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# Comparative Study on Seismic Analysis of Irregular Buildings with Optimized Exoskeleton and Shear Walls

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***Abstract:-*** **Exoskeleton structures are external self-supporting structural system suitably connected to primary inner structure. Exoskeleton structure is optimized by removing the intermediate bracing between corners of the building and analyzed and compared it with shear wall building and normal exoskeleton building.**

**Shear walls have very high in-plane strength and stiffness, which can be used simultaneously for resisting large horizontal and gravity loads. Nonlinear static analyses are performed for the buildings by utilizing the software program, ETABS 2016. An analytical study is performed to show that shear walls will increase the seismic performance of RC frame buildings and compared it with optimized exoskeleton RC building.**

**In the present study the comparison of seismic behaviour of G+5 storey buildings having horizontal irregularity with the regular building of similar properties with and without shear wall by using ETAB software was done.**

**For this purpose four multi-storey building plans are considered that are symmetric plan, L shape, T shape, and + shape. For the comparison, parameters taken are lateral displacement, storey drift.**

***Key words- Regular and Irregular Buildings, Shear wall, ETABs Software, Seismic and wind forces, Storey Displacement, Storey drift***

## I. INTRODUCTION

In earthquake-prone regions, where innovative structural control systems are crucial to the achievement of a resilient built environment the feasibility of exoskeleton structures for seismic protection is particularly worthy of being investigated. In the present study, the exoskeleton structure is hence regarded as a structural control system that can be designed for the external seismic retrofitting of a building frame structure. External structural control systems, like reinforced concrete cores and walls, stepping and pinned rocking walls and reaction towers, are considered in literature as a promising strategy due to a number of reasons: service or business downtime as well as residents displacement are kept to a minimum, because the retrofitting process is operated from outside of the building; interference with existing structural and non-structural components is limited; the possible strengthening of structural members is restricted to the ones locally interested by the connections to the external control system. Exoskeleton structures further meet a number of advantages specific to them: they can boost both the economical and the ecological efficiency of the retrofitting intervention.

## II. LITERATURE REVIEW

Building with exoskeleton without exoskeleton were analyzed for comparing the effectiveness of exoskeleton structure.For case study consider a building consists of a 4-storey, 4 bays by 2 bays, reinforced concrete moment-resisting frame designed with non-ductile behaviour. Constant span length and inter-storey height are l = 6 m and h = 3.50 m , respectively, with global dimensions of 24 m × 12 m × 14 m in the longitudinal (x), transverse (y) and vertical (z) directions. Exoskeleton structure consists of a system made of S235 steel columns and diagonal beams, whose cross-sections are HE100A and 114.3 mm × 5 mm circular hollow, respectively; the beam inclination angle is 49°.FEM RCC building shown in Fig. 1.

Distributions of mass and stiffness are uniform in plan and in elevation: columns and beams cross-sections are rectangular with dimensions 40 cm × 40 cm and 40 cm × 30 cm, respectively; Exoskeleton structures can be a viable and effective means to control structural response under seismic loading. The exoskeleton structure is conceived as a dynamic system whose mass, stiffness and damping properties can be varied and, possibly, designed in order to modify the response of a primary structure, connected by way of a rigid coupling.

A significant displacement and deformation control is achieved over the entire height of the primary structure: peak floor displacements are reduced, on average, by 40%–50% , while reductions of peak interstorey drifts are higher and up to 75%.[1]

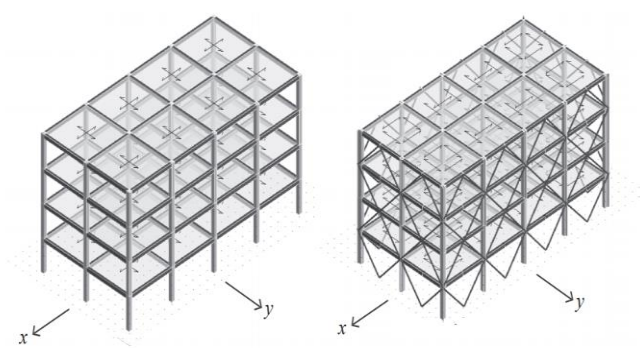


Fig. 1 FEM of RCC building with without and exoskeleton structure

Another study shows the effect building with and without exoskeleton structure .In that study they concluded that a floor displacements reduction at most by 80% for both Damage and

