quick haven issues as opposed to substitutions of structures. Additionally it has frequently been seen that retrofitting of structures is by and large more practical when contrasted with destruction and reproduction even on account of serious underlying harm. Accordingly, seismic retrofitting of building structures is one of the main viewpoint for alleviating seismic risk particularly in quake inclined nations. The need of seismic retrofitting of structures emerges under two conditions: (I) tremor harm structures and (ii) quake weak structures that poor person yet experience extreme tremors.

Retrofitting Strategies

Various method used for retrofitting of reinforced concrete buildings are:

1. **Structural level (or Global) Retrofit Methods:** Two approaches are used for structure-level Retrofitting.

   - **Conventional method:** This methods of retrofitting are used to enhance the seismic resistance of existing structure by elimination or reducing the adverse effect of design. It includes
     Adding Shear walls
     Adding Infill walls
     Adding steel bracings

   - **Non-Conventional Methods:** This methods of retrofitting are used to reduce the horizontal seismic forces. It includes
     Seismic base isolation
     supplemental damping device

2. Member Level (or Local) Retrofit Methods

Approaches Used for member level retrofit methods are:

- Jacketing/confinements
- Jacketing of columns
- Reinforced concrete jacketing
- Steel jacketing
- FRP jacketing
- Beam jacketing
- Beam-column jacketing

3. Adopted Retrofiting Strategy - Reinforced Concrete Jacketing: Reinforced concrete jacketing can be used as a strengthening or repair method. Prior to its jacketing, damaged areas of the existing members should be rectified. In order to achieve a strong column-weak beam design, jacketing columns serves two main purposes: (i) increasing the shear capacity of the columns; and (ii) enhancing the column's flexural strength through the use of longitudinal steel of the jacket that is continuous through the slab system and anchored to the foundation. It is accomplished by inserting fresh concrete into the joints between the beam and column and passing new longitudinal reinforcement through holes drilled in the slab.

4. Details for Reinforced Concrete Jacketing

Properties of Jackets:

- Match with the concrete of the existing structure
- Compressive strength greater than that of existing structure by 5 N/mm^2 (50 Kg/cm^2), or at least equal to that of the existing structure.

5. Minimum width of Jacket:

- 10 cm for concrete cast in place and 4 cm for shotcrete
- If possible, four-sided jacket should be used
- Narrow gap should be provided to prevent any possible increase in flexular capacity

6. Minimum area of longitudinal reinforcement:

- Spacing should not exceed six times of width of the new elements (the jacket in the case) up to limit of 60 cm.
- Percentage of steel in the jacket with respect to jacket area should be limited between 0.015 and 0.04
- At least, a 12 mm bar should be used at every corner for a four-sided jacket.

7. Shear stress in the Interfere: Chipping the concrete cover of the original member and roughening its surface may improve the bond between the old and new concrete.

8. Connector

- Connectors should be anchored in both the concrete such that it may develop at least 80% of the yeilding stress.
- It is better to use reinforced bars anchored with epoxy resigns of grouts .

Spacing of ties:			S=	(Fy*d^2)/(sqrtFck*tj)
			Fy=	500
			d=	10
			Fck=	25
			tj=	125
			S=	80
Provide spacing of ties 10mm dia @ 75 mm c/c.				

DESIGN DATA

1	Building Type	:	Educational Building	
2	Type of structure	:	Frame Structure (Rigid joined Frame structure)	
3	No. of Storey	:	4	
4	Concrete Grade	:	M 25	
5	Reinforcement Used	:	Fe 415	For Existing column
6	Cement Used	:	Fe 500	Retrofit Column
7	Load Taken	:	Educational Building	
	Class		3	kN/sqm
	Kitchen, Laundaries & Laboratories		2.5	kN/sqm
	Toilets & Bathrooms		2	kN/sqm
	Corridore, Passage & Lobby		4	kN/sqm
	Finishing Load		1.5	kN/sqm
8	Design Philosophy - Limit State Design Confirming IS : 456-2000			
9	Analysis Software Used =	SAP 2000	VER 16	
10	Earthquake Load Consideration =	IS 1893-2002		
11	Retrofitting Guidelines Consideration=	IS 15988-2013		

