Study the progressive collapse analysis of shear wall-framed building with waffle and ribbed slab for different seismic zones factor

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Abstract:
The progressive collapse of the building occurs when one or more vertical load-carrying structural elements like columns and shear walls are removed. once a column is removed due to an extreme load generated either by natural hazards such as earthquake or by manmade like gas explosions, terrorist attacks, impact by vehicles, etc. the weight of the structure transfers to neighboring columns in the structure. The present analytical study investigates failure criteria and the potential of structural collapse of irregular R.C frame building having waffle slab and ribbed slab with the shear wall. The column has been removed at one location and the spread of damage is evaluated. The progressive collapse study has been done by removing the column at an identified critical location as per GSA (2003) guidelines. Static analysis is performed using structural analysis program ETABS 16.2.1, For each case, the results have been taken in terms of demand capacity ratio (DCR) at critical sections, and thus, the structure has been assessed for it's susceptible to progressive collapse. but the new version of ETABS 19 Enhancements provides the output tables that have been enhanced to tabulate the demand-capacity ratio (D/C ratio) for the whole model, as well as for each object individually. The results showed the existence of the column in the building makes it resistive to progressive collapse under the loss of vertical load-bearing element by providing sufficient stiffness and load paths for gravity loads.

***KEYWORDS**: Progressive collapse, ETABS ver.16.2.1, Demand Capacity Ratio (DCR), Linear static analysis, General Service Administration (GSA) Guidelines, ASCE 41-17Seismic Evaluation and Retrofit of Existing Buildings, Removed of column.*

1. INTRODUCTION

Progressive collapse is the collapse of all or an enormous aspect of a structure hastened by harm or a disappointment of a little piece. It is some of the time likewise called a progressive collapse, which is characterized as an auxiliary collapse unbalanced to the reason for the collapse it begins a chain reaction that makes other basic segments miss the mark in effect, making a greater and all the more harmful collapse of the structure, A genuine case of progressive collapse is a place of cards; on the off chance that one card comes up short close to the top, it makes various cards fall underneath it because of the effect of the principal card, bringing about a full. The idea of progressive collapse comes into the picture after the collapse of the 22 stories Ronan Point Apartment Towerin1968. The gas blast happened on the eighteenth floor that vivaciously rapped out the kitchen's outside burden-bearing boards close to the structure's edge. This outcomes in loss of help at that story (i.e., eighteenth floor) and set off above floors to fall. This falling floor's capability causes sway load on lower stories and the arrangement of a progressive collapse (Table_1) showing the major structural failures since 1968, The whole outside corner of the structure fallen through and through. As the little fundamental part comes up short [1].

1.1. Guidelines by the U.S. General Services Administration (GSA)

These Guidelines' motivation is to decrease the potential for progressive collapse in new and remodeled Federal structures. For these Guidelines' motivations, a significant modernization is characterized as a significant basic redesign, for example, a seismic upgrade.

The accompanying examination case ought to be thought of:
1. An outside column close to the center of the long side of the structure.
2. An outside column close to the center of the short side of the structure.
3. A column situated at the corner of the structure.

Table _1: List of the major structural failures since 1968.[2]

incident	year	location	structural system	No. floor	triggering event	Damage
Ronan point	1968	London, UK	large-panel	22	Gas Explosion	Partial
hotel new world	1987	little India, Singapore	RC frame	6	static fatigue	total
Sampoong Dept store	1995	Seoul, South Korea	RC frame	5	Overload	Partial
Khobar Towers	1996	Khobar, Saudi Arabia	Pre-cast concrete building	8	Bomb explosion	Partial
WTC Bldg. 1	2001	New York, US	Steel frame	110	Aircraft impact and fire	Total
Rana plaza	2013	Savar, Bangladesh	RC frame	8	Misuse, Overload	Partial
plasco Bldg.	2017	Tehran, Iran	Steel frame	17	fire	total

2. LINEAR STATIC ANALYSIS

The linear static analysis column is eliminated from the area being thought of, and linear static analysis with the gravity load constrained on the structure has been finished. The static results demand at basic areas are gotten, and from the principal seismically arranged zone, the part's restriction is settled. Check for the DCR in each basic part is done. If the DCR of a part surpasses the acknowledgment rules, the member is considered as failed. The demand capacity ratio calculated from the linear static procedure helps determine the potential for the building's progressive collapse.