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Life-safety Limit States and a growth of frequencies, higher than 160%, because of an increase in mass and stiffness. Despite of lower periods of vibration for the coupled system, shear forces in the primary building turned three times smaller and the final configuration showed that more than 86% of them have been taken only by the exoskeleton.[2]

In another study with shear wall and exoskeleton contribution, they made the structural analysis of external diagrid systems coupled with central CS or OS shear wall. In particular, the building response to external lateral and torque actions was investigated, and the influence of the inclination of the external diagonals, as well as the shear wall type, on the structure flexibility was analyzed.Closed shear wall with high diagrid diagonal angle show best seismic performance compared to open shear wall.[3]

In the study of Design of dissipative and elastic high-strength exoskeleton solutions for sustainable seismic upgrades of existing RC buildings .They concluded that dissipation of the input seismic energy and the adoption of the preliminary weakening interventions lead to lower seismic forces in the dissipation solutions when compared to the high-strength solutions. Usually, the base shear on the existing building is reduced, and relatively low shear demand can be expected at the base of the dissipative exoskeleton.[4]

The Dubai Towers, Dubai is a group of four super-tall towers above a podium surrounded by a manmade lagoonThe rotation of the tower causes the perimeter columns to slope which, in turn, cause the gravity loads to generate torsion. This torsion can be resisted by introducing perimeter braces sloped opposite the columns. The structural framing was optimized for strength and vertical and horizontal displacements. This optimization resulted in simplified connections and improved constructability.[5]

## III. METHODOLOGY

### A. Building Parameters

A 6 storied RC frame building consist of 14 bays in X-direction and 9 bays in Y- direction with a bay width of 4m in each direction is considered. The building is located in seismic zone 5, rests on a medium soil. The columns are considered as fixed. The story height is 3m. The building is modeled in the ETAB software. The effect of cracking is considered by giving the reduced moment of inertia of a section. The beam column joints are modeled by giving end-offsets. The structural effect of slabs due to their in-plane stiffness can be taken into account by assigning ‘diaphragm’ action at each floor level. Table 2 shows the seismic data assumed for the analysis. Table 1 shows the material properties and geometric parameters assumed.

Table 1

| Sl No. | Design Parameter | Value |
|---|---|---|
| 1 | Unit weight of concrete | 24 kN/m$^3$ |
| 2 | Characteristic Strength of concrete | 30 MPa |
| 3 | Characteristic Strength of steel | 415 MPa |
| 4 | Story height | 3m |
| 5 | Modulus of elasticity of steel | 2E5 MPa |
| 6 | Slab thickness | 150 mm |
| 7 | Wall thickness | 230 mm |
| 8 | Beam | 200×400mm |
| 9 | Column | 450×300mm |
| 10 | Overall length | 56m |
| 11 | Overall width | 36m |
| 12 | Each floor area | 1152m² |

Table 2

| Sl No. | Design Parameter | Value |
|---|---|---|
| 1 | Seismic Zone | II |
| 2 | Zone factor(Z) | 0.36 |
| 3 | Response reduction factor (R) | 5 |
| 4 | Importance factor (I) | 1 |
| 5 | Soil type | Medium soil |
| 6 | Damping ratio | 5% |

### B. Exoskeleton Frame Details

- Main column =ISMB 150
- Cross beam =ISMB 100
- Bracings= Circular Tube with outer dia 100mm and 5 mm thickness

### C. Loading Details

- Dead load at slab =1 kN/m²
- Live load at slab =2.5 kN/m²
- Wall load =20 x0.2 x 2.5 = 10.0 kN/m

### D. Modelling And Analysis

The dynamic analysis has to be done to quantify the story responses in each type of buildings .ETABS is capable of handling the most complex structures which includes the effect of wide range of non-linear behaviour. Response spectrum analysis has to be executed. It is typically used for performing seismic analysis, calculate the maximum response of the structure from spectrum curve. The results of the analysis on the story drift and displacements have to be compared

