

Collapse Mechanism of Strong Column Weak Beam Buildings of Varying Heights



Mohd Moazzam Ali Irfani, A Vimla

Abstract: During past earthquakes column plastic hinges are more important than beam hinges which gives rise to global structural damage and high life threatening risk. All the structural components transfers their forces through column and then column shares it with foundation to soil, so u can imagine if column fails whole structure can collapse this is strong beam weak column concept. In this paper collapse mechanism of three buildings 5, 12 and 15 storey heights are investigated for strong column weak beam concept. The structure is designed for zone 5 and medium soil. The aim of this work is to determine the static non-linear performance of three buildings of varying heights, each storey height is 3m and each bay width is 5m, the width of the building in X and Y direction is 20m. The heights of the buildings are 15m, 36m and 45m. The parameters which are obtained from the analysis are base shear, displacement and hinge formations in the structure. The base shear and displacement of the structures increases with an increase in strong column weak beam concepts. The hinge formations in the low-rise building involved beam failures whereas the hinge formation in mid-rise buildings involves mixed failure pattern involving beams and columns.

Keywords: strong column-weak beam, push-over curve, base-shear, displacement.

I. INTRODUCTION

The intent of the strong-column weak-beam (SCWB) strength concept in building codes is to reduce the likelihood of the formation of story mechanisms. The formation of plastic hinges in beams helps to build the most desired and suitable energy dissipating mechanism for structure in seismic conditions. If the plastic hinges are formed on both ends of column then column is not able to spread the plasticity and collapses which can lead to global failure. The current ACI 318 provisions, require a column-to-bream strength concept of 1:2 or greater as summed at the joints. Previous research has shown that for tall buildings this is not sufficient to prevent these undesirable plastic mechanisms from forming and leading to collapse of the structure. Furthermore, nonlinear analyses of structures greater than four stories with strength concepts of 1.4 or greater have shown story mechanisms to still occur. It is unclear whether complete prevention of story mechanisms is possible or even necessary in tall buildings. To achieve a complete building mechanism, the required SCWB concept may be greater than is acceptable to the project sponsor..

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The failure modes in all the past earthquakes are almost similar and strong beam weak column comes out to be a major problem which leads columns to sway or sway mechanism and these structures also have lack of ductile detailing in beam and column joints.

I.2 Strong column weak beam

Strong column-weak beam' means that the actual flexural capacity of beam end Mb and Mc of column end at the node should meet the following equation:

$$Mc > Mb$$

As we all know that if a beam of any high rise building fails it will only affect the that particular story but, if a column of structure fails then it will lead to a failure of the whole building. So this demands a strong column weak beam design. A building cannot collapse due to heavy earthquake but it can due to weak design as shown in fig-1.1. So the good design and its implementation takes place for the safety of the people. The intent of the strong-column weak-beam (SCWB) provisions found in many codes is to reduce yielding of columns above the ground floor in moment-resisting frames, thus avoiding excessive local ductility demands and the subsequent formation of story mechanisms. There is, however, little consensus among the codes and current literature as to what that strength concept should be to create a strong-column weak-beam condition. According to seismic design philosophy, plastic hinging of columns is permitted only in the lower storey, while beam hinging is expected to occur at every storey level.

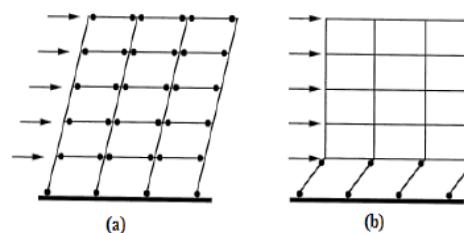


Fig- 1.1: Mechanisms of (a) Strong Column Weak Beam and (b) Weak Column Strong Beam.

II. OBJECTIVE OF THE STUDY

The objectives of the present study are:

- To study the role of Strong column weak beam concepts on base shear and displacement of the buildings of varying heights.
- To Study the influence of Strong-column weak beam requirement on collapse mechanism or structural damage of buildings of different heights.
- Analyzing various structures with three different heights and two strong column weak beam concepts.



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III MODELLING AND ANALYSIS

To determine the effects that Strong column weak beam have on collapse mechanism of buildings, several buildings with differing Strong column weak beam (SCWB) concepts and heights were analyzed. Modeling consists of building details, load combinations and building models.

