DetectionofWeakSectionsinExistingRCStructuredueto Extension of Storey under Seismic Forces

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1. ABSTRACT

Present study we investigate how a building got affected for increasing the storey above it under seismic forces. First, we analyze and design a G+3 (residential/commercial) building according to Indian Standard with considering Earthquake forces, then providing size of section and reinforcement accordingly. After this we extent this building with one storey and determine the response of the building during earthquake, check the member size and reinforcement. Structure analysissoftwareETABSisusedforallthisanalysis.Resultsofboththemodelscomparedtoexplore theimpact of addedstoriesunderseismiccondition. Theaddition ofanextrafklooralters the value offorces,baseshear,displacement,drift,etc.experiencedbythestructure.Let'sexploretheimpact of extending storey on existing building.

Keywords: Equivalentstaticmethod,Dynamicanalysis,GeometricNonlinearity,LateralLoads,Non-Linear Analysis, P-Delta.

1. INTRODUCTION

For areas with limited space, adding an additional floor can be an ideal solution, where expanding horizontally is impractical. Extending an existing building is often more affordable than building a new structure from scratch. This is the very common practice adopting in world.There are many buildings which are either designed without consideration of future expansion with seismic loads or need to be designed with revised code of seismic loads. All those structures are needed to be analysis and retrofit.

Modern construction in earthquake active regions often incorporates sophisticated designs to withstand earthquake forces. These buildings are engineered with specific parameters in mind like the number of floors,thebuilding'smass,thestructuralsystem,andtheexpectedgroundmotion.Butwhathappenswhen these carefully calculated designs are compromised by unauthorized or poorly executed vertical extensions? The consequences can be devastating. This extra floor will increase the mass of the overall building.Shiftingthecenterofmassofthebuilding,AlteredNaturalfrequencyofthebuildingandoverload the structural element below there which leads the cracking, buckling due to amount of seismic force. all this parameter with seismic force can increase the risk in particular to human life.

Aimof this study is to find thecriticalzoneinbeams andcolumnsduring earthquake.Becauseearthquake is very sudden with no warning time natural hazards of life this planet. Earthquakes don't kill peoples, collapsingbuildings,thingslikeitcando.Andtragically,thevastmajorityofthesedeadlycollapsesinvolve homesandsmallresidentialstructuresbuiltwithoutanyseismicengineeringconsideration,oftentheonly shelteravailablebecomedeathtrapswhenthegroundshakes.Toprotectlives,wemustanalysisstructure everytimewhenverticalextensioninstructure.Throughaquantitativeevaluationofseismicvulnerability, this work contributes practical solutions designed to improve the earthquake resistance of this particular building category and for that sometime these buildings need to be retrofied.

2. LITERATUREREVIEW

Gillott C.1, Densley-Tingley D.2 and Davison, B.3 (2021) -This study intends to determine the Sustainable housing provision. This study proves that the vertical extension is very important for various reasons. Compare urban to suburban area vertical extension is more sustainable for densify city. It helps people to live in city centre. Alsohelpconstruction industry to minimize construction waste and lowering the carbon emissions for whole life of building.

A. Bahrami1, S. Deniz2, H. Moalin3 (2022)– This study investigates the behaviour of RC building after verticalextension.Endresultsshowsthattheloadbearingelementsareexperiencedhigherutilizationratio due to this it requires more reinforcement to prevent failure. Strengthening for increased reinforcement are also introduce in this study. Vertical forces and deflection is also increases after vertical extension.

ChandrakarPrakriti1,Bokare P. S.2 (may2017) - Difference instructuredisplacementis verysmall in lower stories in both the methods (Time History analysis and Response Spectrum analysis) both predicts almost same result for lower stories. Design based on response spectrum analysis are uneconomical as large dimension of beam, so for medium-height buildings, the Response Spectrum method offers a rapid analysis without significantly impacting the project's budget.

Kacheru, G. (2018). this study shows for zone 2 or less earthquake risk with regularbuildingwecanuselinearstaticmethodbutforZone(3,4,5)withhighearthquakeriskorirregular buildings, we must switch to the dynamic analysis.

DinarYousuf,Karim Samiul,BaruaAyan, Uddin Ashraf (2013) - highlighting theexponentialincrease indisplacementandaxialforcesunderP-Deltaanalysiswithheight.P-Deltaanalysisiscrucialforaccurate axial force and displacement assessment, while linear static analysis remains relevant for moment evaluation. For safe design of common rigid-joint RC structures, both analyses are essential.

CSI Analysis Reference Manual for SAP2000, ETABS (version 19) - Buildings carrying substantial gravity loads, such as those with heavy floor systems, require careful consideration of P-Delta. In seismic regions, lateral displacements caused by earthquakes can amplify P-Delta effects, making it crucial to include them in the analysis.

DubeyS.K., SangamnerkarPrakash, Soni Deepak(2014) – Thisstudy shows P-Delta analysis resulted insubstantiallyhighernodal andtop-storeydisplacementscomparedtostaticanddynamicanalyses,with increases ranging from 2 to 5 times depending on the zone and building symmetry. caused storey drift curves to change direction (indicating increased drift concentration) much earlier in the building's height comparedtostaticanddynamicanalyses.P-deltaanalysissignificantlyincreasesdisplacementvalues,and changes the distribution of storey drift when compared to linear analysis methods.

Chaudhary P. Krishna, Mahajan Ankit, Kacheru, Goutham. (2021) - The study found that shifting heavy masses within 12 and 16-storey irregular buildings had a negligible effect on overall building cost and material quantities. However,while lateral swayremainedlargelyunaffected,internal forces like bending momentsandshear forces saw slight increases, ranging from 1.17% to 1.84%, with O-shaped buildings showing the most significant variations. L-shaped buildings exhibited the greatest maximum displacement. In essence, mass transfer altered internal forces minimally without impacting overall cost or displacement.

3. METHODOLOGY

Earthquake-resistantconstructionaims to createbuildingsthatwillwithstandseismicforcessignificantly betterthanconventionallybuiltstructures.Forthat wehavetofindthe weaklinksinourstructure.Inthis study we investigate those weak beams and columns and behavior of structure during seismic event with adding one floor with similar configuration of already existing floors.

Wetaketwocasesforthisstudy,Infirst analysiswetakeRCframeG+3 (residential/commercial)building withdeadloads,liveloadsandseismicloadsisconsideredinthisanalysis,thendesignitandreinforcedas per Indian standards (IS456 and IS13920).While in second model we add one more storey in first model and make it RC frame G+4 (residential/commercial) building with same seismic loads parameters along with same dead loads and live loads data in each floor is selected corresponding to model 1 (G+3). Structural analysis software i.e. ETABS is used to performed this analysis. Forces are altered due to extension of floor, Model 1 and Model 2 results are compared to determine the weak beams and columns which get high amount of forces and reinforcement values.

4. MODELLING

Structuretype	RCCresidentialbuilding
Storey's	G+3
Heightofeachstorey	3.5m
Buildingplansize	12mx12m
Buildingheight	15.5m
Depthoffoundation	1.5m
GradeofCONCRETE(f_{ck})	M25
GradeofSTEEL(f_y)	Fe415,Fe500
Typeofsupports	Fixed
Slabthickness	150mm
Columnsize	300mmx500mm
Beamsize	250mmx500mm
Typeofwall	Brickwall

MODEL1(G+3)- Detailsofmodel1in table1.

