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Seismic Response of Concentrically Barced Reinforced Concrete Frames

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Abstract— Due to minor eccentricities in the joints of the frame, a concentrically braced frame has accounted for in the design (which is tried with combinations of V and A-braces, generally called K braces, for twelve storey building with 5-bay structures). An analytical investigation is performed on such frames. The paper aims to find the proper locations of braces. Finally, the results obtained from analytical investigation are utilized to verify the validity of the proposed locations of braces in terms of economy. Every attempt has been made to describe the things in dimensionless form. Results are concluded from tables and discussed comprehensively.

Index Terms— Bare Frames, Concentrically Braced Frames (CBF), V-Braced Frames, A-Braced Frames, Baywise Braced Frames, Levelwise Braced Frames, Outriggers.

1 Introduction

DUE to Industrial revolution, availability of jobs and facilities, population from rural area is migrating towards cities. Because of this metro cities are very thickly populated. Availability of land goes on decreasing and land cost also increases. To overcome this problem the use of multistoreyed buildings is must. But such provisions increases self weight and live load along with earthquake forces. With increase in height stress, strain, deformation and displacement in the structure increases; which ultimately increases the cost of construction due to increased cross-sections of the elements. Bracing systems provide lateral stability to the overall framework. The bracing members of such braced frame act as truss system to resist lateral forces and are subjected primarily to axial stress in the elastic range. It is but obvious that bare frames are found to be more flexible and have large section requirement to with stand forces induced. The same can be minimizing by making structure more rigid but it seems to be not feasible and uneconomical.

2 Objective of Study

In this paper use of bracing to increase the stiffness of structure has been tried. The A- type, V- type of bracing system has been used. Frames were considered as fully braced frames in preceding discussion, however, partially braced frames are also analyzed and optimum locations of braces have been found. Behavior of bare frame, fully braced frames with the partially braced frames is studied and has been presented in results and discussion.

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3 Description of Study Building

Frames can be analyzed by various methods(1). However, the method of analysis adopted depends upon the types of frame, its configuration of (portal bay or multi-bay) multi-storey frame and degree of indeterminacy(1). As the analysis is problem specific, it is felt necessary that an attempt must be made to generalize the same and results so obtained are directly used to predict the behavior of structures. With this view point all parameters are expressed in dimensionless form.

3.1 Bare and Fully Braced Frames:

In order to study the behavior of moment resisting V-braced frames (fully, partially bay braced and partially level braced and outrigger frames) 5 bay 12 storey structures are modeled and analyzed numerically. The sections of columns are reduced from top to bottom which is same for every 3 storey (1-3, 4-6, 7-9, and 10-12) in order to achieve an economy in bare frames itself. In all cases, span length and story elevation are 4 and 3 meters, respectively. A typical frame of this type is shown in Fig. 1 below.

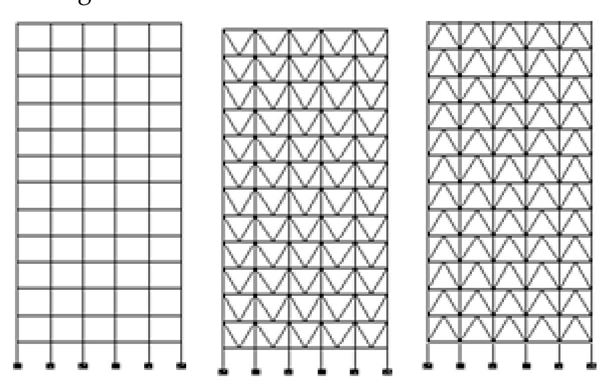

Figure 1: The specific member considered for the analysis of various frames with typical pattern

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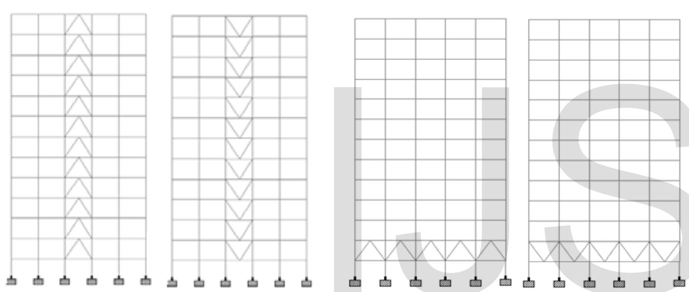
For all frames 350 mm beam depth is considered. For braced frames cross-section of bracing 230 mm x 230 mm is considered. The sections of columns of bare frames are reduced from top to bottom, which is kept same for every 3 storey i.e. 1-3, 4-6, 7-9 and 10-12, in order to achieve an economy in bare frames itself. In the limit state design of reinforced concrete structures, following load combinations are accounted as per I.S. 1893 (Part I) – 2002[6]. Where the terms D.L., I.L., and E.L. stand for the response quantities due to dead load, imposed load and designated earthquake load respectively.

3.2 Baywise and Levelwise Braced Frames

To study the behavior of baywise and levelwise bracing pattern 5 bay 12 storeyed structures are modeled and analyzed numerically. A typical bracing pattern of this type is shown in Fig. 2 below. A number of structures and their different patterns with and without braces have been analyzed. The responses of braced frames of different configurations have been compared with bare frame and the same also have been compared with each other. Behaviors of fully braced frames with the partially braced frames also studied.



a b

Figure 2: Typical Frames showing Baywise and Levelwise optimization patterns

3.3 Outrigger i.e. Partially Braced Frames

The logic of placing the braces baywise and levelwise share the algorithm which allows for combining them evolving a "braced frame with outrigger" i.e. a partially braced frame which results the new combination of above two scenarios. To study the behavior of such outrigger frames 5 bay 12 storeyed structures are modeled and analyzed numerically. A typical frame of this type is shown in Fig. 3 above.