Load Combination			
Combination	1	=	(DL+LL)x1.5
Combination	2	=	(DLx1.2 + LLx1.2+ EQ1x1.2)
Combination	3	=	(DLx1.2 + LLx1.2+ EQ2x1.2)
Combination	4	=	(DLx1.2 + LLx1.2+ EQ1x-1.2)
Combination	5	=	(DLx1.2 + LLx1.2+ EQ2x-1.2)
Combination	6	=	(.9 X DL+1.5X EQ1)
Combination	7	=	(.9 X DL-1.5X EQ1)
Combination	8	=	(.9 X DL+1.5X EQ2)
Combination	9	=	(.9 X DL-1.5X EQ2)
Combination	10	=	(1.5 XDL +1.5 X EQ1)
Combination	11	=	(1.5 XDL -1.5 X EQ1)
Combination	12	=	(1.5 XDL +1.5 X EQ2)
Combination	13	=	(1.5 XDL -1.5 X EQ2)

Load Calculation

A. Slab Load

Slab Thickness	0.1	25	2.5
Floor finish			1
		Total	3.5

B. Beam Load

L	B	Density		WEIGHT/M	
0.45	0.25	25		2.81	
0.35	0.25	25		2.19	
			Total	5.00	kN/m

C. Column Load

	L	B	Density	H	WEIGHT
Column C1	0.3	0.3	25	3	6.75
Rc 500*500	0.5	0.5	25	3	18.75
				Total	**25.50** kN/m

D. Wall Load

Description	L	B	Density	H	Weight	% of wall	Adopt
4" wall	1	0.138	19	2.655	6.96	4.87	5.00
9" wall	1	0.23	19	2.655	11.60	8.12	10.00

III. SEISMIC WEIGHT OF THE BUILDING

As per IS 1893(part I): 2002 Seismic weight of the building = dead load + percentage of imposed load

As per IS 1893(part I): 2002 clause 7.3.1 percentage of imposed load = 25

Table 1: Joint Reactions

Joint	OutputCase	CaseType	F3
Text	Text	Text	KN
262	COMB15	Combination	150.857
263	COMB15	Combination	173.731
264	COMB15	Combination	151.955
265	COMB15	Combination	152.032
266	COMB15	Combination	152.929
267	COMB15	Combination	152.459
268	COMB15	Combination	162.617
269	COMB15	Combination	132.027
270	COMB15	Combination	423.084
271	COMB15	Combination	503.824
273	COMB15	Combination	370.319
274	COMB15	Combination	370.391
275	COMB15	Combination	428.055
277	COMB15	Combination	370.214
278	COMB15	Combination	376.429
279	COMB15	Combination	346.72
280	COMB15	Combination	372.901
281	COMB15	Combination	449.389
282	COMB15	Combination	372.133
283	COMB15	Combination	371.788
284	COMB15	Combination	429.969
285	COMB15	Combination	371.399
286	COMB15	Combination	376.105
287	COMB15	Combination	347.977
			7509.304

IV. EARTHQUAKE LOAD CALCULATION

Lateral load distribution										
Type of soil =		medium								
Height of building (H) =		12.000	m							
base dimenstion of building at the plinth level (d) in X-direction =						20.60	m			
base dimenstion of building at the plinth level (d) in Y-direction =						6.60	m			
Time Period in X-direction =			$0.075H^{0.75}$ =		0.484	clause IS 1893:2002; 7.6.1				
Time Period in Y-direction =			$0.075H^{0.75}$ =		0.484	clause IS 1893:2002; 7.6.1				
Sa/g (X-dir) =		2.500	Check			clause IS 1893:2002; 6.4.5				
Sa/g (Y-dir) =		2.500				clause IS 1893:2002; 6.4.5				
Zone factor (Z) =		0.360	for Zone V			clause IS 1893:2002; Table 2				
Importance factor (I)=		1.500								
Response reduction factor (R)=			5	for special RCC building		clause IS 1893:2002; Table 7				
Seismic coefficient (Ah) = (Z/2)*(I/R)*(Sa/g) =					**0.135**	clause IS 1893:2002; 6.4.2				
Seismic Weight (W)=		7509.304								
Base Shear	(vb)=	Ah*W	1013.756							
U=	$(T_{rem}/T_{use})^{0.5}$									
	0.987									
Hence Taking U=			1							
Final Base Shear		(fvb)=	vb*U=	1013.756						
									7509.306	1013.756
Program Generated Base Shear along X direction									7509.306	1013.756
Base shear Vb x = Ah X W =			1013.756	**KN**						
Program Generated Base Shear along Y direction										
Base shear Vb y = Ah X W =			1013.756	**KN**						