Table1Modeldata (G+3)

Liveloadonfloor	4kN/m^2
Liveloadonterrace	1.5kN/m^2
Seismiczone	ZoneIV
Liveloadforseismicmass	50%(IS1893:2016)

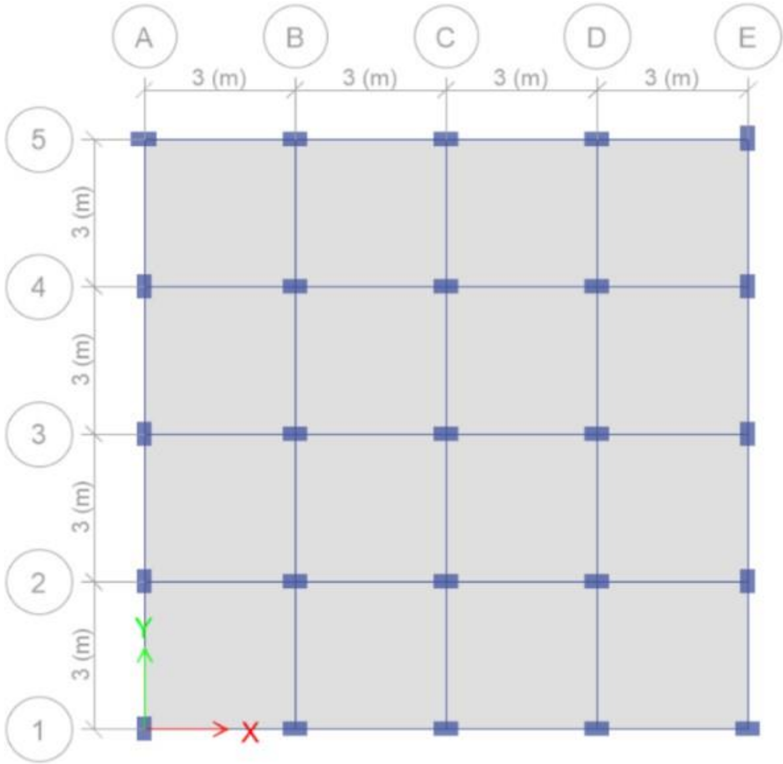

Fig1Planview(G+3)

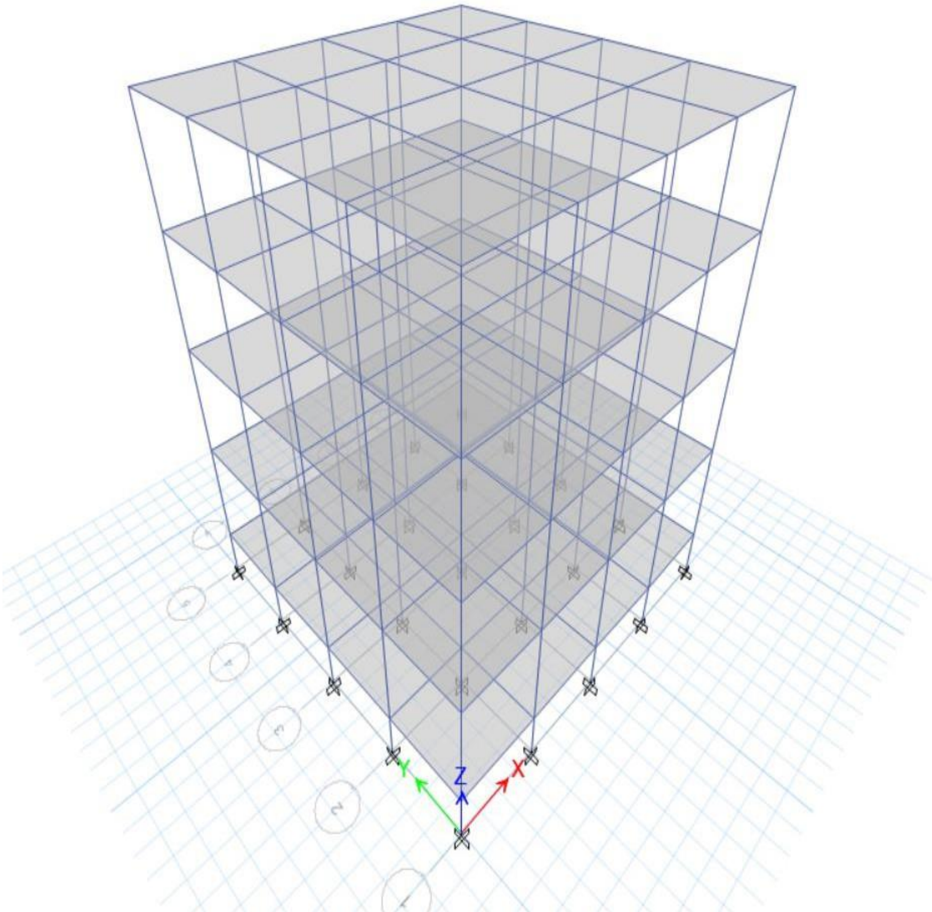

Fig2Isometricview(G+3)

MODEL2(G+4)-Detailsofmodel1intable2.

Table2Modeldata(G+4)

Structuretype	RCCresidential building
Storey's	G+4
Heightofeachstorey	3.5m
Buildingplansize	12mx12m
Buildingheight	19m
Depthoffoundation	1.5m
GradeofCONCRETE(f_{ck})	M25
GradeofSTEEL(f_y)	Fe415,Fe500
Typeofsupports	Fixed
Slabthickness	150mm
Columnsize	300mmx500mm
Beamsize	250mmx500mm
Typeofwall	Brickwall
Liveloadonfloor	4kN/m^2
Liveloadonterrace	1.5kN/m^2
Seismiczone(Z)	ZoneIV
Liveloadforseismic mass	50%(IS1893:2016)

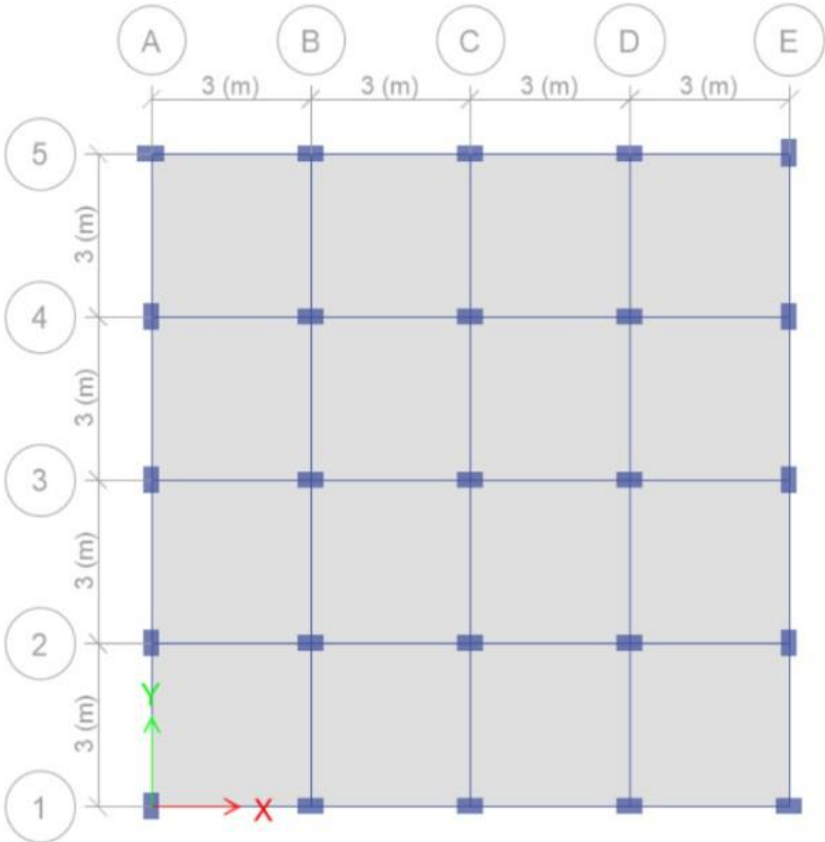

Fig3Planview(G+4)

