e-ISSN: 2455-5703

A Comparative Study of Regular and Irregular Shaped RC Building using Software-Aid

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Abstract

Configuration is very much important for good seismic performance of the building. To makes the structure having good aesthetics and functionally effective, both shape and structural system must be sound enough. The wide range of the damages observed during past earthquakes across the world due to poor configuration. A building with simple geometry in plan has performed well during strong earthquake with compare to complex shape as symmetry is maintained. When irregular shapes are included in a building, a higher level of engineering efforts is required to make the structure good earthquake resistant. In these paper ill effects of irregularity which includes Time period, axial load, bending moment, her force, and torsion is reduced to remarkable extent by providing crumple section, which converts an irregular E-shape building into regular one. A building is analyzed having regular and irregular shape under the effect of earthquake loading by using latest software Aid. Analysis make possible to plan an irregular structure even in earthquake prone areas.
Keyword- Configuration, Crumple section, Earthquake resisting structure, Irregularity, Symmetry

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I. INTRODUCTION

Structural engineer's greatest challenge in today's scenario is constructing seismic resistant structure. Uncertainties involved and behavior studies are vital for all civil engineering structures. Modern construction demands the architect to plan the buildings which are irregular in plan and elevation. When such irregular buildings are placed in a high seismic zone, the structural engineer's role becomes further challenging. Structural analysis is a process to analyze a structural system to predict its responses and behaviors by using physical laws and mathematical equations. By which internal forces, stresses and deformations of structures under various load effects are determined. Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. Hence in order to overcome these issues we need to identify the seismic performance of the built environment through the development of various analytical procedures. Earthquake resistant structures are designed to withstand earthquakes.[03]While no structure can be entirely immune to damage from earthquakes, the goal of earthquake-resistant construction is to erect structures that fare better during seismic activity than their conventional counterparts. The building is subjected to random motion of the ground at its base which induces Inertia forces in the building that in turn causes stresses, this is displacement-type loading.[03] These forces are act through center of mass.[04][07]

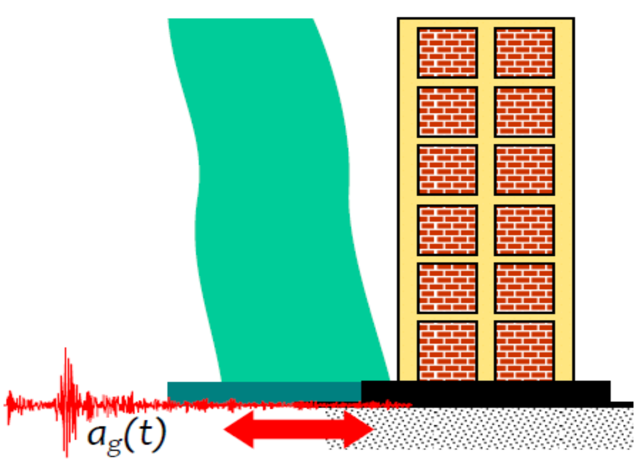
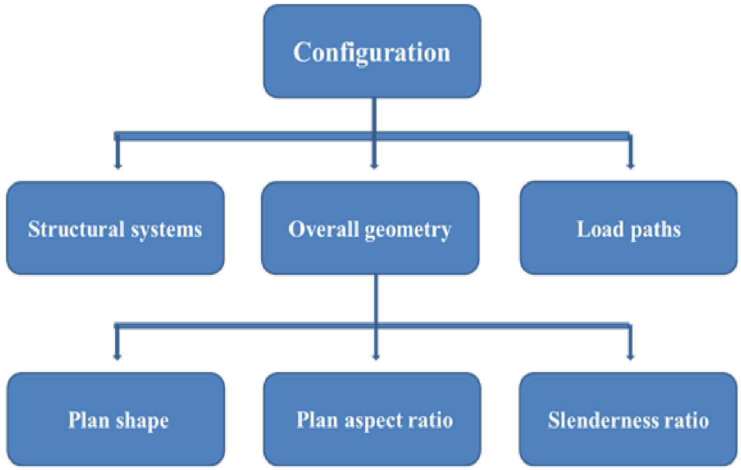
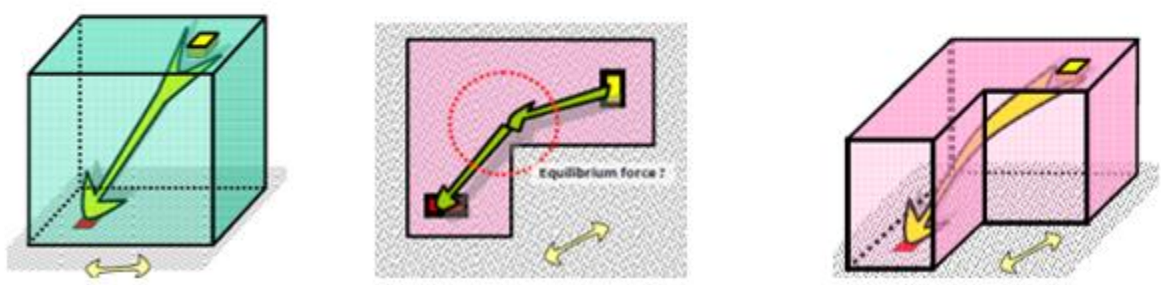


