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Progressive Collapse Analysis of R.C. Framed Structure

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***Abstract**: In this article we analyze G+4, G+7 and G+10 of R.C. framed structure and progressive collapse analysis for the same building. Note the DCR (demand capacity ratio) for all the members of column removal and adjacent members. From the values of DCR we observed the behavior of the building.*

1. Introduction

Progressive collapse may be defined as the local failure of the load carrying elements like column (vertical load carrying member) it will cause the chain or subsequent collapse failure of whole or partial structure so ultimate collapse will disproportionate to local collapse is defined as progressive collapse. In general structure should be capable enough to resist extreme load condition, if it is not then it causes progressive collapse. Mostly federal buildings like military building & government houses should be designed against progressive collapse. Different extreme load conditions which may cause progressive collapse are Gas Cylinder Blast, Terrorist Attack (Bomb Blast), Vehicular Impact, Foundation Failure, Fire, etc.

2. About GSA (General Service Administration)

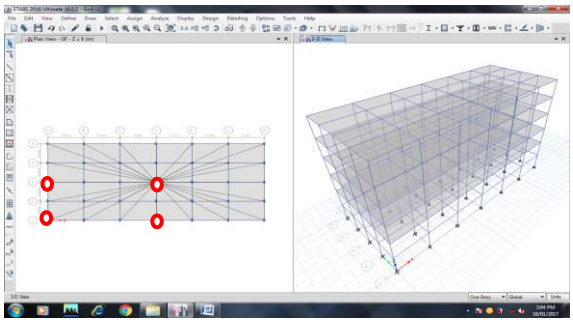
The purpose of this guideline is to reduce the potential for progressive collapse in new and renovated Federal buildings. This guideline addresses the need to save lives, prevent injury and protect federal buildings, function and assets by minimizing the potential for progressive collapse.

3. General data and hypothetical case as per GSA

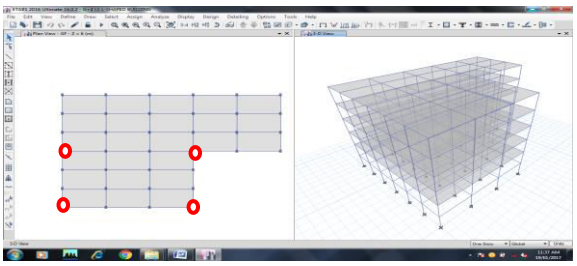
Prepare a plan of frame structure (beam & column) in CAD package.
General Data:
Concrete Grade = M25
Size of beam = 230mm X 450mm
Size of column =300mm X 450mm
Slab thickness = 250mm
Load Combination: As per IS: 1893:2002

1. 1.5 (DL + IL)
2. 1.2 (DL + IL ± EL)
3. 1.5 (DL ± IL)
4. 0.9 DL ± 1.5EL
5. ± ELx ± 0.3 Ely ± 0.3 ELz
6. ± ELy ± 0.3 Elx ± 0.3 ELz
7. ± ELz ± 0.3 Elx ± 0.3 Ely

GSA Load Combination**:** 1.2 DL + 1.2FF + 2.4 GSA FF + 0.5 LL + 1 GSA LL + 1.2 WALL + 2.4 GSA WALL



Hypothetical case for regular building is shown in fig. We have considered four critical column removal cases as per GSA guideline.



1. Long direction mid. Column removal
2. Short direction mid. Column removal
3. Corner column removal
4. Intermediate column removal (regular Shape)/Re-entrant column removal (L-Shape)

4. Progressive collapse analysis for linear static method

As per GSA linier static method is limited to 10-storeies building so we have worked on three

different buildings for analysis**.** So we worked on linear static analysis for progressive collapse of regular and irregular shape building of G+4, G+7 and G+ 10. As mention above, four column removal cases are considered for analysis of the progressive collapse. From the software analysis we determined the demand of the various members after the removal of column and from the spread sheet we determine the capacity of the various members also determine the shear capacity of different members from the software analysis.