Table 2: Foundation Load

TABLE: Joint Reactions			
Joint	**OutputCase**	**CaseType**	**F3**
Text	Text	Text	KN
262	COMB14	Combination	532.936
263	COMB14	Combination	556.27
264	COMB14	Combination	529.728
265	COMB14	Combination	528.937
266	COMB14	Combination	529.466
267	COMB14	Combination	532.053
268	COMB14	Combination	720.727
269	COMB14	Combination	502.435
270	COMB14	Combination	775.607
271	COMB14	Combination	877.348
273	COMB14	Combination	693.883
274	COMB14	Combination	694.938
275	COMB14	Combination	780.461
277	COMB14	Combination	696.961
278	COMB14	Combination	850.406
279	COMB14	Combination	677.006
280	COMB14	Combination	702.167
281	COMB14	Combination	809.119
282	COMB14	Combination	667.406
283	COMB14	Combination	669.071
284	COMB14	Combination	756.248
285	COMB14	Combination	667.698
286	COMB14	Combination	695.685
287	COMB14	Combination	704.81
		Total	16151.37

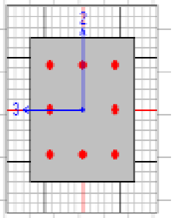
column 300*300

Units: KN, m, C

Indian IS 456-2000 COLUMN SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Summary)

L=3.000			
Element : 300	B=0.300	D=0.300	dc=0.057
Station Loc : 3.000	E=22360680.0	fc=20000.000	Lt.Wt. Fac.=1.000
Section ID : C1	fy=415000.000	fys=415000.000	
Combo ID : COMB11	RLLF=1.000		

Gamma(Concrete): 1.500
Gamma(Steel) : 1.150



AXIAL FORCE & BIAXIAL MOMENT CHECK FOR Pu, Mu2, Mu3

Capacity Ratio	Design Pu	Design Mu2	Design Mu3	Factored Mu2	Factored Mu3
0.601	58.117	9.970	39.944	9.970	39.944

AXIAL FORCE & BIAXIAL MOMENT FACTORS

	K Factor	L Length	Initial Moment	Additional Moment	Minimum Moment
Major Bending(M3)	1.000	3.000	15.978	0.000	1.162
Minor Bending(M2)	1.000	3.000	3.988	0.000	1.162

SHEAR DESIGN FOR Vu2,Vu3

	Rebar Asv/s	Shear Vu	Shear Vc	Shear Vs	Shear Vp
Major Shear(V2)	3.325E-04	55.924	55.872	29.160	55.924
Minor Shear(V3)	3.325E-04	80.097	55.872	29.160	80.097

JOINT SHEAR DESIGN (INFORMATIVE ONLY)

	Joint Shear Ratio	Shear VTop	Shear VuTot	Shear Vc	Joint Area
Major Shear(V2)	0.401	0.000	241.935	603.738	0.090
Minor Shear(V3)	0.435	0.000	262.495	603.738	0.090

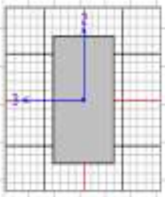
Beam design
bm 250*450

Units: KN, m, C

Indian IS 456-2000 BEAM SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Summary)

L=4.500			
Element : 63	D=0.450	B=0.250	bf=0.250
Station Loc : 4.500	ds=0.000	dct=0.025	dcb=0.025
Section ID : B250*450	E=22360680.0	Fc=20000.000	Lt.Wt. Fac.=1.000
Combo ID : COMB8	Fy=415000.000	Fys=415000.000	

Gamma(Concrete): 1.500
Gamma(Steel) : 1.150



Factored Forces and Moments

Factored Mu3	Factored Tu	Factored Vu2	Factored Pu
-114.403	0.380	71.372	0.785

Design Moments, Mu3

Factored Moment	Torsion Mt	Positive Moment	Negative Moment
-114.403	0.625	0.000	-115.029

Longitudinal Reinforcement for Moment and Torsion (Mu3, Tu)