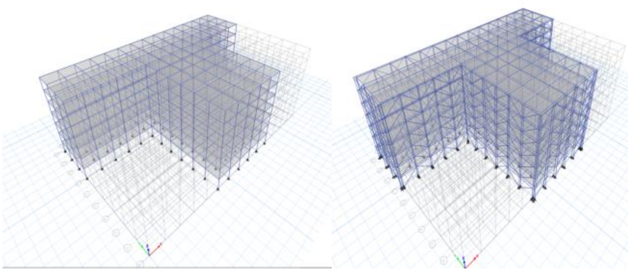

Fig. 2 ETABS modal without exoskeleton and with exoskeleton -T shaped building

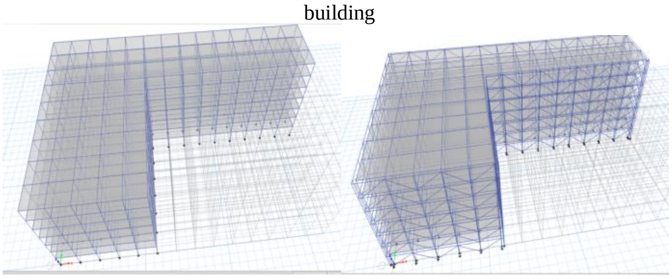

Fig. 3 ETABS modal without exoskeleton and with exoskeleton -L shaped building

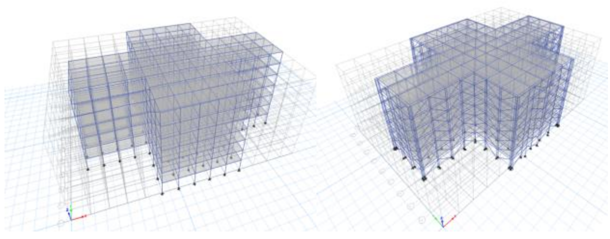

Fig. 4 ETABS modal without exoskeleton and with exoskeleton + shaped building

Exoskeleton structure around the building is not at all economical. So that for economical side need to reduce the no of intermediate bracing. Exoskeleton beam will go round and round around the building. Corner bracing were retained and the other intermediate bracing removed as shown in Fig. 5 and 6. Thus the cost for exoskeleton gets reduced. Model is analysed and compared it with full exoskeleton structure.

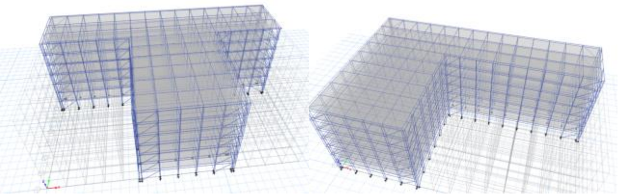

Fig. 5 ETABS modal optimized exoskeleton T and L shaped

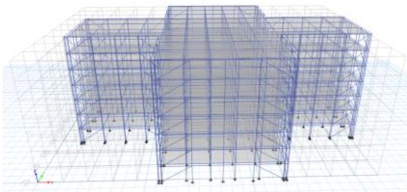

Fig. 6 ETABS modal optimized exoskeleton + shaped

Shear walls are structural systems which provide stability to structures from lateral loads like (due to its self-weight and other living / moving loads) but they are also designed for lateral loads of earthquakes / wind. The shear wall structural systems are more stable because their supporting area (total cross sectional area of all shear walls) with reference to total plans area of building is comparatively more unlike in the case of RCC framed structures. Shear walls are quick in construction, as the method adopted to construct is concreting the members using formwork. Shear wall provided as per the plan showing in fig 7 and 8