A. Modelling and Material Properties:

For this study of reinforced-concrete frame structures, three building heights are selected: 5-, 12-, and 15-stories. For each height, several buildings are designed with varying SCWB concepts that is 1.2 and 1.4

Table I: Details of Structural Elements and Material Used

Plan dimensions	20m x 20m
No. of storeys	5, 12, 15
Story height	3.0 m
Grade of longitudinal steel	Fe500
Grade of confinement steel	Fe415
Grade of concrete	M30
Thickness of slab	130 mm
Cross section of beam	230mm X 600mm
Thickness of wall	230 mm
Specific weight of wall	20 kN/m ³
Seismic zone	V
Live load	3 kN/m ²
Floor finish	1.5 kN/m ²

Table-I shows the structural elements dimensions and materials used, dimension of the plan 4 x 4 considered.

Table- II: Column size for different storeys

Column size	5 storey	300mm X 600mm
	12 storey	400mm X 800mm
	15 storey	500mm X 1000mm

Table-II shows the column sizes considered for three different heights of the buildings.

B. Load combinations

Following load combinations with the appropriate partial safety factor satisfying IS code provision i.e.IS 456:2000, table 18, clause 18.2.3.1 and IS 1893:2002, clauses 6.3.2.1 are as shown in table III.

Table- III: Load combinations considered.

S. No.	Load combinations
1	1.5(DL + LL)
2	1.2(DL + LL + EQX)
3	1.2(DL + LL - EQX)
4	1.2(DL + LL + EQY)
5	1.2(DL + LL - EQY)
6	1.5(DL + EQX)
7	1.5(DL - EQX)
8	1.5(DL + EQY)
9	1.5(DL - EQY)
10	0.9DL + 1.5EQX
11	0.9DL - 1.5EQX
12	0.9DL + 1.5EQY
13	0.9DL - 1.5EQY

C. Building models

In the present work, three models of different heights – 5, 12 and 15 storeys with two different strong column weak beam or moment capacity concepts are analyzed to study the effect of strong column weak beam concepts on the performance of the low rise and high rise buildings in E-tabs software. These frames is first designed for gravity loading and then the results of rebar percentage, column beam capacity concept and seismic results are checked then pushover is done to check the damage and performance of 3 frames with two different scwb concepts.

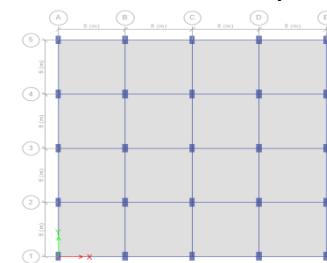


Fig- 3.1: Plan view for all the models.

Fig- 3.1 shows the plan and plan dimensions of the building and it is same for all the buildings with 5, 12 and 15 storeys. It is a square plan 4 x 4 bay, each bay width is considered to be 5 meters.

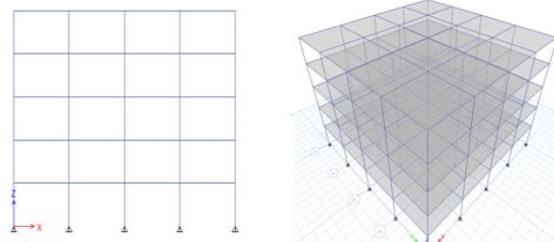


Fig- 3.2: Elevation and 3-D view of 5 storey building.

Fig 3.2 shows the elevation and 3-d view of a five storey building which is designed for two different strong column weak beam concepts that is 1.2 and 1.4 which is achieved by changing its material strength, quantity of reinforcement, wall thickness and using modifiers on which push over analysis is performed.

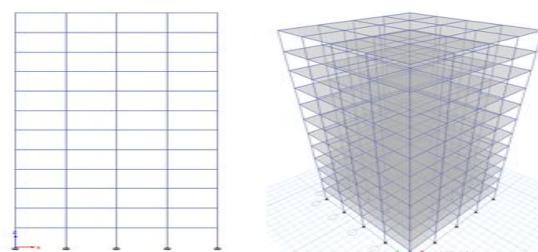


Fig- 3.3: Elevation and 3-D view of 12 storey building.

Fig 3.3 shows the elevation and 3-d view of a twelve storey building which is designed for two different strong column weak beam concepts that is 1.2 and 1.4 which is achieved by changing its material strength, quantity of reinforcement, wall thickness and using modifiers on which push over analysis is performed.

