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Progressive Collapse Analysis of Concrete Diagrid Structure by Using Linear Static Analysis

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Abstract - *Progressive Collapse of Concrete structures is initiated when one or more column is removed due to natural hazards or man-made. Load Carried by Column removed is transferred to adjacent column, if adjacent column is incapable to withstanding extra load leads to progressive failure of adjacent members and finally failure of partial or whole structure. Analysis and Design of 15 Storey Concrete Diagrid Structures of dimension 18m x 14m is Carried out by using ETAB software as per IS Codes Standard. In this study the progressive collapse analysis of concrete diagrid structure is carried out by removing different column one at a time as per the GSA guidelines at different stories. Demand Capacity Ratio, the ratio of member force and member strength as per U.S. General Services Administration (GSA), of different columns adjacent to remove of G+15 structure is evaluated. From results it is observed that most of Columns does not exceeds Demand Capacity Ratio (DCR) after removal of adjacent column at different stories force.*

Key Words: *Progressive Collapse, ETABs, IS Code, DCR, GSA Guidelines*

1. INTRODUCTION

The ability of the structure to withstand local damage that may arise by accidental actions without disproportional failure that is disproportional to the triggering cause is called the robustness of structure. Progressive Collapse is such a disproportional failure, which refers to the condition when the failure of a local component leads to global system failure. The spread of that initial local failure from element to element eventually resulting in the collapse of an entire structure or a disproportionately large part of it is called progressive collapse. After the event of 11 September 2001, more and more researchers have started to refocus on the causes of progressive collapse in building structures. Progressive Collapse occurs and structure can be fails when the structural elements are loaded beyond their ultimate capacities, the structure has its loading pattern or boundary conditions changed. When any element fails, the remaining elements the remaining element of the structure seek alternative load paths to redistribute capacity causing partial or total failure mechanism. It is dynamic process usually accompanies by large deformations, in which the collapsing system continually seek alternative in order to survive.

The term "diagrid" is derived from Diagonal grid, an efficient triangular structure that can guarantee the stability of a buildings. In diagrid structure, the gravity load and lateral loads can resist by diagonal column which provided on periphery of the structures. The rapid growth of urban population and limited land available have influenced the residential development of city. As the height of building increase, the lateral load resisting system becomes more important than the gravitational loads. The lateral load resisting system that are widely used are: rigid frame, shear wall, wall frame, braced tube system, Outrigger system and tubular system. Recently diagrid system is widely used due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of system. Diagrid has good appearance and it is easily recognized. The configuration and efficiency of a diagrid system reduce the number of structural elements required on the facade of the buildings, therefore less obstruction to the outside view.

In this study, firstly analysis and design of Concrete diagrid structure by using linear static analysis. Secondly progressive collapse analysis of concrete diagrid structure has been done. A floor plan of 18m x 14m size is considered. ETabs Software is used for modelling and analysis. After analysis and design, some columns are removed at one time from the different stories to study the progressive collapse analysis by knowing Demand Capacity Ratio of Adjacent Columns of removed column.

Guidelines Provided by the U.S. General Service Administration (GSA)

The purpose of these guidelines is to

- Assist in the reduction of the potential for progressive Collapse of the buildings
- Assist in the assessment of the potential for progressive collapse in existing buildings
- Assist in the development of potential upgrade to facilities if required

1.1 Analysis

In Linear Static Analysis Column is removed from the location being considered and linear static analysis with the gravity load imposed on the structure has been carried out. From the analysis results, the demand at

critical locations are obtained and from the original seismically designed section the capacity of the member is determined. Check the DCR in each structural member is carried out. If the DCR of a member exceeds the acceptance criteria, the member is considered as failed. The demand Capacity ratio calculated from linear static procedure helps to determine the potential of progressive collapse of building.

1.2 Analysis Loading

For static analysis purposes the following vertical load shall be applied to the structure under investigation.