2.1 Permissible Criterion for Progressive Collapse

The GSA guidelines Advice the use of the Demand–Capacity Ratio (DCR), which is defined as the ratio of the structural member force. After the sudden removal of a column to the member strength (capacity), as a benchmark to determine the failure of major structural members by the linear static analysis procedure (GSA 2003).

DCR= $\frac{Qud}{Que}$…*(i)*

Where,

Qud = Acting force (demand) observed in member or connection (shear, axial force, bending moment, and possible combined forces).

Que = Expected ultimate, unfactored capacity of the member or connection (axial force, moment, shear and possible combined forces) The permissible DCR values for primary and secondary structural elements are:

• Demand capacity ratio (DCR) < 2.0 for typical structural configurations.

• Demand capacity ratio (DCR) < 1.50 for atypical structural configurations. [3]

3. REDUCING THE POTINTIAL FOR PROGRESSIVE COLLAPSE OF BUILDINGS

a) **For Beams**: [4]

- ❖ Lateral support provided for the full length of the beam will prevent lateral-torsional-buckling.
- ❖ Loss of floor slab adjacent to a beam or change in support conditions can change the unbraced length and weaken the beams
- ❖ Use moment connections for beams in both directions from the perimeter, i.e., allow beams to cantilever from one bay in from the exterior.
- ❖ If possible, make all beam-column connections fully restrained.
- ❖ Size shear connections to also be capable of developing beam axial tension.

b) **For Column**: [5]

- Check column stability for greater unbraced length due to loss of adjacent beams, increased axial load due to loss of adjacent columns, and for axial-moment interaction from beams delivering their plastic moment to the columns.
- Seismically compact columns (AISC 341) may prevent local buckling under increased flexure.
- If possible, use concrete-filled tube columns or concrete-encased wide flange shapes designed and detailed by AISC 341-16.

c) **Slab design**

a. Lightweight concrete floor slabs will reduce load but the blast resistance performance can be

b. enhanced by using normal weight concrete.

c. More reinforcing steel can help tieback adjacent beam to share load in event of column loss under beam.

d. Provide some amount of continuous top and bottom reinforcement in both directions. Do not splice at midspan or at ends.

e. Add perimeter frame for flat plate systems. Reinforcing steel in perpendicular directions, top and bottom may allow a slab to change span

4. METHODOLOGY

The structures which are used in this study are a10storeys with 9x10 bays reinforced concrete frame structure as shown in Figure1. The Proposed Plan of the buildings is:

- Ground floor to 2nd floor typical [Waffle slab]
- 3rd floor to 6th floor typical [Ribbed slab]
- 7th floor to 9th floor typical [Ribbed slab]

4.1 Detailed Data of The Buildings

- Material

Concrete Grade: M35; for concrete Modulus of elasticity, E =134375 KN/m2; Grade of Steel: Fy 460; Poisson's ratio of Concrete: 0.20; No. of Stories: G+9; Ground story Height: 4 m; Stories height :3.25m

- Overall depth of waffle slab :425 mm
- Overall depth of ribbed slab:425 mm
- Columns size C1 (400*800) mm, C2(500*800) mm, C3 (450*800) mm, C4 (400*500) mm, C5 (400) mm
- beams size: B1(400*600), B2(480*350), B3(480*300), B4(480*250), B5(400*250)
- Loading Consideration

Dead load: 4.5 KN/m^2 and Live load: 2.7 KN/m2 [6]

Seismic loading is taken into consideration as per (UBC97) uniform building code.[7]

- Zone 2B, Z=0.20; Zone 3, Z=0.30; Zone 4, Z=0.40

Soil type: S_C; Importance factor, I =1; Response reduction factor, R =5.5

4.2 Load Combinations

The buildings are analysed and designed as per American Concrete Institute (ACI318-19): BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE Load combination for Progressive collapse analysis as per GSA Static analysis.

$$2\{\text{Dead Load} + 0.25(\text{Live Load})\} \quad \ldots(ii)$$

5. PROGRESSIVE COLLAPSE ANALYSIS

In this analysis method, the structural bearing element(column) removed is (C1) from the ground floor (An exterior middle along y-direction) in a different seismic zone, linear static analysis is executed with gravity loads are given by Equation (ii) forced upon the structure. From the analysis results, demand at the critical section is worked out. Also, the capacity of the section is evaluated from the originally seismically designed section.[8]

Table_2: the effect area of removal elements

Removal element	The effect area of removal element											
Column C1	C1	C2	C3	C4	C5	C6	C7	B1	B2	B3	B4	B5