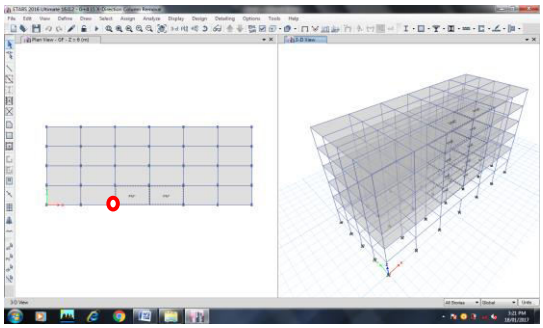
Design Of Rectangular Beam

	Grade Of Concrete	M25		fck=	25	N/mm²				
	Grade Of Steel	Fe415		fy=	415	N/mm²				
	Length	L=	5000	mm						
	Width	B=	230	mm						
	Overall Depth	D=	450	mm						
	Cover	d'=	20	mm						
	Effective depth	d=	430	mm						
	Com. Stress of Concrete	fcc=	11.15	N/mm²						
	Com. Stress of Steel	fsc=	352.75	N/mm²						
Required Steel	Ast=	1252	mm²	Ast=	313	mm²	Ast=	1252	mm²	
Provided Steel	Ast=	678.24	mm²	Ast=	678.24	mm²	Ast=	678.24	mm²	
	2d						2d			
Required Steel	Asc=	626	mm²	Ast=	501	mm²	Asc=	626	mm²	
Provided Steel	Asc=	678.24	mm²	Ast=	678.24	mm²	Asc=	678.24	mm²	
	No of bar	Dia(mm)		No of bar	Dia(mm)		No of bar	Dia(mm)		
Top Bars (Throw)	3	12		3	12		3	12		
Extra Top	3	12		3	12		3	12		
Bottom Bars (Throw)	3	12		3	12		3	12		
Extra Bottom	3	12		3	12		3	12		
Depth of neutral axis	Xu=	6.37	mm	Xu=	6.37	mm	Xu=	6.37	mm	
Max. depth of N.A	Xumax=	190.90	mm	Xumax=	190.90	mm	Xumax=	190.90	mm	
	Under reinforced section			Under reinforced section			Under reinforced section			
Capacity Moment	Mu=	100.63	KN.m	Mu=	100.63	KN.m	Mu=	100.63	KN.m	
Demand moment	Mu=	400	KN.m	Mu=	140	KN.m	Mu=	190	KN.m	
DCR		3.98			1.39			1.89		
	Shear Check			**Shear Check**			**Shear Check**			
Shear Stress	τv=	0.00	N/mm²	τv=	0.00	N/mm²	τv=	0.00	N/mm²	
Compressive Stress	τc=	0.55	N/mm²	τc=	0.55	N/mm²	τc=	0.55	N/mm²	
Shear Capacitry of Concrete	Vuc=	54.89	kN	Vuc=	54.89	kN	Vuc=	54.89	kN	
FROM ETABS/SAP	Asv/Sv=	0.23		Asv/Sv=	0.15		Asv/Sv=	0.23		
		legged	Dia(mm)		legged	Dia(mm)		legged	Dia(mm)	
Area of stirrups	Asv=	2	8	Asv=	2	8	Asv=	2	8	
	area	100.48	mm²	area	100.48	mm²	area	100.48	mm²	
Spacing ETBAS/SAP	Sv=	436.87	mm	Sv=	669.87	mm	Sv=	436.87	mm	
Spacing by ductile detailing	Sv=	100	mm	Sv=	150	mm	Sv=	100	mm	
	>d/4=	107.5	mm	>d/2	215	mm	>d/4=	107.5	mm	
	>8*dia of lo	96	mm	>150mm	150	mm	>8*dia of l	96	mm	
	<100mm	100	mm				<100mm	100	mm	
Spacing recommended	Sv=	100	mm		150	mm		100	mm	
Spacing Provided	Sv=	100	mm	Sv=	150	mm	Sv=	100	mm	
Shear Capacity of stirrups	Vus=	156	kN	Vus=	104	kN	Vus=	156	kN	
Total shear force capacity	V=	210.88	kN	V=	158.89	kN	V=	210.88	kN	
Demand SF	V=	100	kN	V=	100	kN	V=	100	kN	
DCR		0.47			0.63			0.47		