Load=2(DL +0.25LL)

Where, DL=Dead Load, LL= Live Load

1.3 Acceptance Criteria

An examination of the linear elastic analysis results shall be performed to identify the magnitudes and distribution of potential demands on both the primary and secondary structural elements for quantifying potential collapse areas. The magnitude and distribution of these demands will be indicated by Demand Capacity Ratios (DCR) as equation

$$DCR=\frac{QUD}{QCE}$$

Q_{UD} = Acting Force (Demand) determined in component or connection/joint (moment, axial force, shear and possible combined forces)

Q_{CE} = Expected ultimate, un-factored capacity of the component and/or connection/joint (moment, axial force, shear and possible combined forces)

Using the DCR criteria of the linear static approach, structural elements and connections that have DCR values that exceed the following allowable values are considered to be severely damaged or collapsed.

The allowable DCR values for primary and secondary structural elements

DCR < 2.0 for typical configuration.

2. Modelling of Building

For the analysis, a typical frame model of plan as shown in fig.1 and of height 52m is modelled using ETABs software. The ground storey height is taken as 3m and remaining storey of 3.5m.The Column Cross section is taken as 450mm x 450mm and Diagonal Column 300mm x 380mm.Beam cross section is taken as 230mm x 350mm.All supports are modelled as fixed supports.

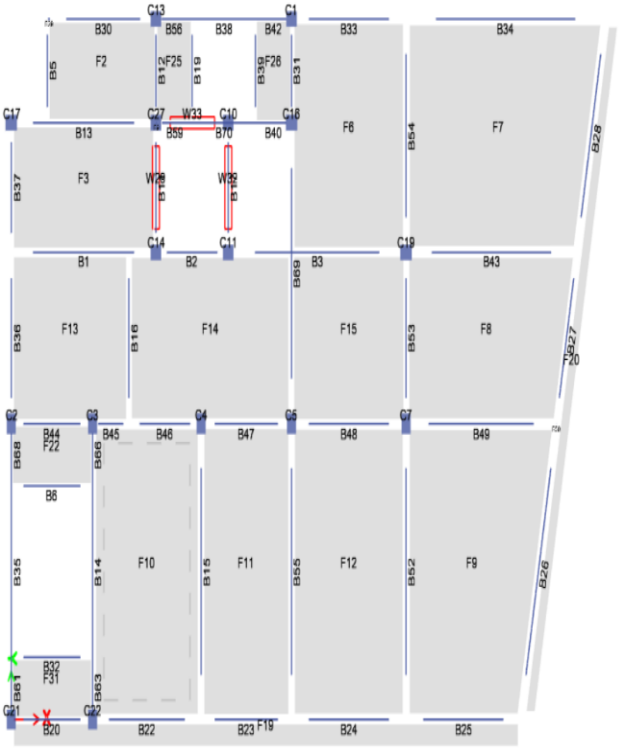

Fig.1 Plan View of Diagrid Structure

Dead Load

Self-Weight of the structural Elements

Floor Finish = 1KN/m^2

Wall load on all beams = 13.8KN/m

Live Load

On Floors = 4 KN/m^2 Seismic Loading as per IS 1893:2002, Zone II Soil Type II. Response Reduction Factor =5, Importance Factor = 1

The Characteristic Compressive Strength of Concrete (f_{ck}) is 20N/mm^2 and Yield strength of Steel(f_y) is 500N/mm^2. G+15 storey diagrid structure is designed for seismic loading in ETAB according to the IS456:2000.