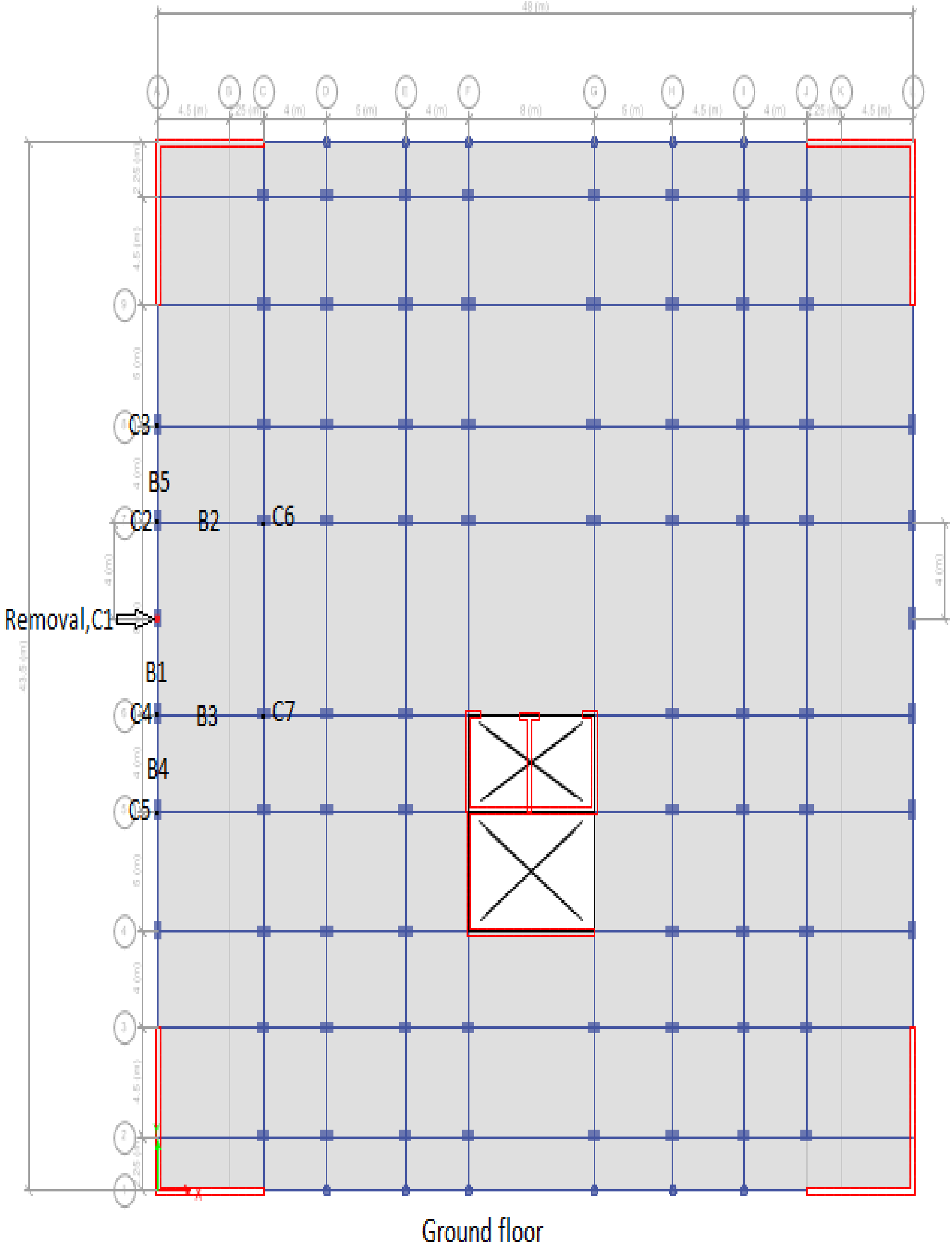

Figure1

6. CALCULATION OF DEMAND CAPACITY RATIO

The member's capacity at any section is evaluated as per (ACI318-19) from the obtained moment. After analysis and design. The member moment after removal of the column and loaded with the load combination as per GSA and ASCE 41-17code of practice,[9] Demand of the member is found out. The demand Capacity ratio for each section is found using the above data. Member moment is obtained by analysis results carried out in ETABS 16.2.1.