Fig. 1: Natural Actions of Earthquake Ground Movement at Base Earthquake Behaviour of Buildings by C. V. R. Murty- Gujarat State Disaster Management Authority

All buildings are vertical cantilevers projecting out from the earth's surface. When the earth shakes, these cantilevers experience whiplash effects, especially when the shaking is violent. Hence, special care is required to protect them from this jerky movement. These Competing demands are accommodated in buildings by incorporating desirable characteristics called four virtues in them.[03]Good seismic configuration,[05]A minimum lateral stiffness and lateral strength in each of its plan directions and Good overall ductility in it to accommodate the imposed lateral deformation between the base and the roof of the building, along with the desired mechanism of behaviour at ultimate stage. The four virtues are achieved by inputs provided at all stages planning, design, construction and maintenance.



Configuration influences seismic performance.[05]When Buildings oscillate during earthquake shaking, Inertia forces are mobilized and travel along different paths, called load paths, through different structural elements, until transferred to the soil through the foundation. The generation of forces based on basic oscillatory motion and final transfer of force through the foundation are significantly influenced by Plan shape, Load path overall geometry of the building. Irregular system, commentary: re-entrant corners, insets, setbacks and similar break in the continuity of the lateral force resisting system [09] tend to result in areas of localized damage. Buildings are placed in two categories, simple and complex.[03]