	Required Rebar	+Moment Rebar	-Moment Rebar	Minimum Rebar
Top (+2 Axis)	9.164E-04	0.000	9.164E-04	2.910E-04
Bottom (-2 Axis)	4.582E-04	0.000	0.000	4.582E-04

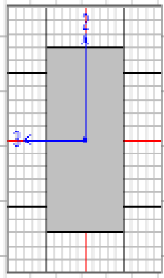
Shear Reinforcement For Shear and Torsion (Vu2, Tu)

Rebar Asv/s	Shear Ve	Shear Vc	Shear Vs	Shear Vp
2.771E-04	94.116	62.434	42.500	60.132

bm 250*350

Units: KN, m, C

Indian IS 456-2000 BEAM SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Summary)



L=2.800			
Element : 70	D=0.350	B=0.250	bF=0.250
Station Loc : 0.000	ds=0.000	dct=0.025	dcb=0.025
Section ID : Beam 250*350	E=22360680.0	fc=20000.000	Lt.Wt. Fac.=1.000
Combo ID : COMB7	fy=415000.000	fys=415000.000	

Gamma(Concrete): 1.500
Gamma(Steel) : 1.150

Factored Forces and Moments

Factored Mu3	Factored Tu	Factored Vu2	Factored Pu
-77.602	1.351	76.365	0.513

Design Moments, Mu3

Factored Moment	Torsion Mt	Positive Moment	Negative Moment
-77.602	1.907	0.000	-79.509

Longitudinal Reinforcement for Moment and Torsion (Mu3, Tu)

	Required Rebar	+Moment Rebar	-Moment Rebar	Minimum Rebar
Top (+2 Axis)	8.390E-04	0.000	8.390E-04	2.263E-04
Bottom (-2 Axis)	4.195E-04	0.000	6.354E-05	4.195E-04

Shear Reinforcement for Shear and Torsion (Vu2, Tu)

Rebar Asv/s	Shear Ve	Shear Vc	Shear Vs	Shear Vp
5.073E-04	101.806	50.951	59.499	69.863

Table 3: Joint Reactions

TABLE: Joint Reactions								
Joint	**OutputCase**	**CaseType**	**F3**	**Design Load**	**Bearing Load**	**Area required**	**Area Provided**	**Remarks**
Text	**Text**	**Text**	**KN**	**KN**	**KN/m^2**	**m^2**	**m^2**	
262	COMB14	Combination	532.936	390.82	100	3.91	1.21	micropiling Required
263	COMB14	Combination	556.27	407.93	100	4.08	1.21	micropiling Required
264	COMB14	Combination	529.728	388.47	100	3.88	1.21	micropiling Required
265	COMB14	Combination	528.937	387.89	100	3.88	1.21	micropiling Required
266	COMB14	Combination	529.466	388.28	100	3.88	1.21	micropiling Required
267	COMB14	Combination	532.053	390.17	100	3.90	1.21	micropiling Required
268	COMB14	Combination	720.727	528.53	100	5.29	1.21	micropiling Required
269	COMB14	Combination	502.435	368.45	100	3.68	1.21	micropiling Required
270	COMB14	Combination	775.607	568.78	100	5.69	1.69	micropiling Required
271	COMB14	Combination	877.348	643.39	100	6.43	1.69	micropiling Required
273	COMB14	Combination	693.883	508.85	100	5.09	1.69	micropiling Required
274	COMB14	Combination	694.938	509.62	100	5.10	1.69	micropiling Required
275	COMB14	Combination	780.461	572.34	100	5.72	1.69	micropiling Required
277	COMB14	Combination	696.961	511.10	100	5.11	1.96	micropiling Required
278	COMB14	Combination	850.406	623.63	100	6.24	1.69	micropiling Required
279	COMB14	Combination	677.006	496.47	100	4.96	1.69	micropiling Required
280	COMB14	Combination	702.167	514.92	100	5.15	1.69	micropiling Required
281	COMB14	Combination	809.119	593.35	100	5.93	1.69	micropiling Required
282	COMB14	Combination	667.406	489.43	100	4.89	1.69	micropiling Required
283	COMB14	Combination	669.071	490.65	100	4.91	1.69	micropiling Required
284	COMB14	Combination	756.248	554.58	100	5.55	1.69	micropiling Required
285	COMB14	Combination	667.698	489.65	100	4.90	1.69	micropiling Required
286	COMB14	Combination	695.685	510.17	100	5.10	1.96	micropiling Required
287	COMB14	Combination	704.81	516.86	100	5.17	1.69	micropiling Required