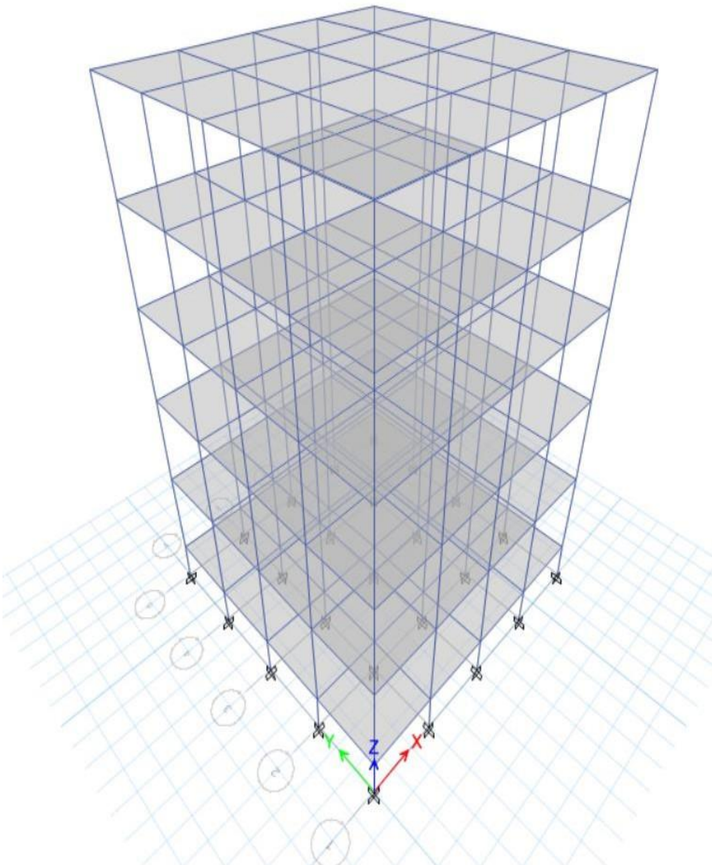

Fig4Isometricview(G+4)

5. LOADCALCULATION-

Deadloadsandliveloads–Deadandliveloadsonmodel1andmodel2arecalculatedandtabulated below-

Table3DeadandLiveLoads

member	loadcalculation	load
deadloadofwall200mm	0.2x3x20	12 kN/m
deadloadofparapetwall 100mm	0.1x1.2x20	2.4 kN/m
deadloadfloorfinishing	0.075x20x1	1.5kN/m^2
deadloadofceilingplaster	0.015x20x1	0.3kN/m^2
liveloadonfloor	byIScode	4kN/m^2
liveloadonterrace	byIScode	1.5kN/m^2

Earthquakeloads -ParametersofEarthquake loadsformodel1andmodel2arecalculatedandtabulatedbelow-

Table4ParametersofEarthquakeloads

Parameters	Values
Location(ZONEIV)	Zonefactor=0.24
Responsereductionfactor(OrdinaryRCmomentresistingframe)	RF=3
Importantfactor(Residentialandcommercial)	I=1.2
Soiltype(medium)	SS=2
Typeofstructure(RCframebuilding)	OMRF=1
Dampingratio	DM= 0.05

6. METHODOLOGY-

1. ModellingofG+3structureinETABSSoftware.
2. Analyzethisstructureforthegravityloadsandearthquakeloadsandnoteddownforcesandbendingmoment in all beam and columns of the building.
3. DesignbuildingaccordinglyIS456andIS13920.
4. DetermineReinforcementandprovidedit.
5. Extent the G+3 model and make it G+4 structure is ETABS. analyze this structure in ETABS considered same amount of dead loads and live load on each floor corresponding to G+3 model with same earthquake loads, noted down the forces and moments in all beams and column.
6. DesignbuildingaccordinglyIS456andIS13920.
7. DetermineReinforcementandcomparewiththeG+3model.
8. Comparetheresultsofbothmodelsdeterminedthecriticalmembers.

7. LOADCASESANDCOMBINATIONS

AccordingtoIS875(part1),IS875(part2)andIS1893(part1)2016.

LoadPattern-Basicloads(loadpatternsinETABS)–

Table5Basicloadpattern

Loadsname	Type
Dead	Dead
Live	Live
Liveterrace	Live
EQX	StaticSeismicinX
EQY	StaticSeismicinY
RSP-X	ResponsespectrumSeismicinX
RSP-Y	ResponsespectrumSeismicinY

LoadCombination-Combinations ofloadsaccordingtoIS456:2000andIS1893:2016(part1) Strengthload combinations

Table6Loadcombinations(Strength)

Loadcasenumber	Loadcasecombinations
1.	1.5DL
2.	1.5DL+1.5LL
3.	1.2DL+1.2LL-1.2EQX

4.	1.2DL+1.2LL-1.2EQY
5.	1.2DL+1.2LL+1.2EQX
6.	1.2DL+1.2LL+1.2EQY
7.	1.2DL+1.2LL+1.2RSLC-X
8.	1.2DL+1.2LL+1.2RSLC-Y
9.	1.2DL+1.2LL+1.2RSLC-Z
10.	1.5DL-1.5EQX
11.	1.5DL-1.5EQY
12.	1.5DL+1.5EQX
13.	1.5DL+1.5EQY
14.	1.5DL+1.5RSLC-X
15.	1.5DL+1.5RSLC-Y
16.	1.5DL+1.5RSLC-Z
17.	0.9DL-1.5EQX
18.	0.9DL-1.5EQY
19.	0.9DL+1.5EQX
20.	0.9DL+1.5EQY
21.	0.9DL+1.5RSLC-X
22.	0.9DL+1.5RSLC-Y
23.	0.9DL+1.5RSLC-Z

8. RESULTS-

BaseShear-

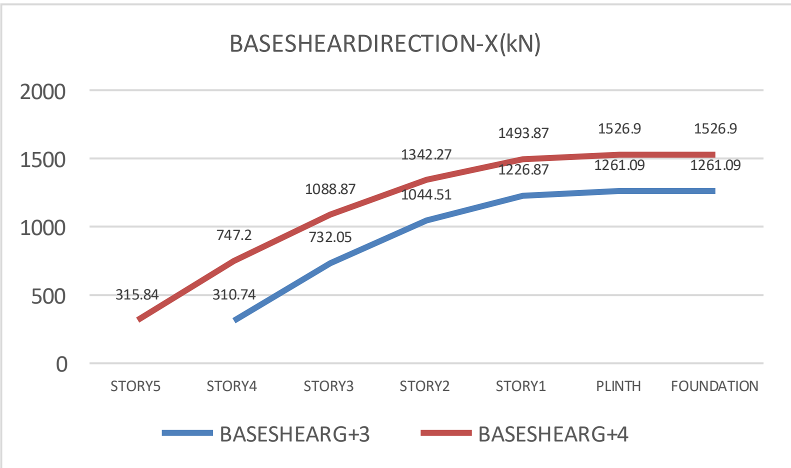

Fig5BaseShearXDir

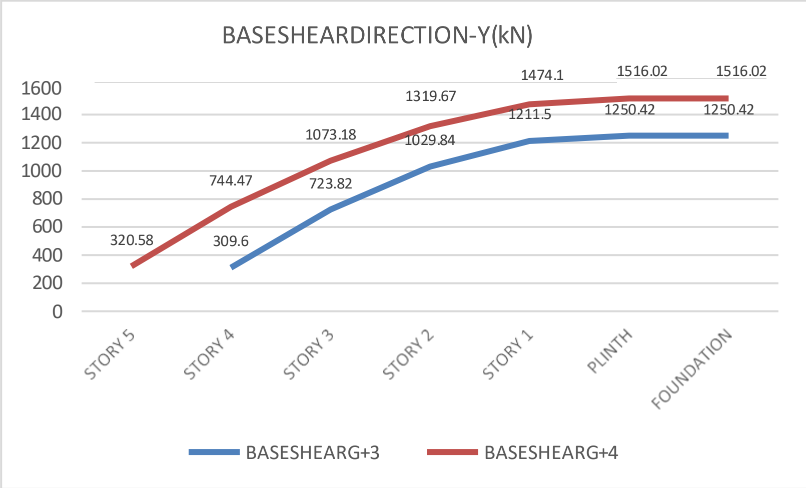

Fig6BaseShearYDir

BaseShear,V=Ah*W(IS1893:2016)

Comparisonof base shearformodel 1& model 2.Fromthe above chartitis concludedthatbase shearfor model2buildingismorethanmodel1buildingthisisbecausetheseismicweightofbuildingisproportional to base shear.

