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Torsional Reduction Techniques in High Rise Structures

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Abstract: **This paper studied the reasons behind the four trends in torsional effects in asymmetric-plan buildings observed in the current literature. It was found that the modal eccentricities and the non-proportionality between the modal translations and the modal rotation are key to understanding these trends in torsional effects in asymmetric-plan buildings. These key points were obtained from the three-degree-of-freedom modal systems, which represent the single vibration mode of a two-way asymmetric-plan building. This paper showed that the modal eccentricities, rather than the overall structural eccentricities, are the critical parameters for deciding the trend of the unequal displacement demand on the floor diaphragm. In addition, the non-proportionality between the modal translations and the modal rotation leads to the trend that the torsional effects generally decrease when plastic deformations increase.**

I.INTRODUCTION

Centre of mass (CM) is the point where entire mass of the system is concentrated. During an earthquake, acceleration induced inertia forces will be developed at each floor level, where the mass of an entire story may be assumed to be calculated. Hence, the location of a force at a particular level will be determined by the centre of the accelerated mass at that level.

In regular buildings, the portions of the centres of floor masses will differ very little from level to level. However, irregular mass distribution over the height of the building may result in variations in centres of masses, which may need to be evaluated. The summation of all the forces, Fj, above a given story with due allowance for the in-plane position of each, will then locate the position of the resultant force, Vj, within that story.

Centre of rigidity (CR) is the point that locates the position of a story shear force which will cause only relative floor translations. It is also referred as centre of stiffness of a system.

If, as a result of lateral forces, one floor of the building translates horizontally as a rigid body relative to the floor below, a constant inter-story displacement say ‘Δx’ will be imposed on all frames and walls in that story. Therefore, the induced forces in these elastic frames and walls, in the relevant planes, will be proportional to the respective stiffness. The resultant total force, Vj=Vx, induced by the translational displacement Δx, will pass through the centre of rigidity (CR).

The position of CR may be different in each story. It is relevant to story shear forces applied in any direction in a horizontal plane. Such a force may be resolved into two components, such as Vx & Vy, which will cause simultaneous story translations ‘Δx’ & ‘Δy’ respectively. The displacement due to story twist are proportional to the distance of the element from the centre of rotation i.e. CR.

Calculation of Centre of Rigidity (Centre of Stiffeness):

X coordinate = Σ (Kyi x Xi)/ Σ Kyi ; Y coordinate = Σ (Kxi x Yi)/ Σ Kxi where, Kxi & Kyi correspond to the lateral stiffness of the ‘n’ lateral load resisting elements in the ‘x’ and ‘y’ directions respectively.

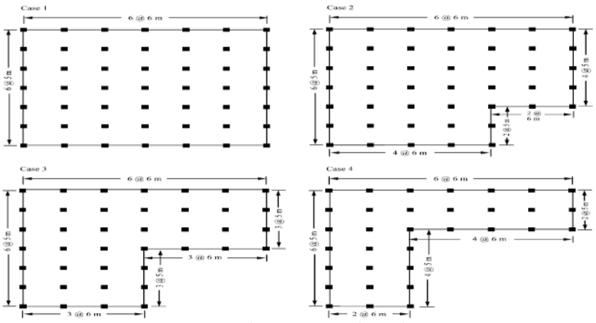

Fig:1 Configurations of the four plans

Note: Displacements due to story twist, when combined with those resulting from floor translations, can result in total element inter-story displacements that may be difficult to accommodate. For this reason the designer should attempt to minimize the magnitude of story torsion (Mt). This may be achieved by a deliberate assignment of stiffness to lateral force resisting components, such as frames or walls, in such a way as to minimize the distance between the CR and the line of action of the story shear force. To achieve this in terms of floor forces, the distance between the CR and CM should be minimized.

II.EVALUATION OF PLAN CONFIGURATION (BASE ISOLATION TECHNIQUE)

where, KE indicates the kinetic energy, DE is the dissipated energy, SE is the strain energy and IE is the seismic input energy. DE is the sum of VE and HE, which are the viscous and hysteretic energies, respectively.

