A RESEARCH ON PROGRESSIVE COLLAPSE ANALYSIS OF REINFORCED CONCRETE BUILDING SUBJECTED TO SEISMIC LOADS

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Abstract

Progressive collapse is a catastrophic chain reaction of failure initiated by loss of vertical bearing load element of the structure resulting in damage of a part of the structure or entire structure. In our study we are considering 10 storey regular reinforced concrete building seismically designed. Progressive collapse analysis is performed by using general service administration GSA (2016) guidelines with different column removal scenarios at ground storey level. Shear force and bending moment for every scenario were compared and results were analysed. Keywords: General service administration (GSA), Catastrophic, Progressive collapse analysis, Seismic analysis, column removal scenarios. Computer Software Used for Analysis – SAP 2000 v20.20

1.Introduction

There are several types of actions, such as wind, dead load and snow that will act on a structure during its life. It is impossible, and certainly not economical, to design a structure for every possible event. However, if the risk for it to occur is high enough and it leads so severe consequences, it needs to be considered by the designer. The term "progressive collapse" has been used to describe the spread of an initial local failure in a manner analogous to a chain reaction that leads to partial or total collapse of a building. The underlying characteristic of progressive collapse is that the final state of failure is disproportionately greater than the failure that initiated the collapse. ASCE Standard 7-05 defines progressive collapse as

progressive collapse—the spread of local damage, from an initiating event, from element to element resulting, eventually, in the collapse of an entire structure or failure of one member causes a major collapse, with a magnitude disproportionate to the initial event. Thus, "progressive collapse" is an incremental type of failure wherein the total damage is out of proportion to the initial cause s. Details in the numerical model, type of analysis and how these factors affect the load carrying mechanisms within the model and its resistance to progressive collapse are the main focus of the thesis.

2.Design Approaches

The design approaches as per ASCE Standard 7-05 defines three methods to attain progressive collapse resistance: 1) Indirect Method, 2) Specific Local Resistance Method, and 3) Alternate Load Path Method. The methods are ordered by increasing levels of analytical complexity, and would be used for buildings with increasing levels of risk for the consequences of failure. The latter two methods are referred to collectively as direct methods.

Alternate Load Path Method: Both GSA and DOD guidelines follows alternate load path method. APM is a threat independent methodology, meaning that it does not consider the type of triggering event, but rather, considers building system response after the triggering event has destroyed critical structural members. If one component fails, alternate paths are available for the load to distribute to adjacent members thus prevents global collapse. The methodology is generally applied in the context of a 'missing column' scenario to assess the potential for progressive collapse and used to check if a building can successfully absorb loss of a critical member.

Details of the software

The SAP name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. SAP2000 version 20 follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities. SAP2000 has proven to be the most integrated, productive and practical general purpose structural program on the market today. From a simple small 2D static frame analysis to a large complex 3D nonlinear dynamic analysis, SAP2000 is the easiest, most productive solution for your structural analysis and design needs.

3.Modelling of the Building Types of

Models

By using the SAP2000 software different models are created by altering the position of column loss both in plan and elevation. Based on the location of column loss the following models have been considered.

Model 1: Model without considering any type of column loss scenarios Model 2:

External long side middle column loss at ground storey level Model 3: External

short side middle column loss at ground storey level Model4: Corner column loss

at ground storey level.