Storeydisplacement-

Fig7Displacementof(G+3)inX&Ydirection

Abovefigshowsthatthemaximumstoreydisplacementincreaseswithincreaseinheightof storey. Global X = Blue, Global Y = Red

Maximum value in X = 18mm

MaximumvalueinY=24mm

Permissiblevalue=H/500=(15.5*1000)/500=31mm

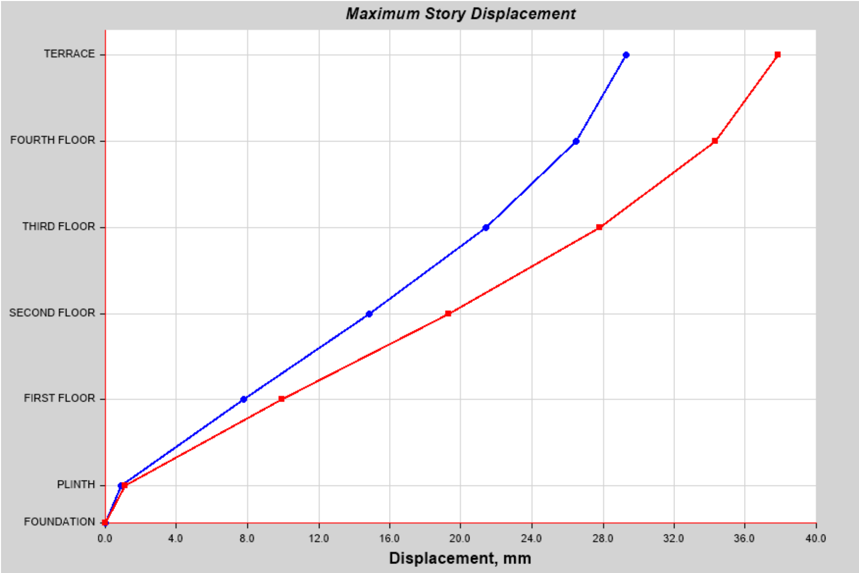

Fig8Displacementof(G+4)inX&Ydirection

Abovefigshowsthatthemaximumstoreydisplacementincreaseswithincreaseinheightof storey. Global X = Blue, Global Y = Red
MaximumvalueinX=29mm
MaximumvalueinY=37mm
Permissiblevalue=H/500=(19*1000)/500= 38mm

Effect of additional storey on beams - Thisisadiscussionabouttheshearforceofbeamsinmodel1 and 2, and how it altered when more floors are added.

I. ShearForceinbeams-

a) Plinth level beam- This table discusses the shear force of plinth level beams in model 1 and model 2. Total numbers of beam are 40 but we are selecting exclusively those beams which have the highest stress level.

Table7ShearforceresultatPlinthlevelbeamsinmodel1andmodel 2.

	G+3		G+4		% increment	
Beam	**V**	**Ast**	**V**	**Ast**	**V**	**Ast**
no.	kN	mm^2/m	kN	mm^2/m	kN	mm^2/m
B10	82.3	856.4	97.6	1019.7	18.63%	19.07%
B12	103.3	1047.2	122.7	1219.8	18.75%	16.48%
B26	108.4	930.8	127.7	1107.5	17.83%	18.98%
B27	107.9	930.8	127.2	1104.2	17.92%	18.62%
B29	105.6	1163.6	124.8	1378.7	18.20%	18.49%
B30	109.0	930.8	129.9	1109.0	19.19%	19.14%
B31	109.0	930.8	129.9	1109.0	19.19%	19.14%
B32	105.6	1163.6	124.8	1378.7	18.20%	18.49%
B34	107.9	930.8	127.2	1104.2	17.92%	18.62%
B35	108.4	930.8	127.7	1107.5	17.83%	18.98%

The comparison resultindicates a positive variance inshearforce,resultingina necessaryincrease inshear reinforcement requirements. Accordingly, member B30 and B31 are identified as having maximum shear force and the highest reinforcement alteration.

b) First floor level beams - This table discusses the shear force of first floor level beams in model 1 and 2. Total numbers of beam are 40 but we are selecting exclusively the beams with the highest stress level.

Table8ShearforceresultatFirstfloorlevelbeamsinmodel1andmodel 2.

	G+3		G+4		% increment	
Beam	**V**	**Ast**	**V**	**Ast**	**V**	**Ast**
no.	kN	mm^2/m	kN	mm^2/m	kN	mm^2/m

B12	143.0	1454.4	175.4	1775.9	22.62%	22.10%
B14	107.8	1163.6	132.2	1429.1	22.72%	22.82%
B15	107.3	1163.6	131.9	1425.7	22.91%	22.53%
B16	147.0	1396.3	179.7	1715.8	22.26%	22.89%
B17	186.7	1163.6	228.4	1406.5	22.31%	20.88%
B19	207.3	1279.9	251.5	1548.8	21.30%	21.01%
B2	207.3	1279.9	251.5	1548.8	21.30%	21.01%
B25	144.5	1687.2	176.5	2052.4	22.09%	21.65%
B26	157.5	1338.1	194.8	1647.4	23.67%	23.12%
B27	157.2	1338.1	194.5	1646.7	23.71%	23.07%

The comparison resultindicates a positive variance inshearforce,resultingina necessaryincrease inshear reinforcementrequirements.Accordingly,memberB2andB19havemaximumshearforcevaluebutmember B26 and B27 is identified as having the highest reinforcement alteration.

c) Secondfloorlevelbeams-Thistablediscussestheshearforceofsecondfloorlevelbeamsinmodel1and 2.Totalnumbersofbeamare40butweareselectingexclusivelythebeamswiththehigheststresslevel.

Table9ShearforceresultatSecondfloorlevelbeamsinmodel1andmodel2.

	G+3		G+4		% increment	
Beam	**V**	**Ast**	**V**	**Ast**	**V**	**Ast**
no.	kN	mm^2/m	kN	mm^2/m	kN	mm^2/m
B10	103.6	1105.4	133.6	1437.4	29.0%	30.0%
B11	103.6	1105.4	133.6	1437.4	29.0%	30.0%
B12	126.7	1279.9	163.0	1670.0	28.7%	30.5%
B19	187.3	1163.6	244.8	1507.6	30.7%	29.6%
B2	187.3	1163.6	244.8	1507.6	30.7%	29.6%
B26	142.1	1221.7	186.6	1581.1	31.3%	29.4%
B27	142.4	1221.7	187.0	1583.5	31.4%	29.6%
B28	125.0	1454.4	162.4	1911.5	29.9%	31.4%
B33	125.0	1454.4	162.4	1911.5	29.9%	31.4%
B34	142.4	1221.7	187.0	1583.5	31.4%	29.6%

The comparison resultindicates a positive variance inshearforce,resultingina necessaryincrease inshear reinforcementrequirements.Accordingly,memberB2andB19havemaximumshearforcevaluebutmember B28 and B33 is identified as having the highest reinforcement alteration.

d) Thirdfloorlevel beams-This tablediscussestheshearforceofthirdfloorlevelbeamsinmodel1and2. Total numbers of beam are 40 but we are selecting exclusively the beams with the highest stress level.