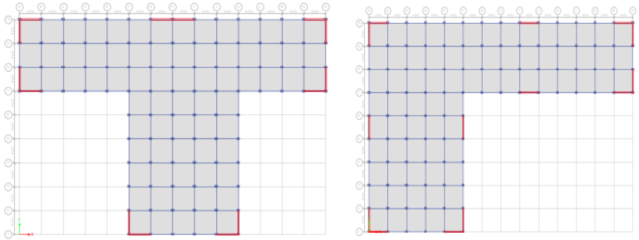

Fig. 8 Shear wall in T and L shaped plan

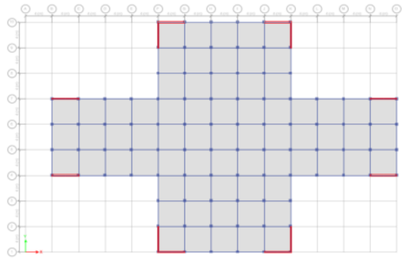

Fig. 9 Shear wall in + shaped plan

## IV. RESULTS AND DISCUSSIONS

Table 3 and Table 4 shows the displacement changes in X and Y direction for L,T and + shaped building. In all types of building there is large difference in displacement for with and without exoskeleton structure. There is an 40-60% difference in displacement for without and wuth exoskeleton building. Hence it shows the similar effect of irregular building with shear wall structure. Irregular shear wall building and optimized exoskeleton building shows about 20-30%.shera wall structure is not all good in appearance or not aesthetically good. So that exoskeleton structure show more aesthetically good appearance.

Table 3 Displacement in X direction

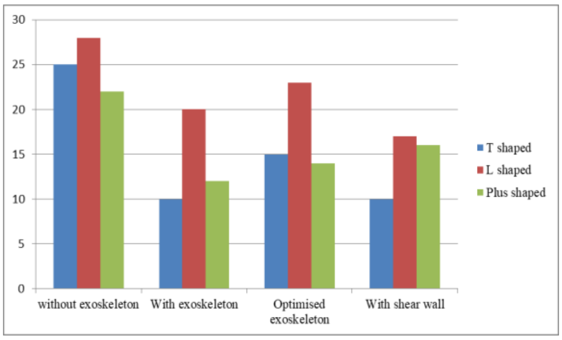


Table 4 Displacement in Y direction

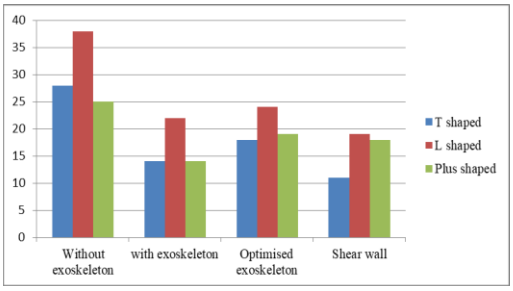


Table 5 and Table 6 shows the maximum story displacement changes in X and Y direction for L,T and + shaped building. In all types of building there is large difference in maximum story displacement for with and without exoskeleton structure. There is an 40-60% difference in displacement for without and with exoskeleton building.

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Table 5 maximum story drift in X direction

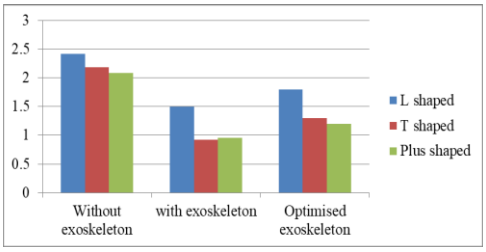
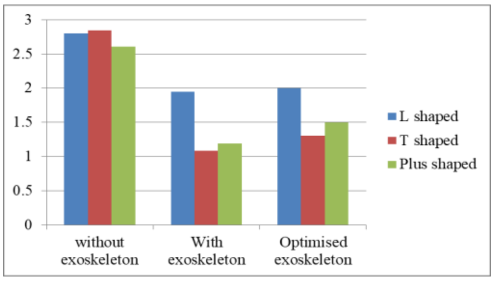



Table 6 maximum story drift in Y direction




## V. CONCLUSIONS

The exoskeleton building is more aesthetically and architecturally good in appearance comparing to normal RCC bulidngs. It also used as an retrofitting method for existing building.

1. Floor displacements are reduced, on average, by 40%–50% compared to with and without exoskeleton structure
2. Reductions of peak inter-storey drifts are higher and up to 75%.
3. By optimization of exoskeleton –Only 10-30% variation in displacement and storey drift in comparing with normal exoskeleton structure
4. In optimized exoskeleton - Quantity get reduced for exoskeleton elements. Thus the building became more economical
5. Optimized exoskeleton shows 16-30% difference compared with shear wall building

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