Table 3: Top Storey Deflection

TABLE: Joint Displacements				
Joint	**OutputCase**	**CaseType**	**U1**	**Allowable deflection**
Text	Text	Text	mm	mm
204	EQX	LinStatic	15.10	48

Table 4: Time Period

TABLE: Modal Periods And Frequencies			
OutputCase	**StepType**	**StepNum**	**Period**
Text	Text	Unitless	Sec
MODAL	Mode	1	0.466
MODAL	Mode	2	0.446
MODAL	Mode	3	0.405
MODAL	Mode	4	0.158
MODAL	Mode	5	0.156
MODAL	Mode	6	0.139
MODAL	Mode	7	0.085
MODAL	Mode	8	0.084
MODAL	Mode	9	0.076
MODAL	Mode	10	0.061
MODAL	Mode	11	0.057
MODAL	Mode	12	0.055

Table 5: Drift

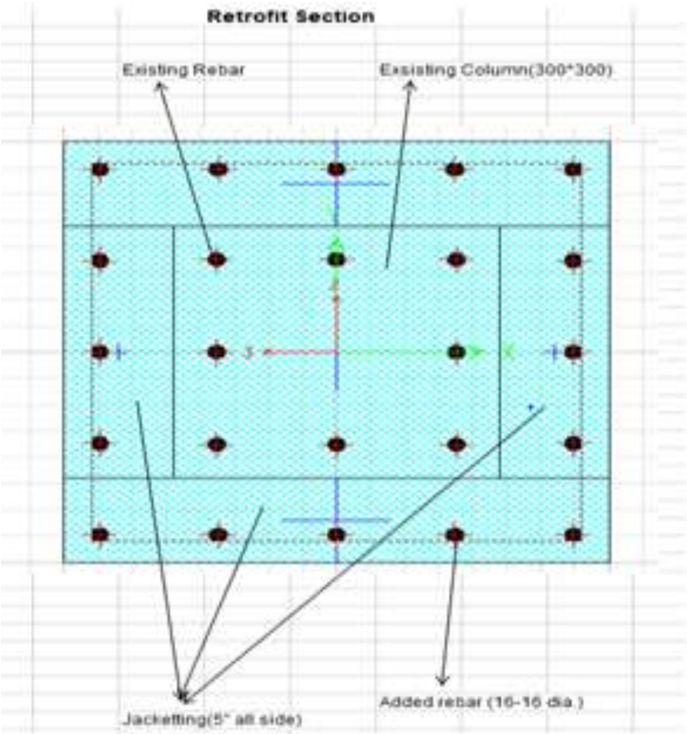
According to IS 1893:2002 Clause 7.11.1

TABLE: Joint Displacements				**Inter Storey Drift**	**Height**	**Drift Limitation**	**Check**
Joint	**OutputCase**	**CaseType**	**U1**			**0.004 x H**	**0.004 x H >**
Text	Text	Text	mm	mm	H (m)	mm	ID
287	EQx	LinStatic	0.00	0	0	0	PASS
35	EQx	LinStatic	2.56	2.56	3	12	PASS
63	EQx	LinStatic	6.96	4.41	3	12	PASS
87	EQx	LinStatic	11.09	4.12	3	12	PASS
215	EQx	LinStatic	15.10	4.01	3	12	PASS

Table 6: Joint Displacements

TABLE: Joint Displacements				**Inter Storey Drift**	**Height**	**Drift Limitation**	**Check**
Joint	**OutputCase**	**CaseType**	**U2**			**0.004 x H**	**0.004 x H >**
Text	Text	Text	mm	mm	H (m)	mm	ID
287	EQy	LinStatic	0.00	0.00	3	12	PASS
35	EQy	LinStatic	2.40	2.40	3	12	PASS
63	EQy	LinStatic	6.35	3.95	3	12	PASS
87	EQy	LinStatic	10.07	3.72	3	12	PASS
215	EQy	LinStatic	13.86	3.79	3	12	PASS