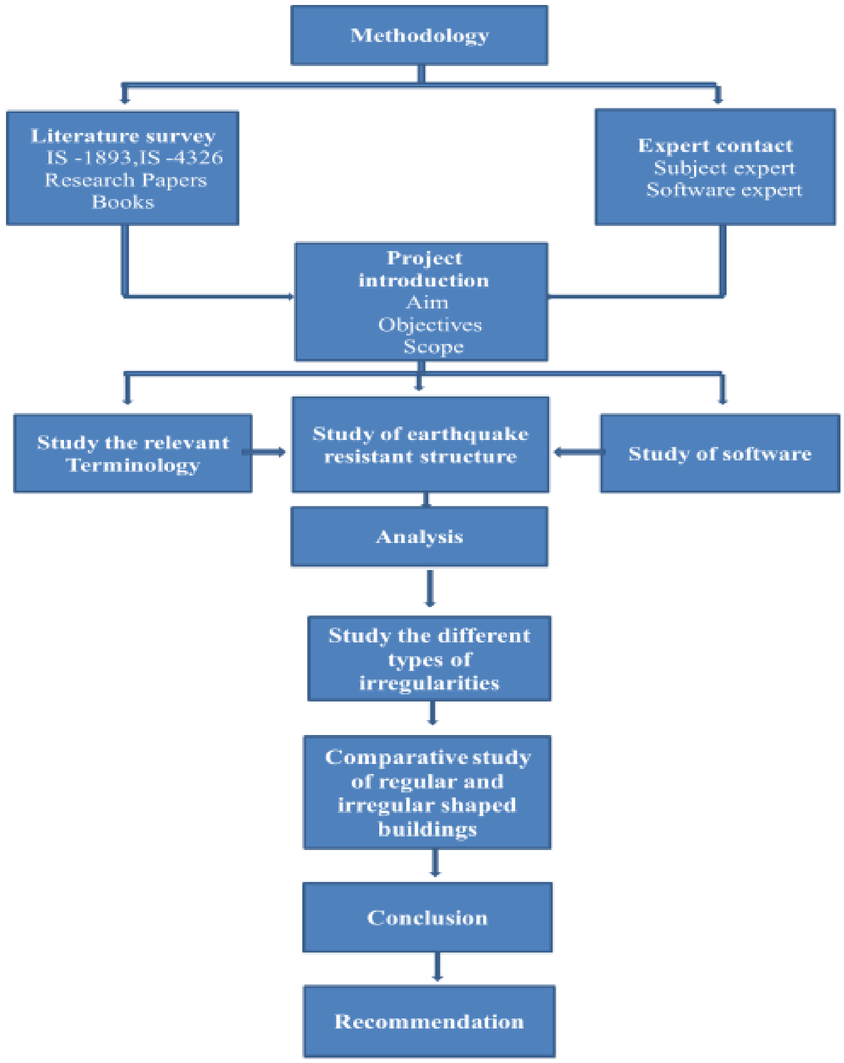


Simple Shape Complex Shape

Fig. 2: Simple and Complex Shapes Earthquake Behavior of Buildings By C. V. R. Murty Gujarat State Disaster Management Authority

Buildings with rectangular plans and straight elevation stand the best chance of doing well during an earthquake. It is because inertia forces are transferred without having to bend due to the geometry of the building. But, buildings with setbacks and central openings offer geometric constraint to the flow of inertia forces which have to bend before reaching the ground results in stress concentrations at that points.[03] In this paper, evaluation is done about the effect of plan configurations on the response of structure in accordance with The Indian Standard Codes guidelines.[01],[02] Earthquake resistant engineering emphasis the inconvenience of using irregular plans, recommending instead the use of simple shapes.[08] Here preservation of symmetry plays a very important role.[01],[07] Structural symmetry means that the centers of mass and the center of resistance are located at the same point. In a configuration the eccentrically between the center of mass and resistance will produce torsion and stress concentration [04] [06] and therefore the symmetrical forms are preferred to the asymmetrical ones.[10]

II. METHODOLOGY



Plan Irregularity	Description
Torsion irregularity	To be considered when floor diaphragms are rigid in their own plane in relation to the vertical structural elements that resist the lateral forces.
Re-entrant corners	Plan configurations of a structures and its lateral force-resisting system contains Re-entrant corners, where both projections of the structure beyond the Re-entrant corners are greater than 15 % of its plan dimension in the given direction.
Diaphragms Discontinuity	Diaphragms with abrupt Discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50% of the gross enclosed diaphragm area, or changes in effective Diaphragm stiffness of more than 50%from one storey to the next.
Out-of-plane offsets	Discontinuities in a lateral force-resistance path, such as out-of-plan offsets of vertical elements.
Non-parallel systems	The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force-resisting elements.

Table 1: Description of Plan Irregularities
(Cl 7.1, Table No 4, Page No.18.IS 1893:2002)

Vertical Irregularity	Description
Stiffness Irregularity Soft Storey	A soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storeys above.
Stiffness Irregularity Extreme Soft Storey	A extreme soft storey is one in which the lateral stiffness is less than 60 % of that in the storey above or less than 70 % of the average stiffness of the three storeys above. For example, buildings on STILTS will fall under this category.
Mass Irregularity	Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200percent of that of its adjacent storeys. The irregularity need not be considered in case of roofs.