Building Model

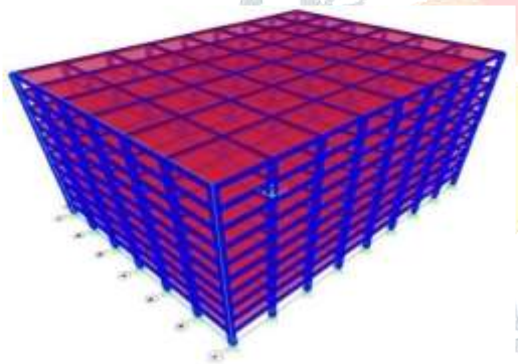

Fig. Isometric view of building model

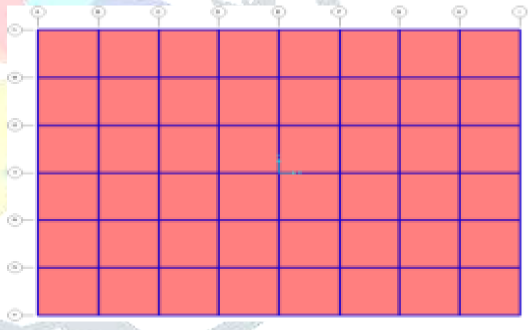

Fig. Plan view of building model

Linear Static Procedure

In the Linear static problem, the building is modelled with linearly-elastic stiffness and equivalent viscous damping that approximate values expected for loading to near the yield point. Design earthquake demands for linear static problem are represented by static lateral forces whose sum is equal to the pseudo lateral load. The magnitude of the pseudo lateral load has been selected with the intention that when it is applied to the linearly elastic model of the building it will result in design displacement amplitudes approximating maximum displacements that are expected during the design earthquake. If the building responds essentially elastically to the design earthquake, the calculated internal forces will be reasonable approximations of those expected during the design earthquake. If the building responds in elastically to the design earthquake, as will commonly be the case, the internal forces that would develop in the yielding building will be less than the internal forces calculated on an elastic basis. Calculated internal forces typically will exceed those that the building can develop, because of anticipated inelastic response of components andelements.

Building Description and Properties

S.NO	NAME	UNITS
1	Plan area	54X42m
2	No.of Bays in X direction	8
3	No.of Bays in Y direction	6
4	Total height	30m
5	Ground storey height	3m
6	Typical storey height	3m
7	Material Grade fck	30
8	Rebar Grade fy	500
9	Column dimensions	0.6*0.6m
10	Beam dimensions	0.55*0.3m
11	Slab thickness	0.15m
12	Length of Beams	6m

Loads on Building

S.No	Load Name	Load Type	Value
1	Self Weight of Structural Members (DL)	DEAD	Default
2	Floor Finish (FF)	DEAD	1.5 KN/m2
3	Live Load On Roof (LL)	LIVE	1.5 KN/m2
4	Live Load on Floors (LL)	LIVE	3.0 KN/m2
5	Wall load on Floor Beams (ML)	DEAD	6.9 KN/m
6	Parapet Wall Load On Roof (ML)	DEAD	3.0 KN/m

IS 1893(part1):2002]

SEISMIC FACTORS	VALUES
Seismic Zone Factor Z	0.36
Soil Type	II (medium)
Importance Factor I	1
Response Reduction Factor RF	5

Codes and Guidelines considered in this study

- IS: 1893-2016…........ For seismic analysis
- IS: 875 Part -1… ....Floor Finish, Masonry Load
- IS: 875 Part -2… ....Live Load
- GSA......................... For Progressive collapse analysis
- IS: 456-2000............. For designing

Load Combinations for Analysis

S.NO	CODE	COMBINATON
1.	IS :456-2000	1.5 (DL+FF+ML)
2.	IS :456-2000	1.5 (DL+FF+LL+ML)
3.	IS :456-2000	1.2 (DL+FF+LL+ML+EQ X)
4.	IS :456-2000	1.2 (DL+FF+LL+ML-EQ X)
5.	IS :456-2000	1.2 (DL+FF+LL+ML+EQ Y)
6	IS :456-2000	1.2 (DL+FF+LL+ML-EQ X)
7.	IS :456-2000	1.5 (DL+FF+ML+EQ X)
8.	IS :456-2000	1.5 (DL+FF+ML-EQ X)
9.	IS :456-2000	1.5 (DL+FF+ML+EQ Y)
10.	IS :456-2000	1.5 (DL+FF+ML-EQ Y)
11.	IS :456-2000	0.9 (DL+ML+FF)+1.5EQ X
12.	IS :456-2000	0.9 (DL+ML+FF)-1.5EQ X
13.	IS :456-2000	0.9 (DL+ML+FF)+1.5EQ Y
14.	IS :456-2000	0.9 (DL+ML+FF)-1.5EQ Y
15.	GSA	G_{LD} = 2[1.2DL+(0.5LL or 0.2S)]
16.		G = 1.2DL+(0.5LL or 0.2S)