Table10ShearforceresultatThirdfloorlevelbeamsinmodel1andmodel2

	G+3		G+4		% increment	
Beam	**V**	**Ast**	**V**	**Ast**	**V**	**Ast**
no.	kN	mm^2/m	kN	mm^2/m	kN	mm^2/m
B25	102.6	854.4	157.4	1332.5	53.49%	55.95%
B26	103.1	853.3	158.2	1332.3	53.46%	56.15%
B27	93.4	1037.7	139.6	1614.9	49.52%	55.62%
B28	149.5	920.4	229.2	1411.3	53.34%	53.33%
B29	150.3	925.6	228.4	1406.4	51.96%	51.96%
B30	87.7	997.1	134.3	1580.6	53.05%	58.53%
B31	87.9	1023.0	134.6	1614.2	53.18%	57.78%
B32	149.5	920.4	229.2	1411.3	53.34%	53.33%
B33	150.3	925.6	228.4	1406.4	51.96%	51.96%

B34	102.8	852.1	157.8	1330.2	53.55%	56.12%

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The comparison resultindicates a positive variance inshearforce,resultingina necessaryincrease inshear reinforcement requirements. Accordingly, member B29 and B33 have maximum shear force value but member B30 is identified as having the highest reinforcement alteration.

e) Terracefloorlevelbeams-Thistablediscussestheshearforceofterracefloorlevelbeamsinmodel1and2. Total numbers of beam are 40 but we are selecting exclusively the beams with the highest stress level.

Table11ShearforceresultatTerracefloorlevelbeamsinmodel1andmodel2.

	G+3		G+4		% increment	
Beam	**V**	**Ast**	**V**	**Ast**	**V**	**Ast**
no.	kN	mm^2/m	kN	mm^2/m	kN	mm^2/m
B1	75.9	484.0	146.1	899.6	92.52%	85.86%
B17	71.1	446.8	128.3	790.2	80.60%	76.86%
B18	72.6	484.0	152.5	939.2	109.96%	94.03%
B19	72.0	446.8	156.0	960.4	116.49%	114.96%
B2	72.0	446.8	156.0	960.4	116.49%	114.96%
B20	75.9	484.0	146.1	899.6	92.52%	85.86%
B23	72.1	446.8	128.1	788.8	77.76%	76.55%
B25	71.3	633.0	92.3	1058.3	29.39%	67.19%
B3	72.6	484.0	152.5	939.2	109.96%	94.03%
B38	72.1	446.8	128.1	788.8	77.76%	76.55%
B4	71.1	446.8	128.3	790.2	80.60%	76.86%

The comparison resultindicates a positive variance inshearforce,resultingina necessaryincrease inshear reinforcementrequirements.Accordingly,memberB1andB20havemaximumshearforcevaluebutmember B2 and B19 is identified as having the highest reinforcement alteration.

II. Bending Moments in beam- Table discusses in model 1 and model 2. Total numbers of beam are 40 but we are selecting exclusively those beams which have the highest bending moment.

a) Plinthlevelbeams–

Table12BendingMomentresultatPlinthlevelbeaminmodel1andmodel2.

	G+3		G+4			
1	**2**	**3**	**4**	**5**	**6**	**7**
Beam	**(-) Moment**	**(+) Moment**	**(-) Moment**	**(+) Moment**	**(-) Moment**	**(+) Moment**
no.	kN-m	kN-m	kN-m	kN-m	(4-2)	(5-3)
B13	-96.53	86.96	-117.00	105.71	-20.47	18.75
B8	-96.53	86.96	-117.00	105.71	-20.47	18.75
B5	-95.97	87.02	-116.29	105.71	-20.32	18.69
B1	-133.87	120.36	-158.13	144.43	-24.26	24.08
B20	-133.87	120.36	-158.13	144.43	-24.26	24.08
B18	-117.01	98.38	-137.92	119.27	-20.91	20.89
B17	-112.15	98.65	-132.46	118.77	-20.30	20.12
B19	-115.74	97.98	-136.49	118.78	-20.75	20.80
B2	-115.74	97.98	-136.49	118.78	-20.75	20.80
B15	-70.55	55.20	-84.68	69.34	-14.13	14.14
B4	-112.15	98.65	-132.46	118.77	-20.30	20.12

Table13ReinforcementresultatPlinthlevelbeamsinmodel1andmodel2.

	G+3	G+4	% Increment

1	2	3	4	5	6	7
Beam	**AsTop**	**AsBot**	**AsTop**	**AsBot**	**AsTop**	**AsBot**
no.	Provide	Provide	mm^2	mm^2	%	%
B13	603.1858	515.2212	690	623	14.39%	20.92%
B8	603.1858	515.2212	690	623	14.39%	20.92%
B5	603.1858	515.2212	683	621	13.23%	20.53%
B1	829.3805	741.4159	982	877	18.40%	18.29%
B20	829.3805	741.4159	982	877	18.40%	18.29%
B18	741.4159	603.1858	829	697	11.81%	15.55%
B17	653.4513	603.1858	789	694	20.74%	15.06%
B19	741.4159	603.1858	818	694	10.33%	15.06%
B2	741.4159	603.1858	818	694	10.33%	15.06%
B15	402.1239	339.292	475	382	18.12%	12.59%
B4	653.4513	628.3185	789	694	20.74%	10.45%

The comparison result indicates a positive variance inbending moment, resulting in a necessary increase in longitudinalreinforcementrequirements.Accordingly,memberB1andB20isidentifiedashavingthehighest (-) moment and (+) moment, but member B4 and B17 is identified as having the highest reinforcement variation on top and member B13 and B8 is identified as having the highest reinforcement alteration as bottom.

b) Firstfloorlevelbeams–

Table14BendingMomentresultatFirstfloorlevelbeamsinmodel1andmodel2.

	G+3		G+4			
1	**2**	**3**	**4**	**5**	**6**	**7**
Beam	**(-) Moment**	**(+) Moment**	**(-) Moment**	**(+) Moment**	**(-) Moment**	**(+) Moment**
no.	kN-m	kN-m	kN-m	kN-m	(4-2)	(5-3)
B12	-136.54	128.32	-168.84	160.76	-32.30	32.44
B16	-136.63	128.40	-168.91	160.77	-32.28	32.37
B26	-124.96	111.89	-154.66	141.53	-29.70	29.65
B27	-124.58	112.24	-154.31	141.92	-29.73	29.68
B30	-124.54	112.06	-154.20	141.68	-29.66	29.62
B31	-124.54	112.06	-154.20	141.68	-29.66	29.62
B34	-124.58	112.24	-154.31	141.92	-29.73	29.68
B35	-124.96	111.89	-154.66	141.53	-29.70	29.65
B5	-136.63	128.40	-168.91	160.77	-32.28	32.37
B9	-136.54	128.32	-168.84	160.76	-32.30	32.44

Table15ReinforcementresultatFirstfloorlevelbeaminmodel1andmodel2.

	G+3		G+4		% Increment	
1	**2**	**3**	**4**	**5**	**6**	**7**
Beam	**AsTop**	**AsBot**	**AsTop**	**AsBot**	**AsTop**	**AsBot**
no.	Provide	Provide	mm^2	mm^2	%	%
B12	829.4	829.4	1068.0	1004.0	28.8%	21.1%
B16	829.4	829.4	1073.0	1009.0	29.4%	21.7%
B26	741.4	653.5	956.0	856.0	28.9%	31.0%
B27	741.4	653.5	955.0	859.0	28.8%	31.5%
B30	741.4	653.5	952.0	856.0	28.4%	31.0%
B31	741.4	653.5	952.0	856.0	28.4%	31.0%
B34	741.4	653.5	955.0	859.0	28.8%	31.5%

B35	741.4	653.5	956.0	856.0	28.9%	31.0%
B5	829.4	829.4	1073.0	1009.0	29.4%	21.7%
B9	829.4	829.4	1068.0	1004.0	28.8%	21.1%

The comparison result indicates a positive variance in bending moment, resulting in a necessary increase in longitudinalreinforcementrequirements.Accordingly,memberB9andB12isidentifiedashavingthehighest (-) moment and (+) moment, but member B5 and B16 is identified as having the highest reinforcement variation on top and member B27 and B34 is identified as having the highest reinforcement alteration as bottom.

c) Secondfloorlevelbeams-

Table16BendingMomentresultatSecondfloorlevelbeamsinmodel1andmodel2.