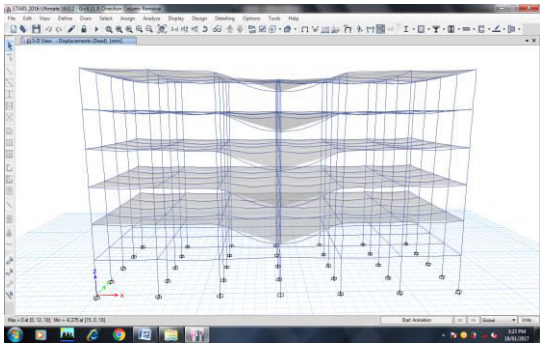
By taking the ratio of demand to the capacity we predict the stability of various members.

By taking different column removal case (ground floor column removal) e.g. X-Direction middle column removal case:

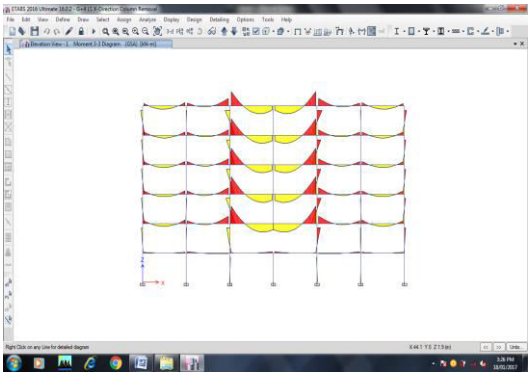
Twice the weight of adjacent slab & assign GSA load combination to adjacent frame structure & slab as shown in fig.



It will show the deformed shape as shown in fig



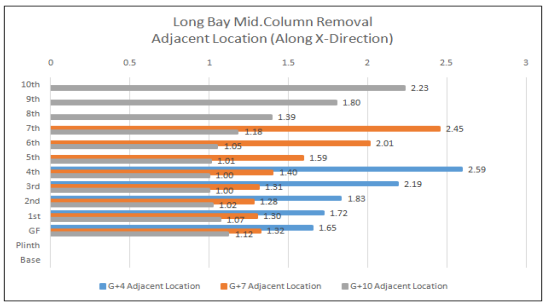
Note the demand moment & shear for different elements. Same way ground floor column removal process is done for Y-Direction middle column, Corner column removal & center

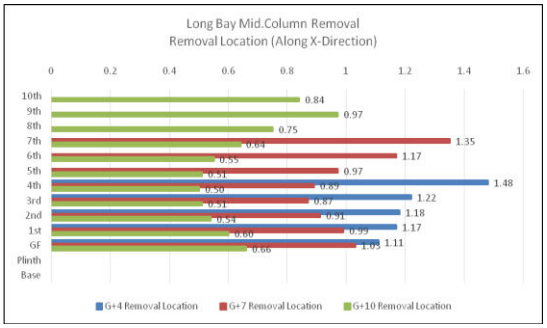


column removal.

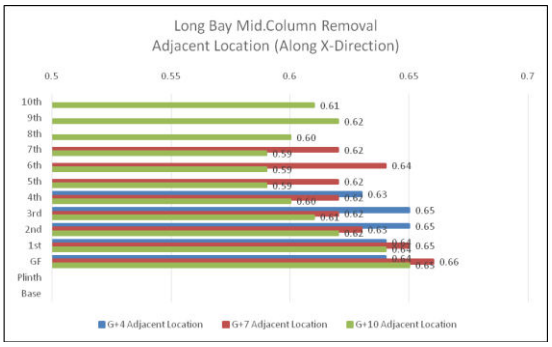
5. Charts for DCR ratio

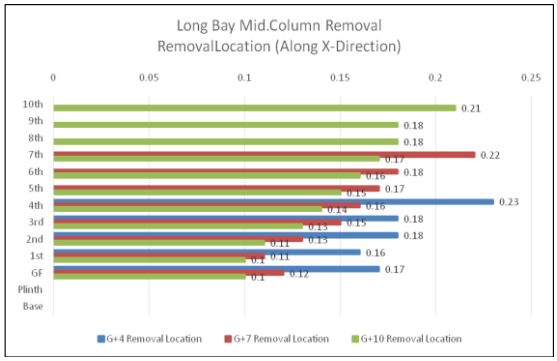
Comparison of moment DCR (Demand Capacity Ratio) for G+4, G+7 & G+10 regular building structure.