Vertical Geometric Irregularity	*Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than150 percent of that in its adjacent storey*
In-Plane Discontinuity	*A in-plane offset of the lateral force resisting elements greater than the length of those elements*
Discontinuity in Capacity-Weak Storey	*It is one in which the storey lateral Strength is less than eighty percentage of that in the storey above, The storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the Considered direction.*

Table 2: Description of Vertical Irregularities
(Cl 7.1, Table No 5, Page No.18.IS 1893:2002)

III. CRUMPLE SECTION

One of the solutions, an irregular building is separated into rectangular parts by providing separation sections at appropriate places. A Crumple section is a section filled with appropriate material (Cl-3.1.1, Pg no 1, IS 4326:1993) which can crumple or fracture in an earthquake so as to reduce all undesirable effects. Typical examples are shown in Fig: 3

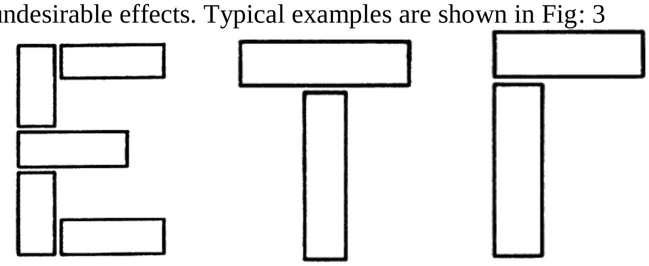


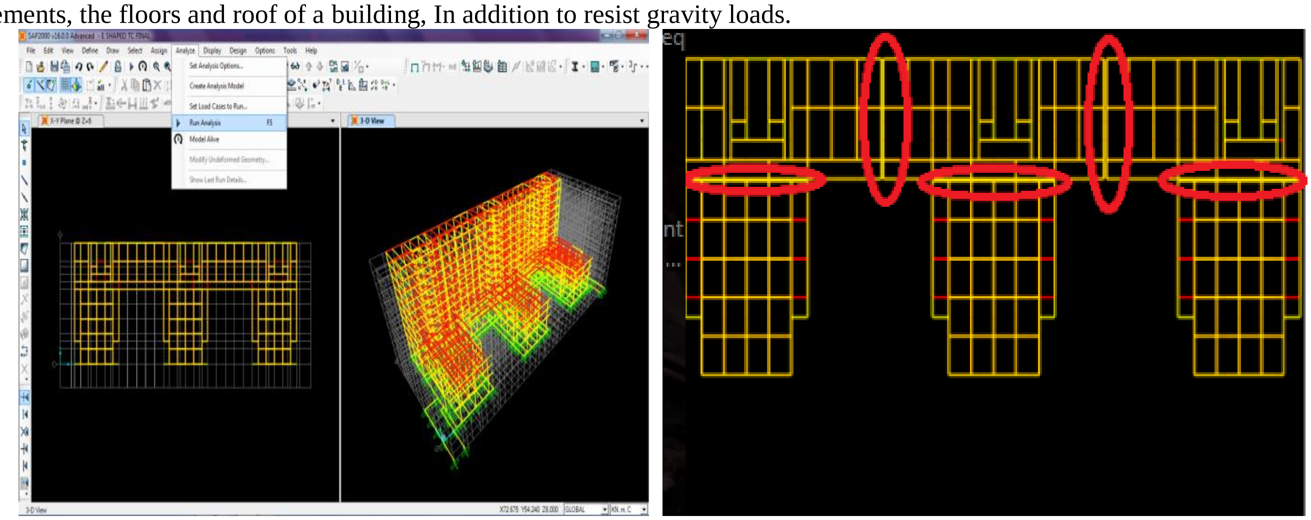
Fig. 3: Typical Shapes Of Building with Separation Sections
(Figure: 1, Page No.3, Is 4326: 1993)

In case of framed construction, members shall be duplicated on either side of the separation or crumple section. (Cl-5.2.1,Pg no 5, IS 4326:1993) As an alternative, in certain cases, such duplication may not be provided, if the portions on either side can act as cantilevers to take the weight of the building and other relevant loads. Gudelines of IS: 4326-1993 is considered to determine Irregularity and Gap Widths for Adjoining Parts. (Fig:2 & Table :1,Pg no-4,IS :4326-1993)

IV. MODELING

An E shape building is considered for analysis having irregularity in plan as well as in vertical plane by SAP2000 which represents the most sophisticated and user-friendly software. Here X, Y represents Horizontal plane and vertical plane is represented by Z axis. Initially grid is Prepared According to liner, lateral and vertical measurement of a building.

