An analytical study of linked column frame system in multi storey multi bay RC building

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Abstract - *The objective of this project investigates the seismic performance of reinforced concrete linked column frame system under earthquake acceleration. Here the concrete is acting as link elements to resist shear and optimize its connection to the columns for shear transfer. Structures subjected to seismic forces must have adequate strength and stiffness to control inter-storey drift in order to prevent damage to structural and non-structural elements during excitations. The concept used here is the replaceable link beams are designed as concrete structures connected to the columns through pinned and fixed connection. Response spectrum are used to investigate the performance 5 storey,7storey and 10 storey building with linked column provided at various locations of building frame with and without infill provided. The storey drift limits, storey displacement and base shear were studied using SAP 2000.According to the study linked column frame system are good in reducing the storey displacement, storey drift and base shear than a normal building frame. Linked column provided at X and Y / -X and –Y direction shows considerable reduction in storey displacement and storey drift values. Linked column with infill shows better results than linked column provided without infill. So, the Linked Column Frame (LCF) system is a better option for a seismic resistant structures and strengthening of structures*

Key Words: **Earthquake, inter storey drift, Response spectrum analysis, storey displacement, base shear, Linked Column Frame system, SAP 2000.**

1. INTRODUCTION

Modern design codes and structural systems have been successful in preventing collapse and loss of life in recent earthquakes [1]. New systems are needed that integrate collapse prevention with post event ease of repair. The Linked Column Frame is a new lateral braced-free structural system intended for rapid return to occupancy performance level. The Linked Column Frame which is a lateral load resisting steel frame system that incorporates easily replaceable link elements and capable of achieving improved seismic performance. The LCF consists of two components: A primary lateral system denoted the linked column, which is built up of closely spaced dual columns interconnected with replaceable link beams. The secondary lateral system denotes a moment resisting frame which acts as part of the gravity load system. The linked column links are sacrificial and intended to be replaced following a design level earthquake [5]. The Linked Column Frame was designed for a multiple performance objectives. Under seismic excitation, the relative deformations of the closely spaced linked columns engage the links which are designed to be yield in shear to control storey drift dissipate energy and limit the forces transferred to the surrounding members. The links are bolted to the columns for allowing controlled shop fabrication and more importantly for rapid replacement when severely damaged. In the proposed system a linked beam column system is designed as a sacrificial beam column system to yield in the inelastic range whereas the main beam column system is in the elastic range [14]. In this paper the concept is the replaceable link beams are designed as concrete structures connected to the columns through bolted joints. Response spectrum analysis is used to investigate the performance of multi storey multi bay RC building using SAP 2000. According to the study linked column frame system are good in reducing the storey displacement, storey drift and base shear than a normal building frame. Linked column provided at X and Y / -X and –Y direction shows considerable reduction in storey displacement and storey drift values. Linked column with infill shows better results than linked column provided without infill. So, the Linked Column Frame (LCF) system is a better option for a seismic resistant structures and strengthening of structures.

1.1 Objective

- The objective of this study is to develop a linked column frame system for reinforced concrete framed structure.
- To design and analyze the multi storey building with and without infill provided at various locations in building frame.
- To compare RCC building bare frame with linked column building provided at various locations of RC building with and without infill provided.
- To compare linked column building with infill provided and without infill provided.
- To compare pinned connection and fixed connection provided in linked column for beam column joints.
- Response spectrum analysis is carried out.

- To explain the parameter selected for analysis;
  - Storey displacement
  - Storey drift
  - Base shear

1.2. Loads Considered

A building is subjected to the following loads during its service life. 1) Dead Load: The dead loads in a building shall compromise of the weight of all the walls, partition walls, floors and roofs and shall include the weight of all the other permanent constructions in the building. Dead Load (DL) have been taken as per IS 875 (Part 1) (1987), 2) Live Load: Live loads are also called the superimposed loads and include all the moving or variable loads, due to people or occupants, their furniture, temporary stores, machinery etc. Live loads on floors shall compromise of all loads other than the dead loads. Live load (LL) have been taken as per IS 875 (Part 2) (1987),3) Earthquake Load: EQ load acts on the structure during earthquake. It will act horizontally on the structure. It is also called as seismic force. Seismic load calculation: has been done based on the IS 1893-2002 (Part 1) approach.4) Wind load (WL) have been taken as per IS 875 (Part 3) (1987).