6.1 Case1: Removed C1 for zone 2B, Z=0.20

Table_3: [Comparison of maximum DCR values for different elements (columns, beams)].

S. No	DEMAND CAPACITY RATIO			
	Columns	DCR	Beams	DCR
1	C2	1.994	B1	5.310
2	C3	1.697	B2	2.000
3	C4	2.000	B3	2.000
4	C5	1.697	B4	19.940
5	C6	1.810	B5	12.120
6	C7	2.872		

6.2 Case2: Removed C1 for zone 3, Z=0.30

Table_4: [Comparison of maximum DCR values for different elements (columns, beams)].

S. No	DEMAND CAPACITY RATIO			
	Columns	DCR	Beams	DCR
1	C2	1.994	B1	5.300
2	C3	1.697	B2	2.000
3	C4	2.000	B3	2.000
4	C5	1.697	B4	19.937
5	C6	1.810	B5	12.117
6	C7	2.872		

6.3 Case2: Removed C1 for zone 4, Z=0.40

Table_5: [Comparison of maximum DCR values for different elements (columns, beams)].

S. No	DEMAND CAPACITY RATIO			
	Columns	DCR	Beams	DCR
1	C2	1.994	B1	5.308
2	C3	1.697	B2	2.000
3	C4	2.000	B3	2.000
4	C5	1.697	B4	19.937
5	C6	1.810	B5	12.117
6	C7	2.872		

Table_6: Number of elements exceeding DCR limiting value for different seismic zone

Elements	Number of elements exceeding DCR limiting value for GSA		
	zone 2B	zone 3	zone 4
Columns	1 (C7)	1 (C7)	1 (C7)
Beams	3 (B1, B4, B5)	3 (B1, B4, B5)	3 (B1, B2, B3)

7. Graphical Representation of DCR

After getting all the DCR values for building models, all cases of column removal for different seismic zone of DCR Vs members are plotted. There are:

1. Case1: Removed C1 for zone 2B, Z=0.20

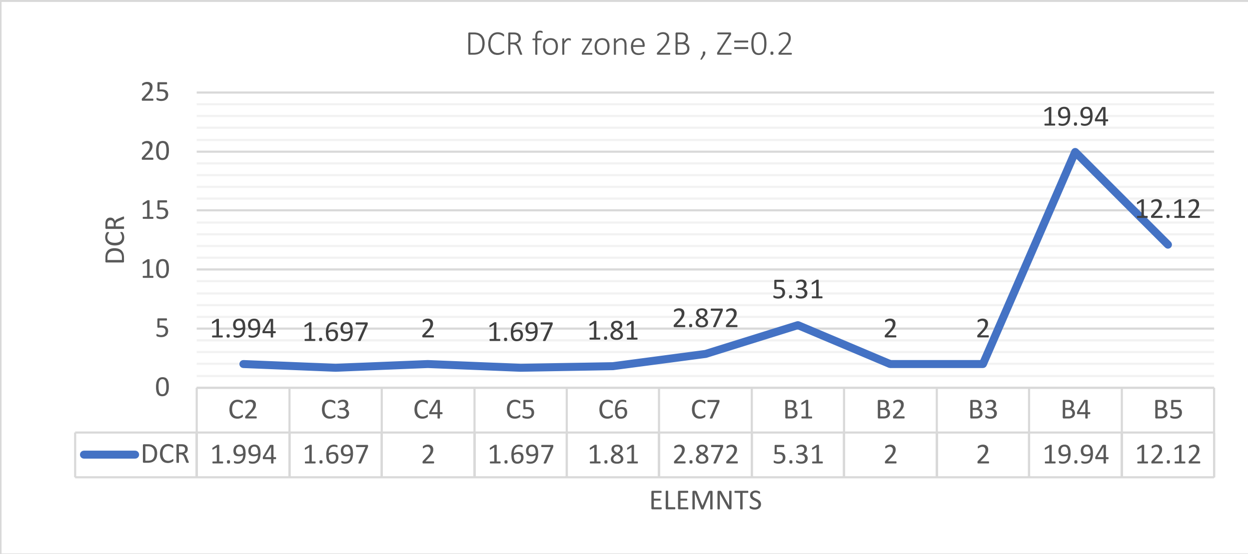

Figure2: Comparison of maximum DCR values for different elements (columns, beams).