3d model in SAP



Two Way Slab Design

Analysis

Shorter Span (Lx) =		5.18	m
Longer Span (Ly) =		5.18	m
Now,	Ly / Lx =	1	ok
Type of Panel (case No.) =		4	
Suggested Span / depth (L/d)		23	
Then, depth (d) =		225.276	mm
depth Taken (d)=		130	mm
	(D)=	150	mm

Load detail			
dead Load=	3.75	kn / m2	
live load=	3	kn / m2	
other=	1	kn / m2	
	7.75		
Load Calculation			
Wx=	11.625	kn / m2	
Shear force (Vx) =	20.0777202	kn	
(Vy)=	15.0582902	kn	
Verification of depth	d min=	72.9010124	mm
check "dadopt >dmin"	OKEY		

	lower		upper		exact	
now,	Ly / Lx =	1	Ly / Lx =	1.1	Ly / Lx =	1
coff.	ax		ax		ax	ay
edge	0.047		0.053		0.047	0.047
mid	0.035		0.04		0.035	0.035
moment	about Y axis		about X axis			
Edge	-14.66817901		-14.66817901			
mid	10.92311203		10.92311203			
fy=	415	n/mm2				
fck=	20	n/mm2				

Reinforcement Design

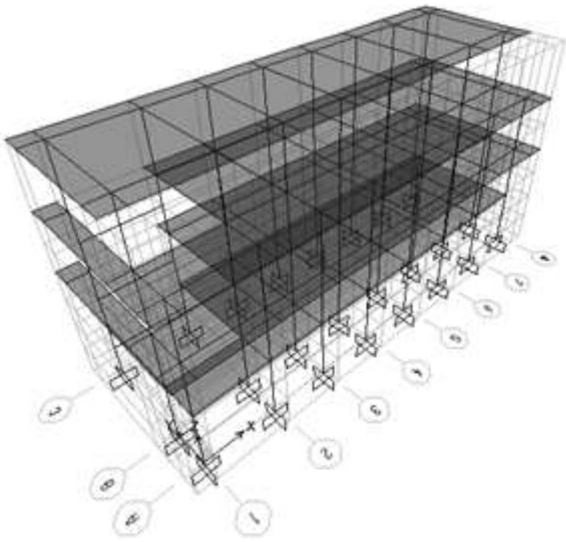
a) Along X-Direction

End Reinforcement

Adopt d =	130	mm	
No Deflection contrl needed at end portion Hence,			
moment (M)=	14.6682	kn-m	
Ast =	329.881	mm2	
Req. Ast =	**329.881**	mm2	
provide the steel as =			
10 mm dia	**150**	mm c/c distance	
then provided steel =	523.599	Okey	
% of tension steel=	0.40277		

Mid Reinforcement

Adopt d =	130	mm		
finding area of steel (Ast) according to deflection control criteria				
moment (M)=	10.923112	kn-m		
Ast =	242.074534	mm2		
Req. Ast =	**242.074534**	mm2		
actual L/d =	39.8565165			
Provided L/d=	23	* modification factor		
Hence needed M.F.=	1.73289202			
provide the steel as	**10**	mm dia	**150**	mm c/c distance
then provided steel =	523.598776	Okey	% of tension steel=	0.40277
fs=	111.282423		Ok and Finished	
hence, modification factor =		2		



b) Along Y-Direction

End Reinforcement

Adopt d =	121	mm	
No Deflection contrl needed at end portion Hence,			
moment (M)=	-14.6682	kn-m	
Ast =	-318.373	mm2	
Req. Ast =	**-318.373**	mm2	
provide the steel as =			
10 mm dia	**150**	mm c/c distance	
then provided steel =	523.599	Okey	
% of tension steel=	0.43273		

Mid Reinforcement

Adopt d =	121	mm		
finding area of steel (Ast) according to deflection control criteria				
moment (M)=	10.923112	kn-m		
Ast =	261.782994	mm2		
Req. Ast =	**261.782994**	mm2		
actual L/d =	42.8210508			
Provided L/d=	23	* modification factor		
Hence needed M.F.=	1.86178482			
provide the steel as	**10**	mm dia	**150**	mm c/c distance
then provided steel =	523.598776	Okey	% of tension steel=	0.43273
fs=	120.342464		Ok and Finished	
hence, modification factor =		2		

V. CONCLUSION

The design and detailing of the mentioned building has been conducted using SAP consideration of the earthquake load in strengthening of the building and durability of the structure which is safe against the seismic effect.

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