In process of modeling, Frame sections are delineated three Basic constituents. 1. Beams, 2. Columns and 3. Slabs. Detailing of appropriate grade (Concrete and Steel) and section properties like depth width and reinforcement along with their Types and numbers are addressed clearly to get more realistic result. Further Fixed joints are also defined at base of structure. At each floor according to design and requirements beams, slabs and columns are assigned in their respective planes XY and XZ. Moments can be released by providing pin joint connection at the end of secondary beams. To transmit lateral forces to vertical-resisting elements, the floors and roof of a building, In addition to resist gravity loads.



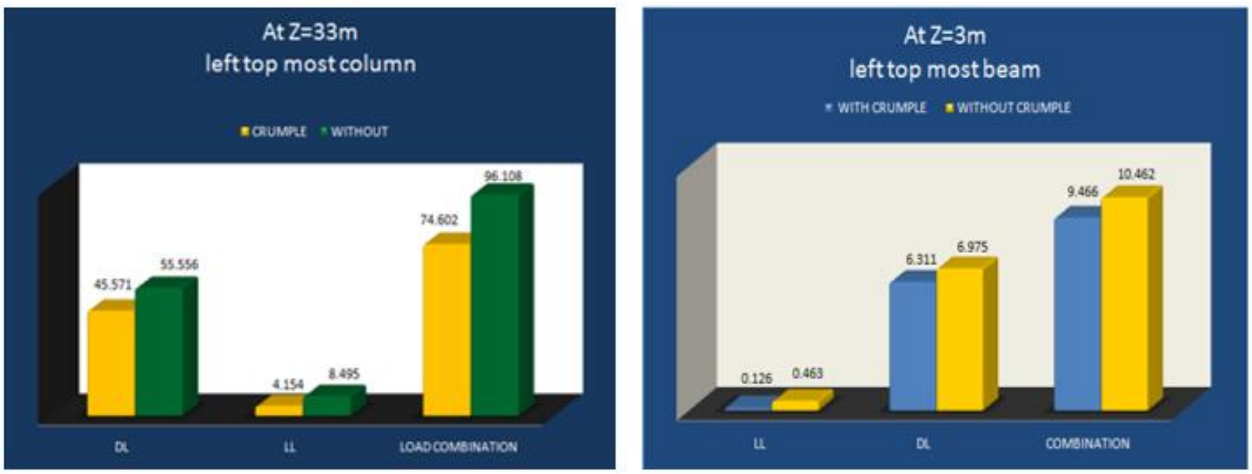
Model without Crumple Section   Model with Crumple Section
Fig. 4: An E Shaped Building With and Without Crumple (Sap: 2000)

Members are designed to act as diaphragms which are assigned by selecting particular slab area. To distribute load from slab to beam meshing is done by dividing the areas. To assign upcoming loads on a structure, load pattern and load combinations are defined which includes Dead loads, Live loads as well as earthquake loads in either direction. To assign Percentage of Imposed Load to be Considered As per table no.8,pg no.24,IS 1893:2002 mass source is defined with the value according to storey height. At each storey the value of Dead loads and live loads are assigned. Analysis is done after assigning all necessary inputs. Indian standard code for plain and reinforced concrete IS: 456-2000 is preferred for designing this concrete frame. During this stage all members are verified.

All procedure is reputed for same building having crumple section. Adhering to all the criteria for providing a crumple section, required gap is maintained starting from grid allocation to the designing stage. Between this gap property of a crumple material is defined.