➢ Columns

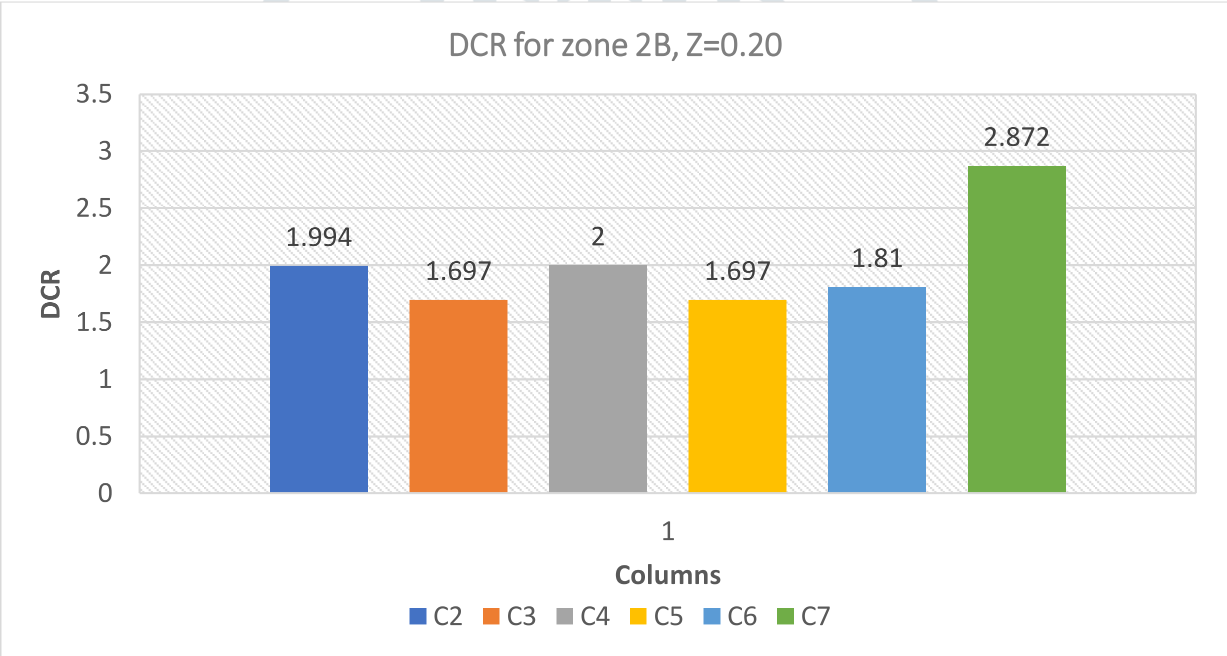

Figure3: Comparison of maximum DCR values for different elements (columns).

➢ Beams

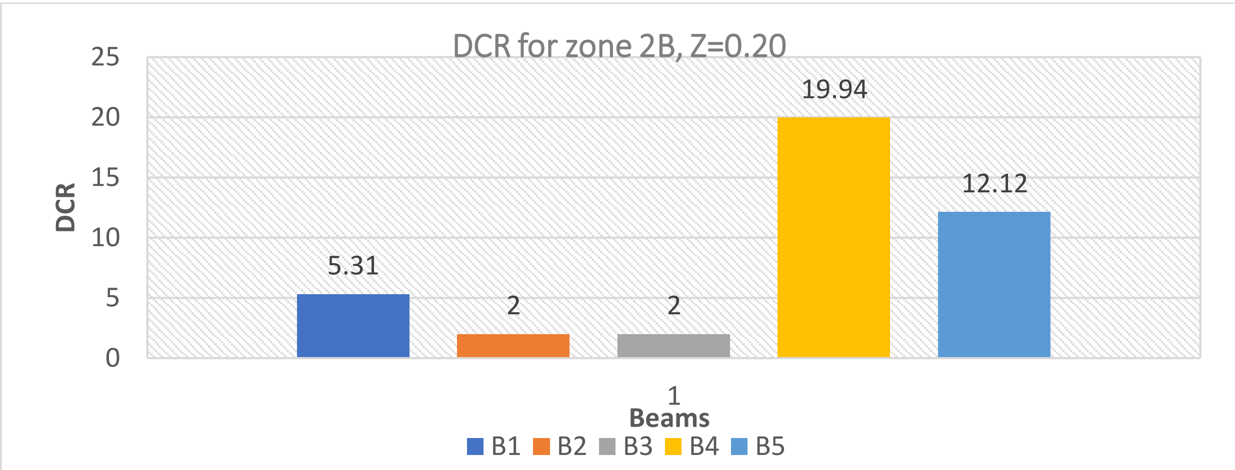

Figure4: Comparison of maximum DCR values for different elements (beams).