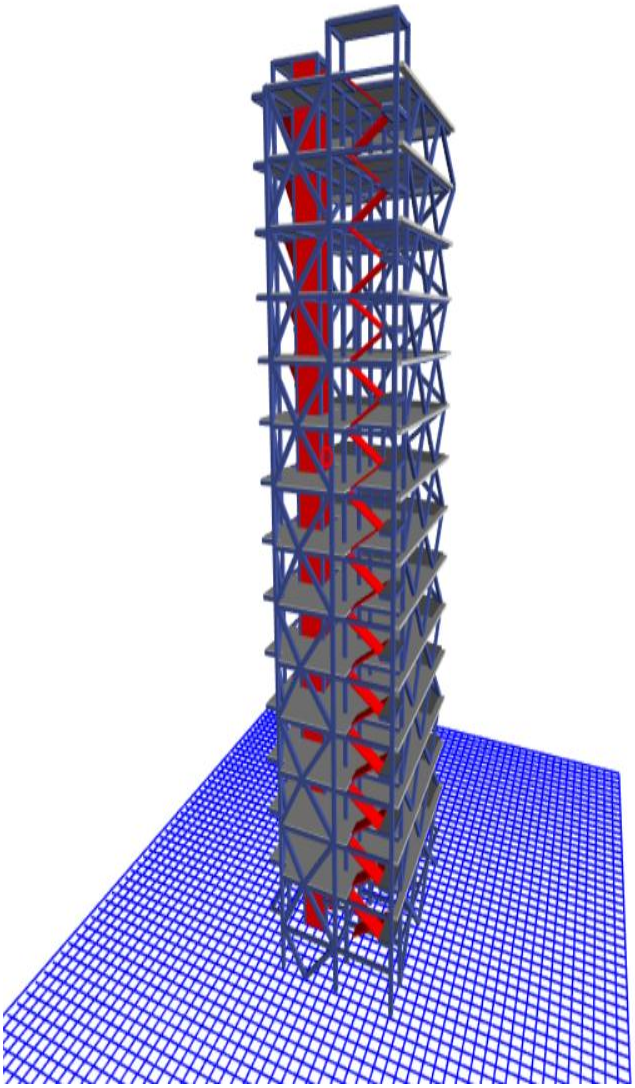

Fig.2.Three Dimensional Model of Structure

3. Analysis

To evaluate the potential for progressive collapse analysis of a 15story concrete diagrid structure using linear static analysis. The four column removal cases are considered. First building is designed in ETABs for the IS 1893 load combinations. Then Separate linear analysis is performed for each case of column removal. Demand Capacity Ratio for flexure at all story is calculated for all four-column failure. Columns D5, D22, D31, D32 are removed for progressive collapse analysis in different cases.

3.1. Calculation of Demand Capacity Ratio:

Capacity of member at any section is calculated as per IS 456:2000 from the obtained reinforcement details after analysis and design. Demand capacity ratio after removal of column is found out considering the member force for the load combinations as per GSA guidelines. Member force are obtained by analysis results carried out in ETAB 2018.

4. RESULTS AND DISCUSSION

Capacity of the member at any section is calculated as per IS 456:2000 from the obtained reinforcement details after analysis and design. Demand capacity ratio after removal of column is found out considering the member force for the load combination as per GSA guidelines. Member forces are obtained by analysis results carried out in ETABs

For Column D5 removed D3 have demand capacity(DCR's) greater than 2 and D9 have demand capacity ratio less than 2 the acceptance criteria value suggested by GSA guidelines so the additional reinforcement is required for column D3 and do not require for Column D9 to resist the progressive collapse analysis as in Table 1

For Column D22 removed Column24 have demand capacity ratios (DCR's) less than the limit of 2 the acceptance criteria value suggested by GSA guidelines and, therefore, do not need additional reinforcement to resist progressive collapse as in Table1

For Column D31 removed D29 have demand capacity (DCR's) less than 2 the acceptance criteria value suggested by GSA guidelines, so the additional reinforcement does not require for Column D29 to resist the progressive collapse analysis as in Table 1

For Column D32 removed D30 have demand capacity (DCR's) less than 2 the acceptance criteria value suggested by GSA guidelines, so the additional reinforcement does not require for Column D30 to resist the progressive collapse analysis as in Table 1.

5. CONCLUSIONS

Based on limited study on progressive collapse analysis of Concrete Diagrid Structure the following broad conclusions can be made

1. As per GSA guidelines, the DCR values of Columns are less than 2, it suggests columns are safe for progressive collapse analysis. Hence seismically designed building columns have inherent ability to resist the progressive collapse.

2. The columns whose DCR values are greater than 2, it suggests that columns are unsafe for progressive collapse and needs of adequate reinforcement to limit the DCR within the acceptance criteria.