Table: load combinations for analysis

Steps Performed For Progressive Collapse Analysis

1.Design the building with the seismic load combinations to obtain Area of Steel required for each structural element

2.Remove the respective column and perform analysis with GSA load combinations and note the Bending Moment values obtained after column loss of all the beams as DEMAND

3. By using Area Of Steel (required) from step 1 , calculate the Moment Of Resistance of the corresponding beams as CAPACITY.

Mu = 0.87 fy Ast d[1-Astfy/bd fck]

4.Calculate DCR values of all the corresponding beams and check for acceptance

DCR = $\frac{\square\square\square}{\square\square\square}$ < 2 safe and acceptance value

Model 1: Seismically analyzed without considering column loss scenarios

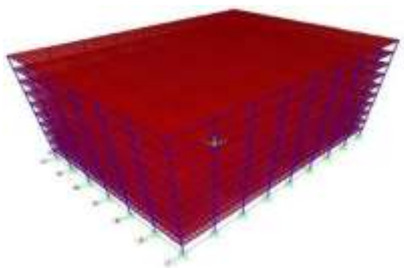

Fig: Isometric view of model 1

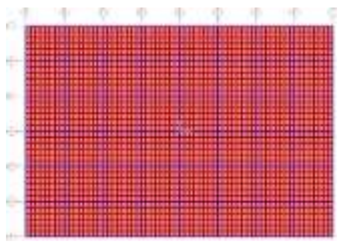

Fig: Plan view of Model 1

Model 2: External long side middle column loss at ground storey level

Fig:Isometric view of Model2

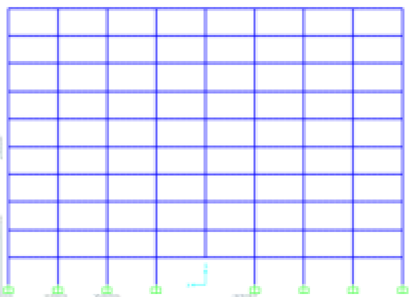

Fig.Elevation view of Model 2

Model 3: External short side middle column loss at ground storey level

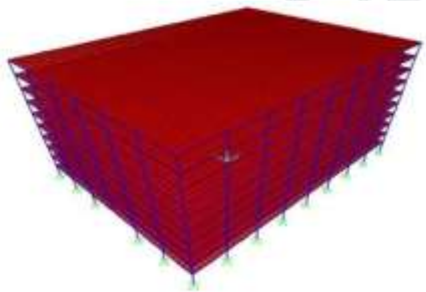

Fig. Isometric view of Model 3

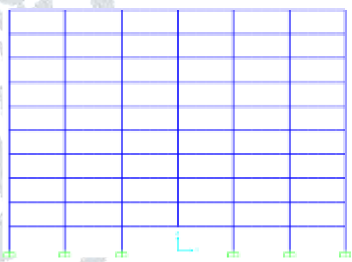

Fig: Elevation view of Model 3

Model 4:Corner column loss at ground storey level

Fig : Isometric view of Model 4

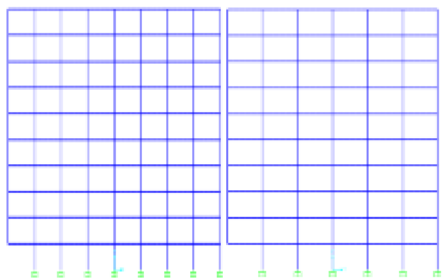

Fig : Elevation view of Model 4YZ and XZ planes

Moment DEMANDS (kN-m) obtained from Progressive Collapse Analysis SAP2000 of model 2, 3, 4