	G+3		G+4			
1	2	3	4	5	6	7
Beam	(-) Moment	(+) Moment	(-) Moment	(+) Moment	(-) Moment	(+) Moment
no.	kN-m	kN-m	kN-m	kN-m	(4-2)	(5-3)
B13	-121.6	111.1	-160.0	149.5	-38.42	38.38
B16	-120.2	111.0	-158.3	149.1	-38.05	38.13
B17	-137.9	121.9	-181.3	164.4	-43.33	42.53
B18	-149.5	132.6	-196.9	180.2	-47.44	47.67
B21	-108.9	92.8	-142.7	125.8	-33.76	32.96
B25	-103.5	93.0	-136.1	125.6	-32.65	32.61
B36	-103.5	93.0	-136.1	125.6	-32.65	32.61
B40	-108.9	92.8	-142.7	125.8	-33.76	32.96
B5	-120.2	111.0	-158.3	149.1	-38.05	38.13
B8	-121.6	111.1	-160.0	149.5	-38.42	38.38

Table17ReinforcementresultatSecondfloorlevelbeaminmodel1andmodel2.

	G+3		G+4		% Increment	
1	2	3	4	5	6	7
Beam	AsTop	AsBot	AsTop	AsBot	AsTop	AsBot
no.	Provide	Provide	mm^2	mm^2	%	%
B13	741.4	653.5	1013	924	36.63%	41.40%
B16	741.4	741.4	991	918	33.66%	23.82%
B17	829.4	741.4	1138	1033	37.21%	39.33%
B18	917.3	829.4	1228	1132	33.86%	36.49%
B21	628.3	603.2	864	742	37.51%	23.01%
B25	603.2	603.2	821	742	36.11%	23.01%
B36	603.2	603.2	821	742	36.11%	23.01%
B40	628.3	603.2	864	742	37.51%	23.01%
B5	741.4	653.5	991	918	33.66%	40.48%
B8	741.4	653.5	1013	924	36.63%	41.40%

The comparison result indicates a positive variance inbending moment, resulting in a necessary increase in longitudinal reinforcement requirements. Accordingly, member B18 is identified as having the highest (-) momentand(+)momentbutmemberB21andB40isidentifiedashavingthehighestreinforcementvariation on top and member B8 and B13 is identified as having the highest reinforcement alteration as bottom.

d) Thirdfloorlevelbeams-

Table18BendingMomentresultatThirdfloorlevelbeaminmodel1andmodel2.

	G+3		G+4			
1	2	3	4	5	6	7

Beam	(-) Moment	(+) Moment	(-) Moment	(+) Moment	(-) Moment	(+) Moment
no.	kN-m	kN-m	kN-m	kN-m	(4-2)	(5-3)
B1	-116.59	98.20	-189.71	170.08	-73.12	71.88
B12	-81.33	70.50	-130.24	120.41	-48.91	49.91
B17	-89.00	76.54	-141.64	130.56	-52.64	54.02
B18	-108.53	90.94	-171.15	153.75	-62.62	62.81
B19	-108.46	93.02	-170.36	154.91	-61.91	61.88
B2	-108.88	90.28	-169.96	151.67	-61.08	61.39
B20	-116.59	98.20	-189.71	170.08	-73.12	71.88
B22	-86.21	68.63	-134.41	117.01	-48.19	48.38
B3	-108.53	90.94	-171.15	153.75	-62.62	62.81
B4	-89.00	76.54	-141.64	130.56	-52.64	54.02

Table19ReinforcementresultatThirdfloorlevelbeaminmodel1andmodel2.

	G+3		G+4		% Increment	
1	2	3	4	5	6	7
Beam	AsTop	AsBot	AsTop	AsBot	AsTop	AsBot
no.	Provide	Provide	mm^2	mm^2	%	%
B1	741.4	603.2	1187.0	1074.0	60.10%	78.05%
B12	453.1	402.1	775.0	706.0	71.04%	75.57%
B17	515.2	452.4	856.0	776.0	66.14%	71.53%
B18	628.3	515.2	1080.0	948.0	71.89%	84.00%
B19	628.3	603.2	1076.0	957.0	71.25%	58.66%
B2	628.3	515.2	1073.0	932.0	70.77%	80.89%
B20	741.4	603.2	1187.0	1074.0	60.10%	78.05%
B22	515.2	402.1	803.0	682.0	55.86%	69.60%
B3	628.3	515.2	1080.0	948.0	71.89%	84.00%
B4	515.2	452.4	856.0	776.0	66.14%	71.53%

The comparison result indicates a positive variance inbending moment, resulting in a necessary increase in longitudinalreinforcementrequirements.Accordingly,memberB1andB20isidentifiedashavingthehighest (-) moment and (+) moment but member B3 and B18 is identified as having the highest reinforcement variation on top and bottom.

d)Terracefloorlevelbeams-

Table20BendingMomentresultatTerracefloorlevelbeaminmodel1andmodel2.

	G+3		G+4			
1	2	3	4	5	6	7
Beam	(-) Moment	(+) Moment	(-) Moment	(+) Moment	(-) Moment	(+) Moment
no.	kN-m	kN-m	kN-m	kN-m	(4-2)	(5-3)
B1	-0.3	0.6	-117.9	96.9	-117.6	96.3
B17	-13.8	1.3	-98.5	79.2	-84.7	77.9
B18	0.0	0.3	-117.4	100.0	-117.4	99.7
B19	-0.8	19.4	-117.4	99.2	-116.7	79.8
B2	-4.2	25.3	-117.4	99.2	-113.2	74.0
B20	-4.6	24.4	-117.9	96.9	-113.3	72.5
B22	0.0	0.3	-93.0	75.6	-93.0	75.2
B23	-0.7	1.4	-93.2	75.1	-92.5	73.7
B24	-4.6	0.0	-95.0	74.0	-90.4	74.0

B3	-3.2	27.0	-117.4	100.0	-114.3	73.0

Table21ReinforcementresultatTerracefloorlevelbeaminmodel1andmodel2.

	G+3		G+4		% Increment	
1	2	3	4	5	6	7
Beam	AsTop	AsBot	AsTop	AsBot	AsTop	AsBot
no.	Provide	Provide	mm²	mm²	%	%
B1	339.3	339.3	303.7	201.7	-10.49%	-40.55%
B17	339.3	339.3	198.7	87.7	-41.43%	-74.15%
B18	339.3	339.3	306.7	213.7	-9.60%	-37.01%
B19	339.3	339.3	308.7	207.7	-9.01%	-38.78%
B2	339.3	339.3	308.7	207.7	-9.01%	-38.78%
B20	339.3	339.3	303.7	201.7	-10.49%	-40.55%
B22	339.3	339.3	164.7	68.7	-51.46%	-79.75%
B23	339.3	339.3	166.7	66.7	-50.87%	-80.34%
B24	339.3	339.3	172.7	64.7	-49.10%	-80.93%
B3	339.3	339.3	306.7	213.7	-9.60%	-37.01%

The comparison result indicates a variance in bending moment, but resulting no need to increase in longitudinal reinforcement requirements. All beams have already sufficient reinforcement.