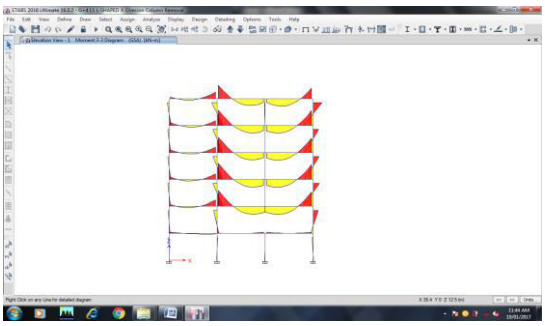




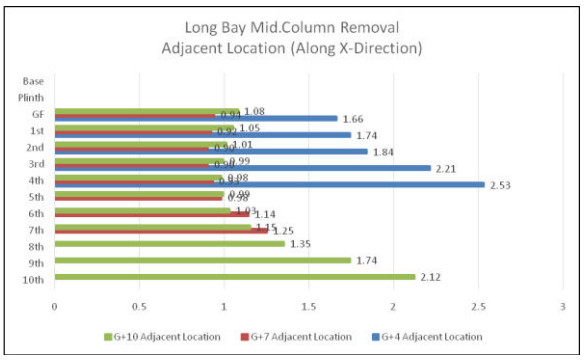
Comparison Of Shear DCR (Demand Capacity Ratio) For G+4, G+7 & G+10 regular building structure.

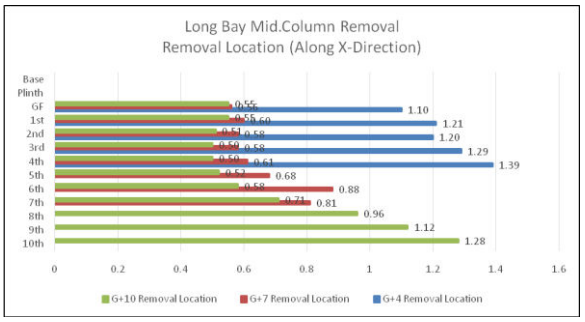


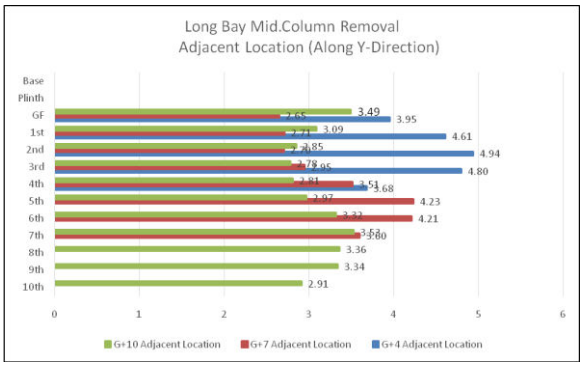


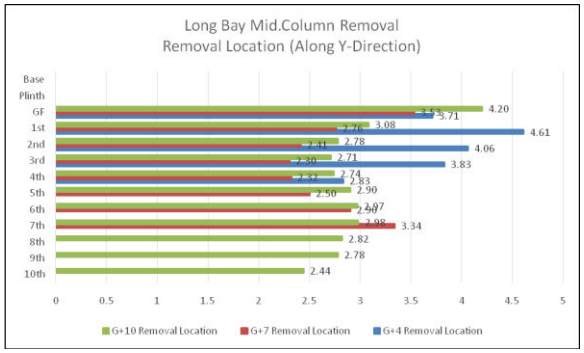


Comparison Of Moment DCR (Demand Capacity Ratio) For G+4, G+7 & G+10 L-Shaped Building Structure.