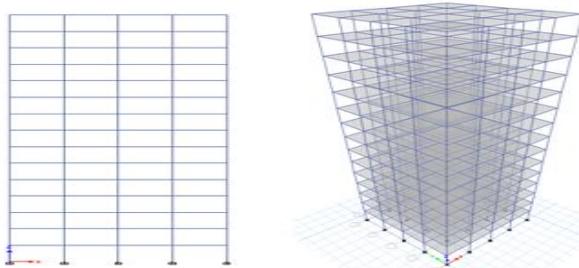
**Fig- 3.4: Elevation and 3-D view of 15 storey building.**

Fig 4.3 shows the elevation and 3-d view of a twelve storey building which is designed for two different strong column weak beam concepts that is 1.2 and 1.4 which is achieved by changing its material strength, quantity of reinforcement, wall thickness and using modifiers on which push over analysis is performed.

IV. RESULTS AND DISCUSSIONS

An attempt is made to study the strong column weak beam concept of low rise and mid-rise buildings with two different strong column weak beam concepts between column and beam. Thus the cross sections of columns are varied as shown in table II.

A. Base shear versus displacement

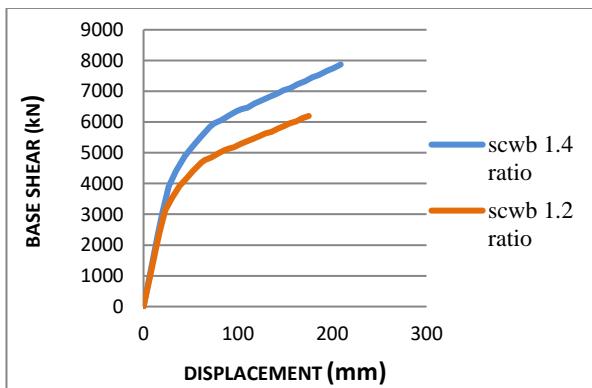
**Fig- 4.1: Capacity curves of five storey building.**

Fig 4.1 shows the capacity curves obtained with static non-linear analysis for five storey building with two different strong column weak beam concepts 1.2 and 1.4. The results indicates that initially the capacity curve is linear for both concepts in the elastic range before yielding, the curve starts to deviate after yielding is occurred and also the displacement via base shear of the structure increases as the strong column weak beam concept is increased.

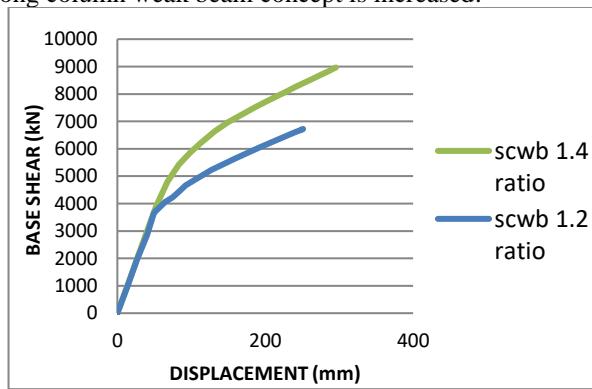
**Fig- 4.2: Capacity curves of twelve storey building.**

Fig 4.2 shows the capacity curves obtained with static non-linear analysis for twelve storey building with two different strong column weak beam concepts 1.2 and 1.4. The results indicates that initially the capacity curve is linear for both concepts in the elastic range before yielding, the curve starts to deviate after yielding is occurred and also the displacement via base shear of the structure increases as the strong column weak beam concept is increased.

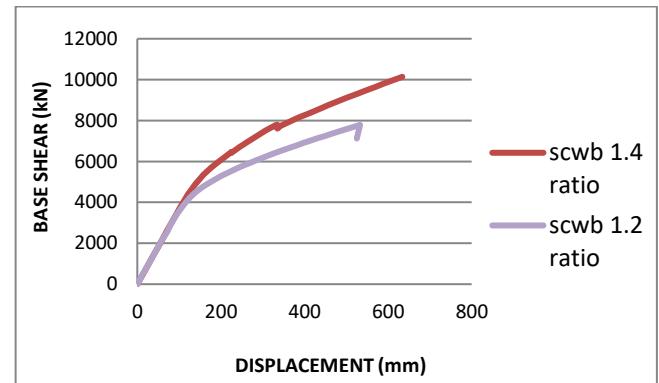
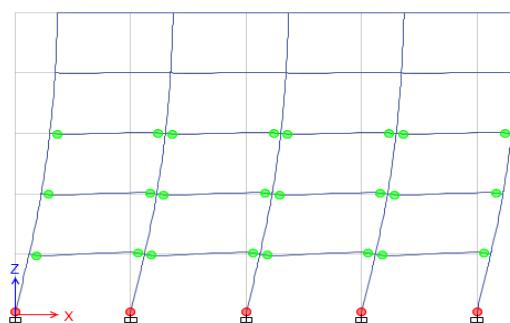
**Fig- 4.3: Capacity curves of fifteen storey building.**