L	C	R
-692.95	380.99	-692.95
-673.58	354.25	-673.58
-646.22	327.09	-646.22
-624.66	304.63	-624.66
-606.35	285.74	-606.35
-591.47	271.93	-591.47
-579.99	262.03	-579.99
-570.36	254.35	-570.36
-572.81	252.35	-572.81
-479.19	258.16	-479.19

L	C	R
-676.91	463.24	-676.91
-658	436.98	-658
-630.73	409.89	-630.73
-609.24	387.49	-609.24
-590.94	368.54	-590.94
-575.98	353.14	-575.98
-564.38	341.08	-564.38
-554.42	331.44	-554.42
-557.01	329.26	-557.01
-475.02	329.51	-475.02

L	C	R
-684.35	385.72	-635.43
-683.83	417.09	-637.82
-655.97	383.5	-609.93
-635.46	362.74	-588.72
-618.14	344.53	-570.9
-603.92	324.69	-556.26
-592.85	318.05	-544.86
-583.66	308.8	-535.58
-587.0	310.88	-538.26
-483.59	271.34	-444.48

Moment CAPACITIES (kN-m) from calculations of model 2, 3, 4

L	C	R
342.14	341.77	342.14
393.73	391.38	393.73
400.52	396.60	400.52
397.14	391.56	397.14
387.21	377.66	387.21
363.98	360.89	363.98
331.26	319.57	331.26
280.84	276.20	280.84
237.96	225.65	237.96
165.16	151.35	165.16

L	C	R
358.26	359.41	358.26
403.71	406.53	403.71
409.33	413.50	409.33
404.59	410.20	404.59
393.55	406.52	393.55
371.30	383.61	371.30
337.63	349.97	337.63
293.90	306.44	293.90
242.70	256.09	242.70
168.58	184.08	168.58

L	C	R
364.93	353.65	345.88
403.81	403.71	389.94
404.77	410.72	390.30
395.88	407.58	378.77
378.40	397.58	357.69
349.20	379.14	328.86
311.39	345.69	291.37
263.58	301.66	244.04
191.10	248.97	190.54
150.11	168.09	130.02

Demand Capacity Ratio values of Model 2, 3, 4

L	C	R
1.97	1.35	1.97
1.67	1.11	1.67
1.57	1.03	1.57
1.53	0.98	1.53
1.52	0.97	1.52
1.58	0.97	1.58
1.55	1.06	1.55
1.67	1.19	1.67
1.98	1.45	1.98
2.87	2.17	2.87

L	C	R
1.93	1.06	1.93
1.66	0.87	1.66
1.57	0.79	1.57
1.54	0.74	1.54
1.54	0.71	1.54
1.59	0.70	1.59
1.71	0.74	1.71
1.94	0.83	1.94
2.36	0.98	2.36
2.84	1.40	2.84

L	C	R
1.87	1.09	1.83
1.69	1.03	1.63
1.62	0.93	1.56
1.60	0.88	1.55
1.63	0.86	1.59
1.72	0.86	1.69
1.90	0.92	1.86
2.21	1.02	2.19
3.07	1.24	2.82
3.22	1.61	3.41

CONCLUSION:

- From the historical events of progressive collapse we can conclude that the initiating factor causing progressive collapse is not always due to blasts and explosions. Sometimes the initiating factors to cause the collapse is due to removal of vertical load bearing elements of the building to create free space to use, surface fault ruptures, differential foundation settlements, design deficiencies, misuse and over load, vehicular collisions etc
- When the DCR values are less than 2,we should provide less reinforcement and where the DCR values

are more than 2 we should provide more reinforcement.

- When comparison of three cases 10% of columns fail in long side middle column removal condition, 20% of columns fail in short side middle column removal condition, 30% of columns fail in corner column removal condition.

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