In Eq. 1, KE and SE are the portions of the structural energy that are recoverable, whereas VE and HE are the portions that are dissipative. When the input energy cannot be dissipated via the viscous damping of the structure, the residual energy will be dissipated in the form of HE for strong motions. Energy input to a fixed-base structure will be dissipated in the form of VE if IE is not too large. In the ductile design of fixed-base structures, plastic deformations may occur in several joints or members when the structure is subjected to strong motion and there is sufficient ductility such that collapse is prevented. The lateral motion of the system is coupled with the torsional motion under horizontal ground excitation when the center of stiffness of the elastomeric bearings does not coincide with the center of mass of the deck. Simplified base-isolated model is introduced to estimate torsional behaviour of seismic isolation with different superstructure plan configuration. Thus, four plans are selected and compared, it is observed that there is considerably more variation in the torsional to lateral frequency ratio in the L-plan (case 4) in comparison with the other cases (Fig. 1). Therefore, this type of plan is suitable for the study of the torsional behaviour of isolated structures.

There is more eccentricity in case 4 relative to the other cases, so shifting the Center of Mass (CM) toward the CS generates a higher torsional response and the structural torque is reduced to a minimum if the center of stiffness of the isolation system coincides with the center of mass of the structure. Case 1 is a system with a symmetric distribution of mass and identical isolators distributed regularly in the building plan. The torsional to lateral frequency ratio varies when the CM is shifted toward the CS in cases 2, 3 and 4 for the same distributed total mass. As a result, the torsional resistance in asymmetric base-isolated structures will be increased when the elastomeric bearings in the exterior of the plan are stiffer and larger than interior or rubber bearings which are used in the interior and lead rubber bearings in the exterior. The torsional to lateral frequency ratio is computed in four cases of eccentricity in the base and for a rigid diaphragm level. The total distributed mass is constant but relative to the plan geometry characteristics and the rotational mass moment of inertia varies. The results of the computed frequency ratios indicate that case 4 is affected more by the torsional components; therefore the plan configuration of case 4 is a suitable selection for this purpose.

III.EXPERIMENTAL APPROACH USING STAAD PRO V8i

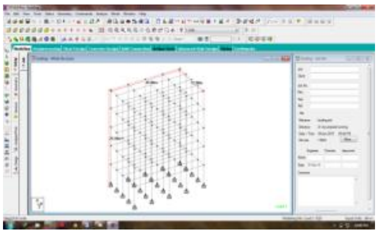

Figure-2 (analytical model)

STAGE-1

Building Configuration (symetric)-as per fig-2

Height = 25m (5 nos storey@5m c/c), Length = 20m (4nos bays@5m c/c), Width=12m (4nos bays@3m c/c)

Beams sizes: 300mmx300mm , Column sizes: 450mmx450mm

Loading : Self Weight + 12KN/m Wall load + 5.2KN/sqm(dead) + 2KN/sqm(live)

IV.RESULTS IN VARIOUS MODES:

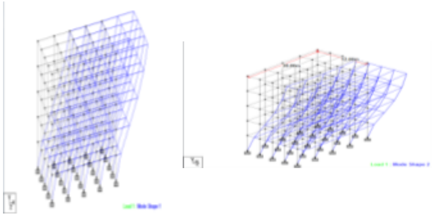

Figure-3

STAGE -2 (L TYPE ASYMMETRIC CONFIGURATION)

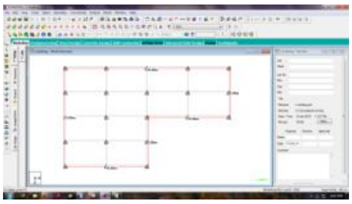

Figure-4

WITH SAME MEMBER SIZES & LOADING SHAPES IN VARIOUS MODES

Figure-5

STAGE-3(TORSION CONTROL USING HIGHER COLUMN SIZES ON GEOMETRY DEFICIENT SIDE OF BUILDING)

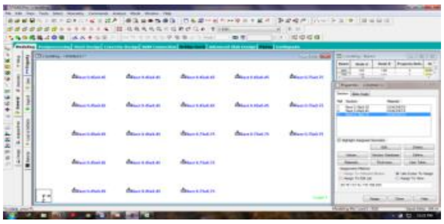

Figure-6

SHAPES IN VARIOUS MODES

Figure-7

V.CONCLUSION

The study of structures of their torsional behavior done above gives us data and points from which we can conclude some points. A uniform shaped structure such as a rectangular shaped does not have torsion behavior in it, where as a structure of L shape (as studied above) have torsional behaviour.

The torsion in the structure can be eliminated by different methods. The base isolation method can be adopted to obtain a structure without torsional forces in the structure. As above shown through experimental approach using STAAD PRO, any structure with torsion in it can be reduced or removed by providing columns of higher sizes in the geometry deficient area.

Any structure with torsion in it becomes expensive as compared to any structure without any torsional forces. As either different methods are adopted to eliminate the torsion such as base isolation, which is an extra added cost to the structure. Or as explained above the column sizes are increased which directly increases the cost of the structure.

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