2. MODELLING

The structural system of the building consists RCC slabs and beams, ordinary RCC columns, Link column and link beam. These buildings are analyzing in compliance to the Indian Code of Practice for Seismic Resistant Design of Buildings. Residential buildings with G+4, G+6, G+9 storeys were considered at Delhi in seismic zone IV. The buildings are assumed to be fixed at the base and floors acts as rigid diaphragms. Storey height for different building is taken as 3.5 m. The program consists of analyzing each of the multi-storey buildings using SAP 2000. The Storey drift, storey displacement, and base shear were observed for all models.

The study investigated the effects of linked column frame system in various locations of RC building with and without infill provided. Linked columns are provided along X-axis with pinned connection and fixed connection (with and without infill),along Y-axis with pinned connection and fixed connection(with and without infill), along X and Y-axis with pinned connection and fixed connection(with and without infill), along -X and -Y-axis with pinned connection and fixed connection(with and without infill), along center portion of building with pinned connection and fixed connection(with and without infill). Total 63 no's of models are designed and analyzed with linked column frame system with and without infill.

Structural modelling

Plan dimensions	20 m X 20 m
Floor to Floor Height	3.5 m
Slab thickness	120 mm
Grade of concrete for slab	M 35
Grade of concrete for beam	M 35
Grade of concrete for column	M 35
Grade of steel	Fe 415
Plinth beam size	230 mm X 300 mm
All other beam size	350 mm X 480 mm
Column size	560 mm X 560 mm
Size of linked beam	200 mm X 200 mm
Size of linked column	400 mm X 400 mm
Spacing of linked column	110 mm
Seismic zone	IV as per IS 1893-2002.
Brick size	200 mm

3. RESULTS AND DISCUSSION

As mentioned in the objective of the study, the behavior of linked column frame system in multi storey multi bay RC building at various locations of the buildings are studied. Response spectrum analysis was carried out using SAP 2000. The linked columns are provided at various locations of the buildings. Linked columns are provided along X-axis with pinned connection and fixed connection (with and without infill),along Y-axis with pinned connection and fixed connection(with and without infill), along X and Y-axis with pinned connection and fixed connection(with and without infill), along -X and -Y-axis with pinned connection and fixed connection(with and without infill), along center portion of building with pinned connection and fixed connection(with and without infill). Total 63 no's of models are designed and analyzed with linked column frame system with and without infill. The results obtained from the analysis are tabulated and graphs are drawn. Here maximum storey displacement**,** maximum storey drift and maximum base shear of normal frame and linked column frame system along -X and -Y(Fixed Connection) were tabulated.

3.1 Maximum Storey displacement

Table 1 max. storey displacement of normal frame and linked column frame system .

	Normal frame (mm)	-X and -Y(Fixed Connection) (mm)
5 STOREY(without infill)	7.095	4.9551
5 STOREY(with infill)	7.095	4.3098
7 STOREY(without infill)	9.500	6.6094
7 STOREY(with infill)	9.500	5.9988
10 STOREY(without infill)	13.3597	9.2812
10 STOREY(with infill)	13.3597	8.6753

From the plot it can be identified that the maximum storey displacement occurs along normal frame as compared to linked column frame system. The storey displacement value also increase with height. The increase of stiffness in link beam reduces maximum displacement. Maximum value shown in normal building frame (7.0950 mm) and minimum for linked column along –X and –Y(Fixed Connection) (4.9551mm).Percentage reduction in storey displacement is 30%.

3.2 Maximum Storey Drift

The following table shows the maximum storey drift of linked column frame system with normal frame.

Table 2 max storey drift of normal frame and linked column frame system.

	Normal frame	-X and -Y(Fixed Connection
5 STOREY(without infill)	0.1630	0.1159
5 STOREY(with infill)	0.1630	0.1719
7 STOREY(without infill)	0.1286	0.0901
7 STOREY(with infill)	0.1286	0.0789
10 STOREY(without infill)	0.1778	0.0750
10 STOREY(with infill)	0.1778	0.1158

The stiffness of link beam affects more on displacements and the values of drift and displacement. The inter storey drift is one of the most important parameter for serviceability of structures. The increase of stiffness in link beam reduces inter storey drift; it occurs because the rotation of beam under lateral force decreases with the increase of beam stiffness. Percentage reduction in storey drift is 42%.

3.3 Maximum Base Shear

The following table shows the maximum base shear of linked column frame system with normal frame.

Table 3 table shows the max base shear of linked column frame system with normal frame.