2. Case2: Removed C1 for zone 3, Z=0.30

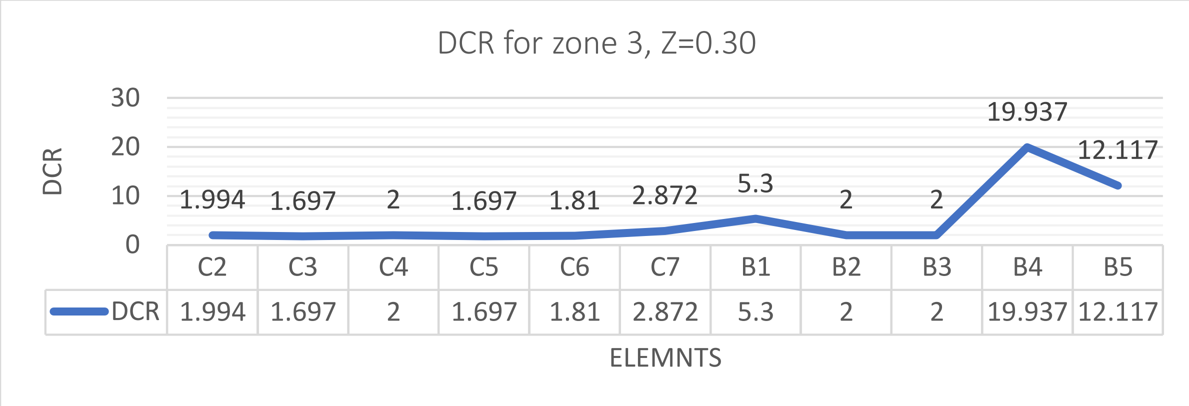

Figure5: Comparison of maximum DCR values for different elements (columns, beams)

- Columns

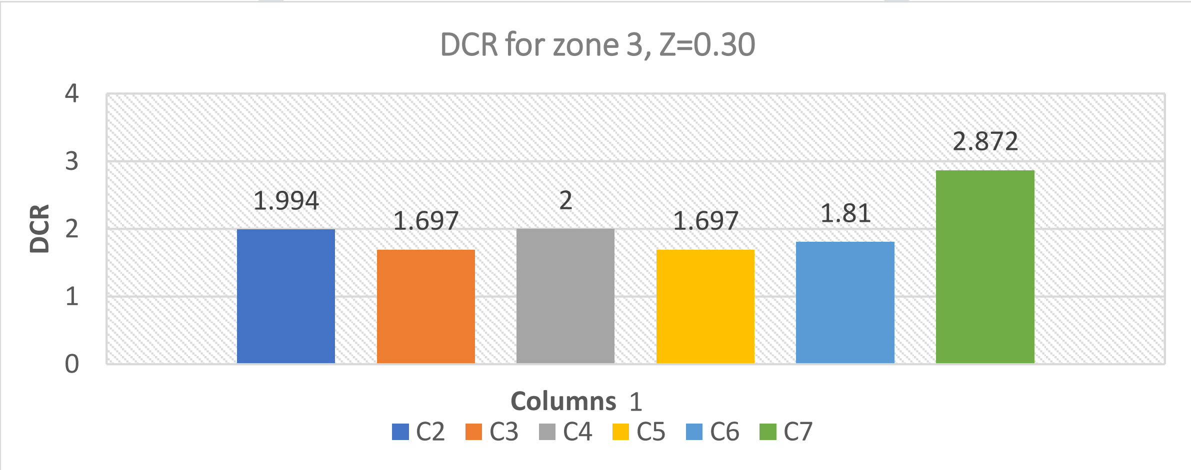

Figure 6: Comparison of maximum DCR values for different elements (columns, beams)