Figure 5.3 shows the capacity curves obtained with static non-linear analysis for fifteen storey building with two different strong column weak beam concepts 1.2 and 1.4. The results indicates that initially the capacity curve is linear for both concepts in the elastic range before yielding, the curve starts to deviate after yielding is occurred and also the displacement via base shear of the structure increases as the strong column weak beam concept is increased.

B. Collapse mechanism

Under the application of pushover loads the members in a structure initially remain elastic up to a certain moment M_p that is the maximum moment of resistance of a fully yielded section. Any further increase of moment will cause the beam to rotate with little increase in load. The rotation occurs at that particular moment M_p . So these expected locations of damage caused by a yielded zone having large inelastic rotation capacity at constant restraining moment M_p are called plastic hinges. The combination of inelastic hinges at the ends of beams and columns which when formed in a building eventually makes it unstable and causes its collapse, hence called collapse mechanism.

**Fig- 4.4: Collapse mechanism of five storey building with 1.2 scwb concept.**

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Fig 4.4 shows the behaviour of collapse mechanism of five storey building with strong column weak beam value 1.2. The plastic hinges are first appeared in beams than in column making it as strong column weak beam but the collapse is taking place in base columns rather than in beam so this strong column weak beam concept of 1.2 as specified earlier by code is unable to distribute the hinges to top storeys involving collapse mechanism in columns.

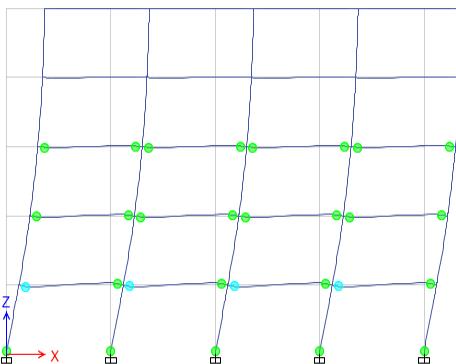


Fig- 4.5: Collapse mechanism of five storey building with 1.4 scwb concept.

Fig 4.5 shows the behaviour of collapse mechanism of five storey building with strong column weak beam value 1.4. The plastic hinges are first appeared in beams than in column making it as strong column weak beam and the collapse is also taking place in beams. So it may stated that this strong column weak beam concept of 1.4 as specified now in codes involves beam collapse mechanism distributing damage throughout the structure. The formation of plastic hinges in the column does not lead to immediate occupant and does not lead to collapse of the structure.

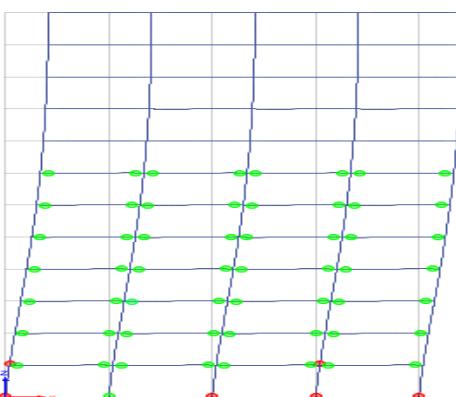


Fig- 4.6: Collapse mechanism of twelve storey building with 1.2 scwb concept.

Fig 4.6 shows the behaviour of collapse mechanism of twelve storey building with strong column weak beam concept 1.2. The plastic hinges are first appeared in beams than in column making it as strong column weak beam but the collapse is taking place in base columns and first storey columns making it a column collapse mechanism. So this scwb concept of 1.2 as specified by codes is not enough to form beam collapse mechanism in twelve story structures involving column collapse mechanism.