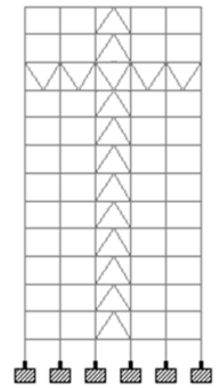


Figure 3: 5-bay 12 storey structures with Outrigger braced algorithms.

4 PARAMETRIC STUDY

Analysis has been made to study and compare following parameters:

1) To study internal forces i.e. axial force, shear force and bending moment in a particular column segment.
2) To study optimum baywise and levelwise locations of bracings.
3) To get locations of partially braced in combination of baywise and levelwise locations of bracings.

4.1 CHECK DIGIT ALGORITHEMS:

Natural logarithm of reference number 'N' as dimensionless parameter has been used as abscissa with respect to considered parameters. The reference number used here is pure number, which is uniquely specified for the frame and bracing pattern tried. The check digits special algorithms are used for alpha and/or alphanumeric character fields. Each character is assigned a numeric equivalent. The numeric equivalents are weighted and the products are summed. The total is divided by the modulus to determine the remainder. The remainder is compared to a pre-assigned index to determine the check digit.

5 RESULTS AND DISCUSSION

The combination of both i.e. baywise and levelwise bracing results in the "braced frame with outrigger" i.e. a partially braced frame as shown in Figure 3 above. To begin with to arrive at the outrigger orientation a combination of an optimum case of baywise bracing viz. case number 03 i.e. central bay A braced and case number 01 of levelwise bracing as the optimum case i.e. the ninth level V braced completely which claim 7.70% and 7.87% saving in the material cost respectively has been tried. Using this combination 5 bay 12 storeyed structur was analysed. A number of other combinations are tried considering various baywise and levelwise bracing patterns considering number of bays or levels braced at a time. However, necessitates a solution of large number of cases with numbers of iterations to be carried out to finalize the most

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optimum sections (i.e. the sections which were used as trial sections are found as the true required cross section for all members) which would be an exorbitantly large figure.

Further it may be noted that when a number of bays or levels are braced simultaneously then normally the cost effectiveness is lost as the number of members increase which compensate the saving claimed due to reduction in the internal forces induced in the structures and the reduced cross sections commensurate with the same. The other structures are also offering maximum economy in regard to their own cases but it is wise to limit ourselves for trying the number of cases for other structures which became more rigid by providing the braces either baywise or levelwise for different combinations, hence it is decided to extend this logic up to 5 bay 12 storeyed structure with 350 mm beam depth which gives maximum economy as compared to other structural cases of combinations. Further, it is again restricted to do the combinations for those cases which have more economy than other combinations of baywise and levelwise bracing for 5 bay 12 storeyed structure i.e. localizing the view over the cases which produce more economy than other, such as central bay braced and ground level braced for 5 bay 12 storeyed structure.

The structure comprises of a frame with central bay braced clubbed with a system of two equal length outriggers. Such outriggers show more stiffening effect for overall structure. The induced compression and tension forces in the columns create a large resisting moment to applied horizontal loading. The frame with combination i.e. central bay braced and ninth level braced throughout for 5 Bay 12 storeyed structure is shown in Figure 4 below. Such frames definitely give more economy as compared to bare frame but less than other cases-central bay braced for baywise and levelwise optimum bracing pattern for 5 bay 12 storeyed structure. For other cases economy is tabulated below. The pattern of bracing with common bays and level variation which gives an optimum result is shown in Figure 4.

Table No 1 shows percentage saving in material cost for optimum cases

Case no.	Percentage Saving
3V (B) + 1A (L)	14.31%
3A (B) + 12V (L)	13.70%
3A (B) + 6V (L)	13.23%
3A (B) + 9V (L)	13.11%
3A (B) + 1V (L)	10.54%

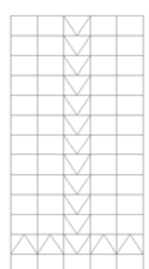

Figure 4: Optimum bracing pattern for 5-bay 12 storey structures, outrigger bracing pattern

The frame with combination i.e. Case- 3V (B) + 1A (L) which means that from baywise bracing pattern of case number 03 and levelwise bracing pattern of case number 1 are shown in Figure 2. The net saving in the cost of the structure is 14.31%. In case of outriggers considering 12th levels and 7th levels braced at a time with the central bay braced as before it is found that the net saving in the cost of the structure is 13.70% and 13.23% respectively. Table above reflects that the net saving goes on decreasing along with central bay bracing together with arbitrary levels braced simultaneously, which indicates that arbitrarily placed cell bracing pattern offer better economy.

6 Conclusion

The substantial reduction in bending moment for worst loaded column leads to section reduction. In case of multilevel bracing it is observed that the optimum positions of levels to be braced is found at position immediate above the ground floor level/position of consequent cross sectional change in column sizes. Frames with combination of baywise and levelwise bracing at a time (outrigger) give more economy as compared to bare frame but give less economy as compared to the separate cases of baywise and levelwise braced frames. Such braced structures (outrigger) are more economical than bare frames. Maximum saving is found to be 14.31% as compared to bare frame. However, further work is needed in order to achieve more economy by developing new scenario i.e. cellwise braced frames. This work is important, because braced frames are a very efficient and effective system for resisting lateral forces.

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