3. To avoid the progressive collapse analysis of columns, caused by failure of particular column, additional reinforcement can develop alternate load paths and prevent progressive collapse analysis due to the loss of columns

4. Applying the GSA criteria to prevent progressive collapse for concrete buildings can be accomplished by the structural engineer using readily available software and for little additional construction cost.

5.1 Future Scope

Future study can be done by doing progressive collapse analysis of Concrete Diagrid Structure by considering Wind load for analysis and Design of Buildings.

1. Future study can be done by doing progressive collapse analysis of Concrete Diagrid Structure by considering Wind load for analysis and Design of Buildings.

2. To study the progressive collapse analysis of Concrete Diagrid structure for Different Zones of earthquake.

REFERENCES

[1] Jinkoo Kim and Young-Ho Lee "Progressive Collapse Analysis Resisting Capacity of Tube-Type Structures" Published in John Wiley & Sons, Ltd.2015.

[2] Kwangho Kwon and Jinkoo Kim "Progressive Collapse and Seismic performance of Twisted Daigrid Buildings" Published in International Journal of High-Rise buildings September 2014, Vol 3, No.3,223-230

[3] Niloufar Mashhadiali and Ali Kheyroddin "Progressive Collapse assessment of new Hexagrid structural system for tall buildings" Published Online in Wiley online library 2013.

[4] Mehrad Sasani and Jesse Kropelnicki "Progressive Collapse Analysis of an RC Structure", Published in Wiley interscience, John Wiley & Sons,Ltd., 2007.

[5] Rakshith K G,Radhkrishana, "Progressive Collapse Analysis of Reinforced Framed Structure",IJRET Nov-2013.

[6] Raghvendra C,Mr.Pradeep A R "Progressive Collapse Analysis of Reinforced Concrete Framed Structure", International journal of Civil and Structural Engineering Research, vol.2,PP(143-149) 2014.

[7] Kevin A.Giriunas, Dr.Halil Seze "Progressive Collapse Analysis of An Existing Buildings",

[8] Jinkoo Kim,Youngho Lee and Hyunhoon Choi, "Progressive Collapse Resisting Capacity of Braced Frames"Published in Wiley Online Library,John Wiley & Sons,Ltd. 2009.

[9] GSA 2003 "Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects. The U.S. General Services Administration, Washington D.C.

[10] Khushbu Jani, Paresh Patel, "Analysis and Design of Diagrid Structural System for High Rise Steel Buildings", Published by Elsevier Ltd, Procedia Engineering 51, PP 92-100,2013.

[11] Ravish Khan, S.B.Shinde, "Progressive Collapse analysis of reinforced concrete framed Structure" IJRET, Nov-2013

[12] IS 456-2000, "Plain and Reinforced Concrete-Code of Practice (Third Revision), Bureau of Indian Standard, New Delhi.

[13] IS 1893-2002(Part I) Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standard, New Delhi.

[14] ETABS V9.6 Analysis of reference manuals, computers and Structure, Inc. Berkeley.

[15] Deshpande R.D.,Patil S.M.Ratan Subramanya, "Analysis and Design of Diagrid and Conventional Strcutural System" Volume 2 IRJET,2015.

Table 1 Summary of DCRs for Columns Adjacent to Removed Columns

Storey	Removed Column	Adjacent Columns	Demand			Capacity			Ratio		
			P	M2	M3	P	M2	M3	P/P	M2/M2	M3/M3
Storey1	D5	D3	6653.3	346.33	-133.1	6609.6	151.91	-132.2	1.0066	2.2799	1.0066
		D9	2605.5	159.06	-52.11	4284.7	105.92	-85.69	1.6445	0.6659	1.6445
Storey 4	D22	D24	1500.9	125.91	-30.52	1385.3	103.75	-28.17	0.923	0.824	0.923
Storey 7	D31	D29	284.4	45.976	-18.32	274.78	38.72	-17.7	0.9662	0.8422	0.9662
Storey 2	D32	D30	691.52	57.576	35.717	764.7	43.429	36.878	1.1058	0.7543	1.0325