- Beams

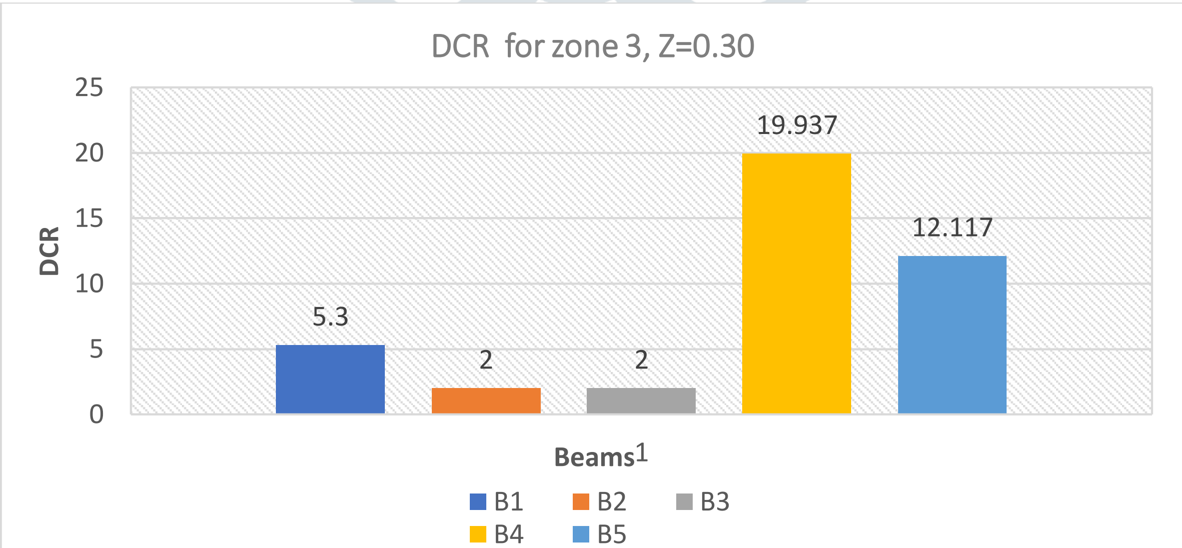

Figure7: Comparison of maximum DCR values for different elements (beams)

3. Case2: Removed C1 for zone 4, Z=0.40

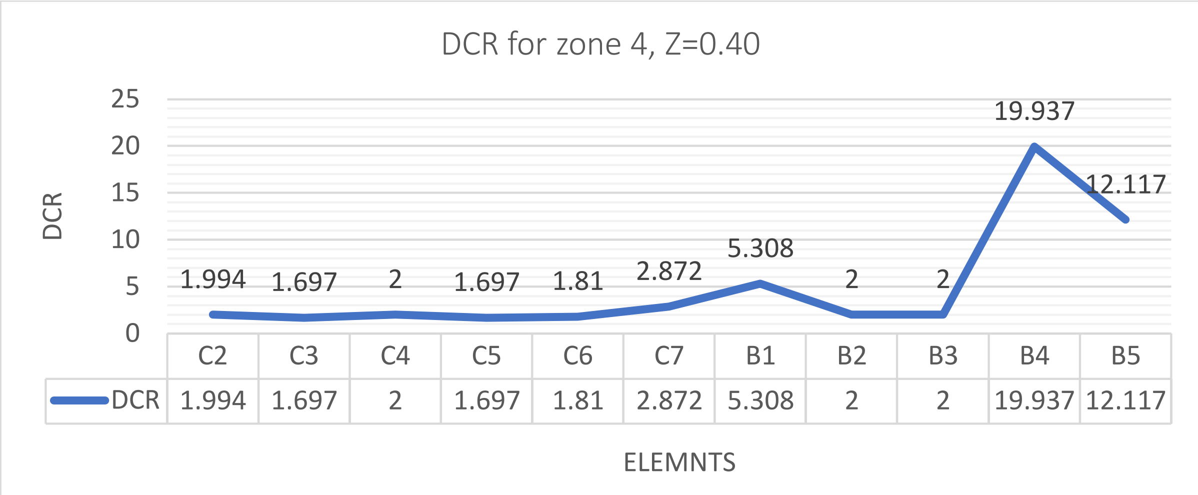

Figure 8: Comparison of maximum DCR values for different elements (columns, beams)