Effectofadditionalstoreyoncolumns

This discusses is about the Axial loads and Bending Moment in columns in model 1 and 2. Total numbers of columns are 25 but we are selecting exclusively the columns with the highest bending moment and axial loads.

I. ShearForceinbeams-allcolumnsarepassedinshearreinforcement,definitelyshearforceincreasesdue to extension of storey but the required reinforcement is less than provided reinforcement.

II. AxialloadandBendingmomentincolumns-

a) Plinthcolumns-

Table22AxialloadsandBendingMomentsresultatPlinthcolumnsinmodel1andmodel2.

	G+3			G+4			% Increment		
Column	P	MMajor	MMinor	P	MMajor	MMinor	P	M Major	M Minor
no.	kN	kN-m	kN-m	kN	kN-m	kN-m	kN	kN-m	kN-m
C10	20.99	0.22	-72.09	-62.44	0.37	-86.705	-397.44%	68.78%	20.27%
C11	35.56	-0.03	69.53	-37.71	-0.03	85.0363	-206.04%	1.11%	22.31%
C12	286.99	-0.02	-92.53	349.40	-0.01	-113.51	21.75%	-35.71%	22.67%
C14	286.99	0.02	92.53	349.40	0.02	113.5099	21.75%	2.98%	22.67%
C15	35.56	0.03	-69.53	-37.71	0.03	-85.0363	-206.04%	1.11%	22.31%
C16	20.99	-0.22	72.09	-62.44	-0.37	86.705	-397.44%	68.78%	20.27%
C18	358.53	0.56	-90.38	431.16	0.59	-111.235	20.26%	4.22%	23.08%
C20	21.36	-0.04	-71.40	-64.43	-0.24	-85.8327	-401.64%	454.23%	20.22%
C6	21.36	0.04	71.40	-64.43	0.24	85.8327	-401.64%	454.23%	20.22%
C8	358.53	-0.51	90.38	431.16	-0.59	111.2347	20.26%	14.72%	23.08%

Table23ReinforcementresultatPlinthcolumnsinmodel1andmodel2.

	G+3		G+4		% Increment
Column	Astprovided	Rebar %	Astrequired	Rebar %	Ast
no.	mm^2		mm^3		%
C10	1658.76	1.11%	2280	1.52%	37.45%

C11	1482.83	0.99%	2190	1.46%	47.69%
C12	1658.76	1.11%	2235	1.49%	34.74%
C14	1658.76	1.11%	2235	1.49%	34.74%
C15	1482.83	0.99%	2190	1.46%	47.69%
C16	1658.76	1.11%	2280	1.52%	37.45%
C18	1482.83	0.99%	2055	1.37%	38.59%
C20	1658.76	1.11%	2265	1.51%	36.55%
C6	1658.76	1.11%	2265	1.51%	36.55%
C8	1482.83	0.99%	2055	1.37%	38.59%

Thecomparisonresultindicatesapositivevarianceinreinforcementrequirement.Accordingly,memberC11 and C15 needs more reinforcement than other columns.

b) Groundfloorcolumns-

Table24AxialloadsandBendingMomentsresultatGroundfloorcolumnsinmodel1andmodel2.

	G+3			G+4			% Increment		
Column	P	M Major	M Minor	P	M Major	M Minor	P	M Major	M Minor
no.	kN	kN-m	kN-m	kN	kN-m	kN-m	kN	kN-m	kN-m
C11	26.49	0.27	-101.18	-32.01	0.29	-127.44	-220.8%	6.8%	26.0%
C12	216.32	0.15	-125.45	277.99	0.16	-157.91	28.5%	3.7%	25.9%
C13	199.01	0.00	123.98	260.60	0.00	156.78	30.9%	43.1%	26.5%
C14	216.32	-0.15	125.45	277.99	-0.10	157.91	28.5%	-35.2%	25.9%
C17	227.52	1.11	-126.59	289.49	1.07	-159.42	27.2%	-3.5%	25.9%
C18	214.23	0.04	124.79	275.58	0.14	157.64	28.6%	263.7%	26.3%
C19	227.76	0.83	126.55	289.78	0.79	159.27	27.2%	-4.9%	25.9%
C7	227.75	-0.83	-126.55	289.78	-0.79	-159.27	27.2%	-4.9%	25.9%
C8	214.23	-0.04	-124.79	275.58	-0.14	-157.64	28.6%	263.7%	26.3%
C9	227.52	-1.11	126.59	289.49	-1.07	159.42	27.2%	-3.5%	25.9%

Table25ReinforcementresultatGroundfloorcolumnsinmodel1andmodel2.

	G+3		G+4		% Increment
Column	Astprovided	Rebar%	Astrequired	Rebar%	Ast
no.	mm^2		mm^3		%
C11	2463.01	1.64%	3165.00	2.11%	28.50%
C12	2689.20	1.79%	3630.00	2.42%	34.98%
C13	2689.20	1.79%	3615.00	2.41%	34.43%
C14	2689.20	1.79%	3615.00	2.41%	34.43%
C17	2689.20	1.79%	3660.00	2.44%	36.10%
C18	2689.20	1.79%	3615.00	2.41%	34.43%
C19	2689.20	1.79%	3645.00	2.43%	35.54%
C7	2689.20	1.79%	3645.00	2.43%	35.54%
C8	2689.20	1.79%	3615.00	2.41%	34.43%
C9	2689.20	1.79%	3660.00	2.44%	36.10%

The comparisonresult indicates a positive variance inreinforcement requirement. Accordingly, member C9 and C17 needs more reinforcement than other columns.

c) Firstfloorcolumns-

Table26AxialloadsandBendingMomentsresultat Firstfloorcolumnsinmodel1andmodel 2.

	G+3			G+4			% Increment		
Column	P	MMajor	MMinor	P	MMajor	MMinor	P	M Major	M Minor
no.	kN	kN-m	kN-m	kN	kN-m	kN-m	kN	kN-m	kN-m
C12	163.69	0.28	125.45	222.96	-0.29	157.91	36.21%	7.09%	25.87%
C13	150.95	0.00	123.98	209.72	0.00	-156.78	38.93%	39.90%	26.45%
C14	163.69	0.28	125.45	222.96	0.29	-157.91	36.21%	7.09%	25.87%
C17	171.36	1.84	126.59	231.05	-1.77	159.42	34.83%	-4.16%	25.94%
C18	162.13	0.34	124.79	221.05	0.14	-157.64	36.34%	- 57.90%	26.33%
C19	171.53	1.29	126.55	231.28	-1.20	-159.27	34.83%	-6.64%	25.86%
C21	27.65	7.37	115.73	-99.94	8.11	140.08	- 461.50%	10.10%	21.04%
C5	27.65	7.37	115.73	-99.94	-8.11	-140.08	- 461.50%	10.10%	21.04%
C7	171.53	1.29	126.55	231.28	1.20	159.27	34.83%	-6.64%	25.86%
C8	162.13	0.34	124.79	221.05	-0.14	157.64	36.34%	- 57.90%	26.33%
C9	171.36	1.84	126.59	231.05	1.77	-159.42	34.83%	-4.16%	25.94%

Table27ReinforcementresultatFirstfloorcolumnsinmodel1andmodel2.