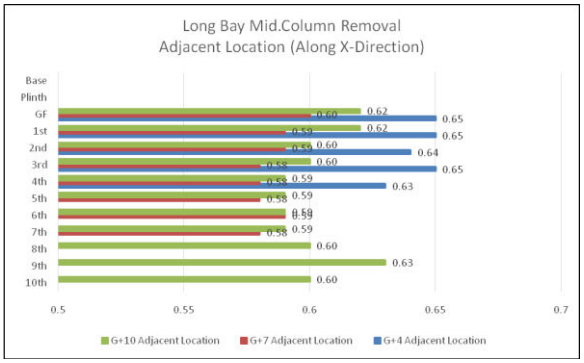


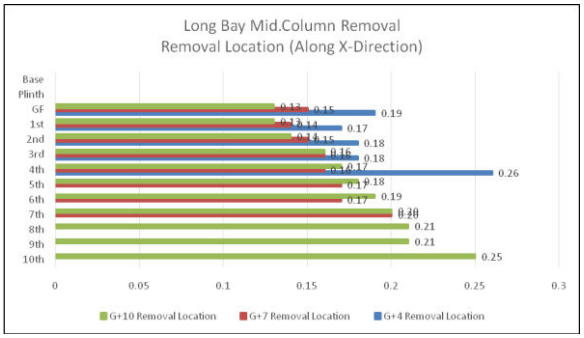


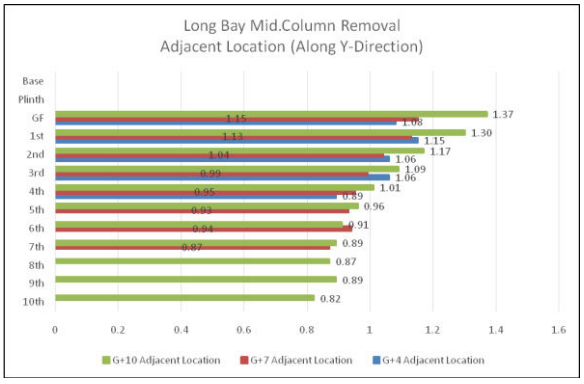


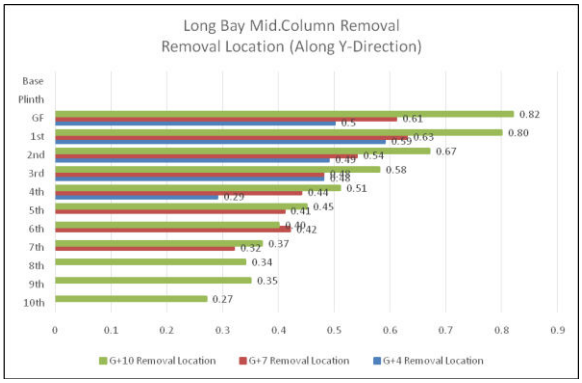


Comparison Of Shear DCR (Demand Capacity Ratio) For G+4, G+7 & G+10 L-Shaped Building Structure.









6. Observation

- Demand capacity ratio (DCR) for flexure is decreases with increase in height of building.
- For the same shear DCR is observed has increases with increase in height of building.
- Lower storey is more susceptible for collapse as compare to large or higher storey.
- Large structure has more reserve capacity to absorb energy over come on elimination of primary load carrying element.
- It has been observed primary load carrying element causes failure of upper storey in the form of flexure.
- It has been observed DCR is found higher at top storey in all three structures so removal of column leads the structure simultaneously from the top also.
- In all removal case short bay has higher DCR compare to long bay because of after removal of column short bay act as over hanging beam and long bay beams are resting on that.
- So to eliminate occurrence progressive collapse in the building one should strengthen in short bay.

7. Conclusion

- From the observation we can conclude that G+4 storey building is more susceptible for progressive collapse as compare to G+7 and G+7 is more susceptible than G+10.
- Due to increase in height of the building redundancy of the building increases and redistribution of load also increases.
- So G+4 is more susceptible for progressive collapse as compare to G+7 & G+10.

8. Acknowledgements

We would like to mention our special thanks to our mentor Prof. Bhavik R. Patel for his encouragement.

9. References

List and number all bibliographical references in 9- point Times, single-spaced, at the end of your paper. When referenced in the text, enclose the citation number in square brackets, for example [2-4], [2, 5], and [1].

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