- Columns

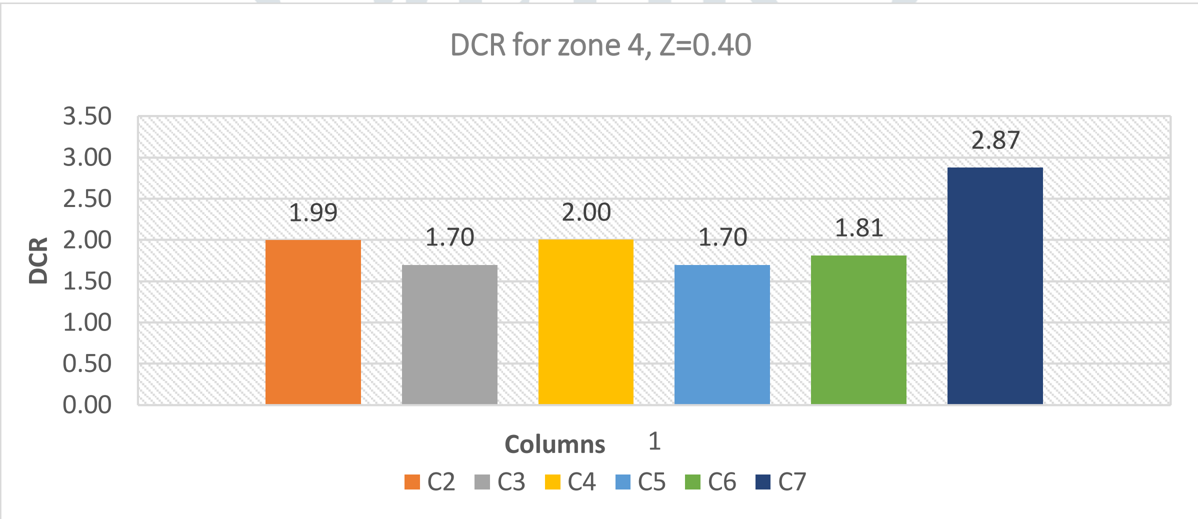

Figure 9: Comparison of maximum DCR values for different elements (columns).

- Beams

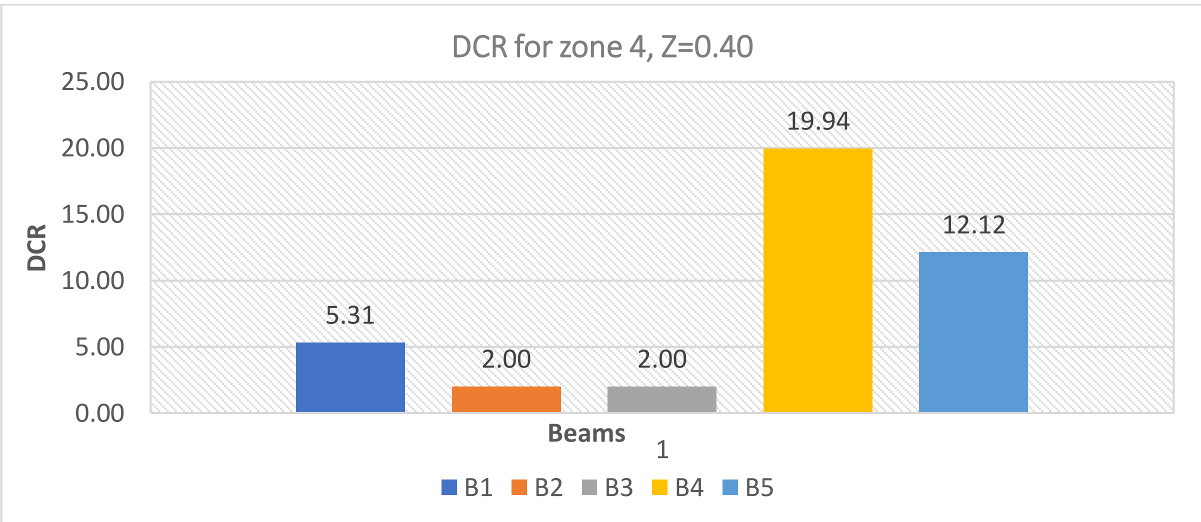

Figure10: Comparison of maximum DCR values for different elements (beams)

8. CONCLUSIONS

- The result of the elastic analysis & design of shear wall -framed building with waffle and ribbed slabs, stories G+9 indicates that:
- The removal of a column gives numbers of elements exceeding the DCR value for beams more than columns in the different seismic zones factor.
- The removal of a column for seismic zone factor (2B, Z=0.20) gives several elements exceeding the DCR limiting value For GSA equal to the removal of a column for seismic zone factor (3, Z=0.30) and the removal of a column for seismic zone factor (4, Z=0.40).
- In the different seismic zones several elements exceeding the DCR but the numbers of elements exceeding the DCR value in beams more than columns.
- Generally, the failure elements equal in different seismic zone factors.

9. V. ACKNOWLEDGMENT

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10. REFERENCES

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