	G+3		G+4		% Increment
Column	Astprovided	Rebar%	Astrequired	Rebar%	Ast
no.	mm^2		mm^3		%
C12	2739.47	1.83%	4322.5	2.47%	57.79%
C13	2739.47	1.83%	4305	2.46%	57.15%
C14	2739.47	1.83%	4322.5	2.47%	57.79%
C17	2739.47	1.83%	4375	2.50%	59.70%
C18	2739.47	1.83%	4322.5	2.47%	57.79%
C19	2739.47	1.83%	4375	2.50%	59.70%
C21	2915.40	1.94%	4392.5	2.51%	50.67%
C5	2915.40	1.94%	4392.5	2.51%	50.67%
C7	2739.47	1.83%	4375	2.50%	59.70%
C8	2739.47	1.83%	4322.5	2.47%	57.79%
C9	2739.47	1.83%	4375	2.50%	59.70%

Thecomparisonresultindicatesapositivevarianceinreinforcementrequirement.Accordingly,memberC7, C9, C17 and C19 needs more reinforcement than other columns.

d) Secondfloorcolumns-

Table28AxialloadsandBendingMomentsresultatSecondfloorcolumnsinmodel1andmodel2.

	G+3			G+4			% Increment		
Column	P	MMajor	MMinor	P	MMajor	MMinor	P	M Major	M Minor
no.	kN	kN-m	kN-m	kN	kN-m	kN-m	kN	kN-m	kN-m
C13	99.25	0.00	112.81	153.93	0.00	152.95	55.10%	55.18%	35.59%
C17	112.52	1.95	112.95	168.98	1.94	152.59	50.18%	-0.72%	35.09%
C19	112.63	1.38	113.15	169.14	1.33	152.71	50.17%	-3.77%	34.96%
C7	112.63	1.38	113.15	169.14	1.33	152.71	50.17%	-3.78%	34.96%
C9	112.52	1.95	112.95	168.98	1.94	152.59	50.18%	-0.71%	35.09%
C12	107.65	0.28	112.19	163.49	0.30	151.45	51.87%	10.42%	34.99%

C14	107.65	0.20	112.19	163.49	0.30	151.45	51.87%	50.74%	34.99%
C18	148.94	0.70	113.44	219.91	0.92	153.65	47.65%	31.17%	35.44%
C8	147.28	0.70	113.44	219.91	0.92	153.65	49.31%	31.17%	35.44%
C21	11.86	7.97	102.21	27.78	9.15	134.57	134.35%	14.74%	31.66%

Table29ReinforcementresultatSecondfloorcolumnsinmodel1andmodel2.

	G+3		G+4		% Increment
Column	Astprovided	Rebar %	Astrequired	Rebar %	Ast
no.	mm^2		mm^3		%
C13	2689	1.79%	3675	2.45%	36.66%
C17	2689	1.79%	3645	2.43%	35.54%
C19	2689	1.79%	3645	2.43%	35.54%
C7	2689	1.79%	3645	2.43%	35.54%
C9	2689	1.79%	3645	2.43%	35.54%
C12	2689	1.79%	3615	2.41%	34.43%
C14	2689	1.79%	3615	2.41%	34.43%
C18	2689	1.79%	3585	2.39%	33.31%
C8	2689	1.79%	3585	2.39%	33.31%
C21	2689	1.79%	3465	2.31%	28.85%

Thecomparisonresultindicatesapositivevarianceinreinforcementrequirement.Accordingly,memberC13 needs more reinforcement than other columns.

e) Thirdfloorcolumns-

Table30AxialloadsandBendingMomentsresultatThirdfloorcolumnsinmodel1andmodel 2.

	G+3			G+4			% Increment		
Column	P	MMajor	MMinor	P	MMajor	MMinor	P	M Major	M Minor
no.	kN	kN-m	kN-m	kN	kN-m	kN-m	kN	kN-m	kN-m
C10	66.82	31.96	60.60	49.74	3.86	98.89	-25.57%	-87.94%	63.17%
C16	66.82	31.96	60.60	49.74	3.86	98.89	-25.57%	-87.94%	63.17%
C2	40.95	136.43	5.01	97.99	229.94	4.89	139.32%	68.55%	-2.57%
C21	14.50	8.70	68.54	17.00	9.55	112.36	17.23%	9.73%	63.92%
C22	41.11	134.24	5.20	96.11	225.08	5.28	133.76%	67.67%	1.51%
C23	47.37	143.32	3.78	120.66	239.44	3.35	154.69%	67.07%	-11.33%
C24	40.95	136.43	5.01	97.99	229.94	4.89	139.32%	68.55%	-2.57%
C3	47.37	143.32	3.78	120.66	239.44	3.35	154.69%	67.07%	-11.33%
C4	41.11	134.24	5.20	96.11	225.08	5.28	133.76%	67.67%	1.51%
C5	14.50	8.70	68.54	17.00	9.55	112.36	17.23%	9.73%	63.92%

Table31ReinforcementresultatThirdfloorcolumnsinmodel1andmodel2.

	G+3		G+4		% Increment
Column	Astprovided	Rebar%	Astrequired	Rebar%	Ast
no.	mm^2		mm^3		%
C10	1834.69	1.22%	2370.00	1.58%	29.18%
C16	1834.69	1.22%	2370.00	1.58%	29.18%
C2	1834.69	1.22%	2625.00	1.75%	43.08%
C21	1834.69	1.22%	2670.00	1.78%	45.53%

C22	1834.69	1.22%	2595.00	1.73%	41.44%
C23	1834.69	1.22%	2670.00	1.78%	45.53%
C24	1834.69	1.22%	2625.00	1.75%	43.08%
C3	1834.69	1.22%	2670.00	1.78%	45.53%
C4	1834.69	1.22%	2595.00	1.73%	41.44%

Thecomparisonresultindicatesapositivevariancein reinforcementrequirement.Accordingly,memberC3, C5, C21 and C23 needs more reinforcement than other columns.

9. CONCLUSION- Even a single storeyaddedin a G+3 buildingsignificantly alters force distributionand this becomes critical in high-rise buildings due to increased deadload and amplified seismic forces. This current investigation focuses onthe structural performance of a RC G+3 (residential/commercial) building evaluate howthestructuralbehaveunderseismicforcewhenextendedonestoreyaboveit.

1. We can clearly see that the difference in **storey displacement** in model 1 and model 2. The lateral displacementalong the X-axisincreasedfrom18mmto29mmasa result of the floorextension, demonstrating asignificantchangeinstructuralresponse.The**X-**directionfloorextensioninduceda**61%**increaseinlateral displacement. Similarly, In **Y-**direction 13mm increase in displacement, from 24mm to 37mm due to floor extension.Approximately **54%**increase inlateral displacement.
2. weare just onlyonestoreyextended,the building **baseshear** isalsoalteredand wecanseethat the base shearinG+4buildingis approximately **22%**morethentheG+3building.
3. Wefoundthatmany beamsandcolumns failedunderseismicloadingdespiteductiledetailing,suggesting insufficientreinforcement.

Also,themostcriticalbeamsstoreybystoreyare–

- Plinthlevelbeams-B17,B4,B13,B8,B30andB31
- Firstfloorlevelbeams-B19,B2,B26,B27,B12,B9,B16,B5,B27andB34
- Secondfloorlevelbeams-B18,B21,B40,B13,B8,B19,B2,B28andB33
- Thirdfloorlevelbeams-B29,B33,B30,B1,B20,B18andB3
- Terrace floor level beams- B19, B2, B1and B18

Andthemostcriticalbeamsinwholestructureare–Thirdfloor**B3**and**B18**. Most critical columns are-

- Plinthcolumns-C11,C15
- Groundfloorcolumns-C9,C17
- Firstfloorcolumns-C7,C9,C17,C19
- Secondfloorcolumns-C13,C17,C19,C7
- Thirdfloorcolumns–C21,C23,C3,C5.

Andthemostcriticalcolumnsinwholestructureare-Firstfloorcolumns**C7,C9,C17, C19**.

4. Buildingissafeundergravityloadbutshowmorerequirementofsteelunderseismicloading.
5. Storey2andStorey3arethemostcriticalstoreyinallofthem.
6. Unnecessaryweightremovalfromstorey2andstorey3canhelpsthestrengthofbuildingafterfloor extension.

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