	Normal frame	-X and -Y(Fixed Connection
5 STOREY(without infill)	619.1783	677.4819
5 STOREY(with infill)	619.1783	728.7718
7 STOREY(without infill)	633.1190	779.2907
7 STOREY(with infill)	633.1190	839.1725
10 STOREY(without infill)	646.8921	854.2907
10 STOREY(with infill)	646.8921	914.3861

Base shear is the estimation of the total horizontal load acting in a "static" time frame. Linked column frame system shows higher base shear value than normal building frame. There are many reasons for the increase of base shear: building stiffness, building weight and seismic zone factor. The base shear is more for RC frame with masonry infill and least for bare frame. This is because base shear depends upon the stiffness in the frame. The LCF system resists the lateral seismic forces through axial compression along the link beam. The contribution of infill increases the stiffness of the frame, resulting increase in base shear than bare frame. The most important part in designing the building is to resist earthquakes is not just capacity of structure to resist force, but the ability of structure to be ductile enough to dissipate energy. If a structure is well detailed, then it has more chances of surviving earthquakes.

4. CONCLUSION

- Percentage reduction of storey displacement obtained for 5 storey with and without infill are: 40% and 30%.Percentage reduction of storey displacement obtained for 7 storey with and without infill are:36% and 30%.Percentage reduction of storey displacement obtained for 10 storey with and without infill are:35% and 31%.
- The stiffness of link beam affects more on displacements and the values of drift and displacement. The increase of stiffness in link beam reduces maximum displacement. It occurs because the rotation of beam under lateral force decreases with the increase of beam stiffness and thus displacements reduce. This change is linear.
- The inter storey drift is one of the most important parameter for serviceability of structures. Percentage reduction of storey drift obtained for 5 storey with and without infill are:42% and 29%.Percentage reduction of storey drift obtained for 7 storey with and without infill are:39% and 30%.Percentage reduction of storey drift obtained for 10 storey with and without infill are:35% and 58%
- Linked column frame system shows higher base shear value than normal building frame. The reasons for the increase of base shear: building stiffness, building weight and seismic zone factor. Percentage increase of base shear of 5 storey with and without infill is 60% and 26%.Percentage increase of base shear of 7 storey with and without infill is 58% and 23%.Percentage increase of base shear of 5 storey with and without infill is 72% and 47%.
- By comparing Y-axis LCF system with X-axis LCF system, the values along X-axis are more because while considering EQ(X) in X-direction X-axis LC are not able to effectively resist seismic actions along X-direction but can reduce storey displacement and

storey drift in overall frame than normal building frame.

- Along X and Y axis (PC/FC)/ -X and -Y axis(PC/FC) storey displacement and storey drift values are reduced than normal building frame. Earthquake acting along EQ(X) direction, so the torsion of the building can be controlled by yielding of sacrificial link beam while providing along both axis than providing sacrificial link beam along one axis and centers of building.
- In case of 10 storey building with infill some linked column positions shows greater variation in lateral storey displacement and storey drift than normal frame. This is because as storey increases, load bearing masonry has a high self-weight or Low strength-to-weight ratio and low tensile strength, can fail during earthquakes. So, brick infill with LCF system is suitable up to 7 storey height.
- The LCF system with fixed connection joints shows reduction in lateral storey displacement and storey drift than LCF system with pinned connection. A fixed support has all three displacements restrained (ux = uy = rz = 0). A pinned support has linear displacements restrained (ux = uy = 0) while rotational displacement is free (rz is unknown). By that reason LCF system with fixed support shows reduction in lateral storey displacement.
- Bricks have great compressive strength, and are best suited to structures with light transverse loading when the cores remain unfilled. Filling some or all of the cores with concrete or concrete with steel reinforcement offers much greater tensile and lateral strength to structures. The infills increase the stiffness of the RC frame and therefore the storey displacement and storey drift values decreases for RC frame with infill.Decrease in storey displacement and storey drift values thus verifies the effect of infill whose stiffness plays vital role in absorbing shocks.
- The base shear is more for RC frame with masonry infill and least for bare frame. Base shear depends upon the stiffness in the frame. The LCF system resists the lateral seismic forces through axial compression along the link beam. The contribution of infill increases the stiffness of the frame, resulting increase in base shear than bare frame.
- This method can be effectively used as rehabilitation of existing structures that are not designed to resist seismic forces and can also be used for the strengthening of RCC building.

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