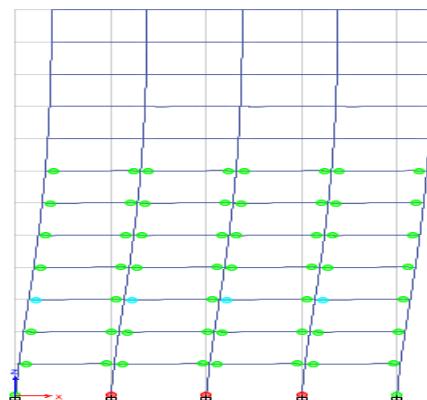


Fig- 4.7: Collapse mechanism of twelve storey building with 1.4 scwb concept.

Fig 4.7 shows the behaviour of collapse mechanism of twelve storey building with strong column weak beam concept 1.4. The plastic hinges are first appeared in beams than in column making it as strong column weak beam. Although the collapse mechanism involves beam, there is also a column collapse mechanism in base columns which make it as a beam-column collapse. So this scwb concept of 1.4 now specified by code is not enough to form only beam collapse mechanism for tall buildings.

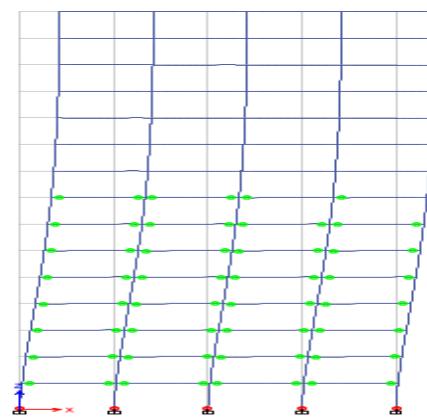


Fig- 4.8: Collapse mechanism of fifteen storey building with 1.2 scwb concept.

Fig 5.8 shows the behaviour of collapse mechanism of fifteen storey building with strong column weak beam concept 1.2. The plastic hinges are first appeared in beams than in column making it as strong column weak beam but the collapse is taking place in base columns rather than in beam so this strong column weak beam concept of 1.2 as specified earlier by code is unable to distribute the hinges to top storeys involving collapse mechanism in columns in tall buildings.

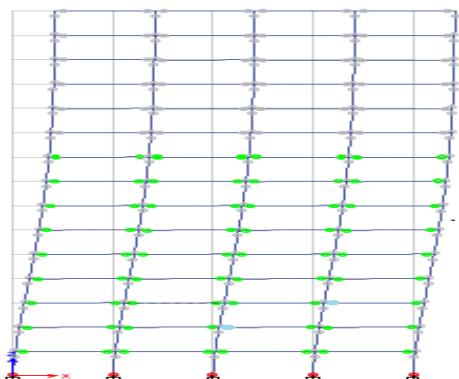


Fig- 4.9: Collapse mechanism of fifteen storey building with 1.4 scwb concept.

Fig 4.9 shows the behaviour of collapse mechanism of fifteen storey building with strong column weak beam concept 1.4. The plastic hinges are first appeared in beams than in column making it as strong column weak beam. Although the collapse mechanism involves beam, the beams are not completely collapsed and there is also a column collapse mechanism in base columns which make it as a beam-column collapse. So this scwb concept of 1.4 now specified by code is not enough to form only beam collapse mechanism for tall buildings.

V. CONCLUSION

The goal of this study was to examine the effects of strong-column weak-beam concept on collapse mechanism of buildings with varying height. Six structures were modeled; three heights; five, twelve and fifteen storeys each at two Strong column weak beam ratio 1.2 and 1.4, non-linear analysis was performed on these structures and capacity curves were obtained as well as collapse mechanism. Following are the conclusions drawn from the present study.

- For low rise buildings the collapse mechanism was first appeared to be in columns causing the failure of columns at bottom storey for 1.2 scwb ratio but as the ratio was increased the hinges were appeared in beams causing the failure of beams.
- In case of mid-rise buildings that is twelve and fifteen storeys, the collapse mechanism followed a mixed failure pattern. For 1.2 scwb ratio the hinges were appeared in columns causing the failure of columns at bottom storey. As the ratio was increased to 1.4, hinges not only appeared in beams but also in columns.
- As the strong column weak beam concepts were increased in mid-rise buildings more storeys were engaged in collapse mechanism.
- It was also noted that with increase of strong column weak beam concepts in both mid and high rise buildings there was an increase in its base shear and displacement.

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