V. Analysis and Results

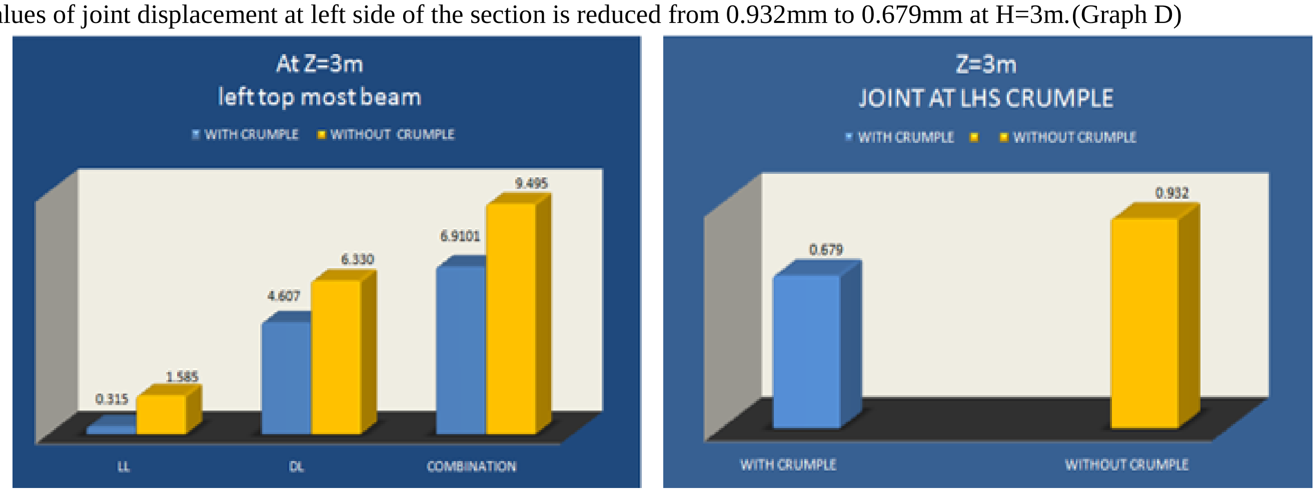
By considering the axial force in top most column to the left side at 33 m height, and Shear force in a top most beam at left side of a building at 3 m height, the values of dead load, Live load and one of the load combinations, are reduced from 55.556 to 45.571, 8.495 to 4.154 and 96.108 to 74.602 respectively. (Graph A) and 6.975 to 6.311, 0.463 to 0.126 and 10.462 to 9.466 respectively (Graph B)



Graph A Graph B

Fig. 5: Comparison of Axial Force and Shear Force between Section with Crumple and Without Crumple (Sap: 2000)

By considering the Bending moment in a top most beam of a building at H=3m,the values of dead load, Live load and one of the load combinations, are reduced from 6.330 to 4.607,1.585 to 0.315 and 9.495 to 6.910 respectively. (Graph C)and the values of joint displacement at left side of the section is reduced from 0.932mm to 0.679mm at H=3m.(Graph D)



Graph C Graph D

Fig. 6: Comparison of Bending Moment and Joint Displacement between Section with Crumple and Without Crumple (Sap: 2000)

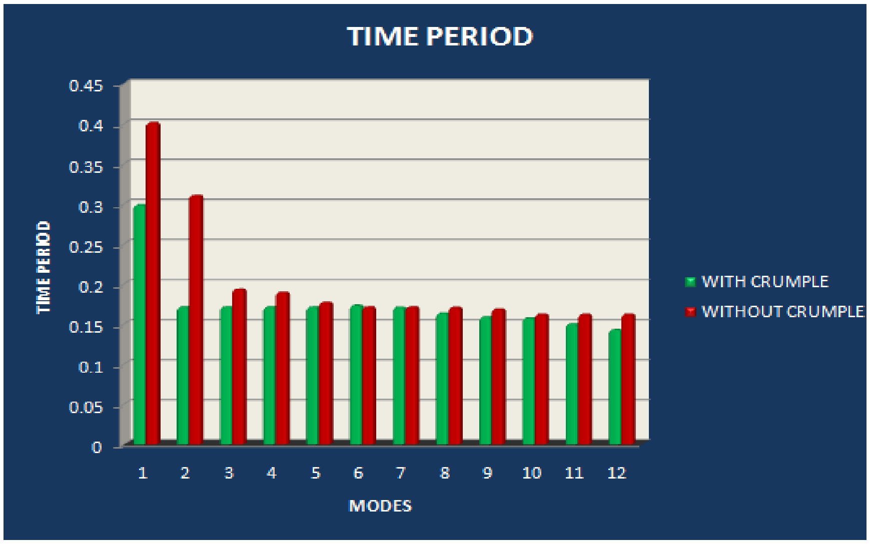
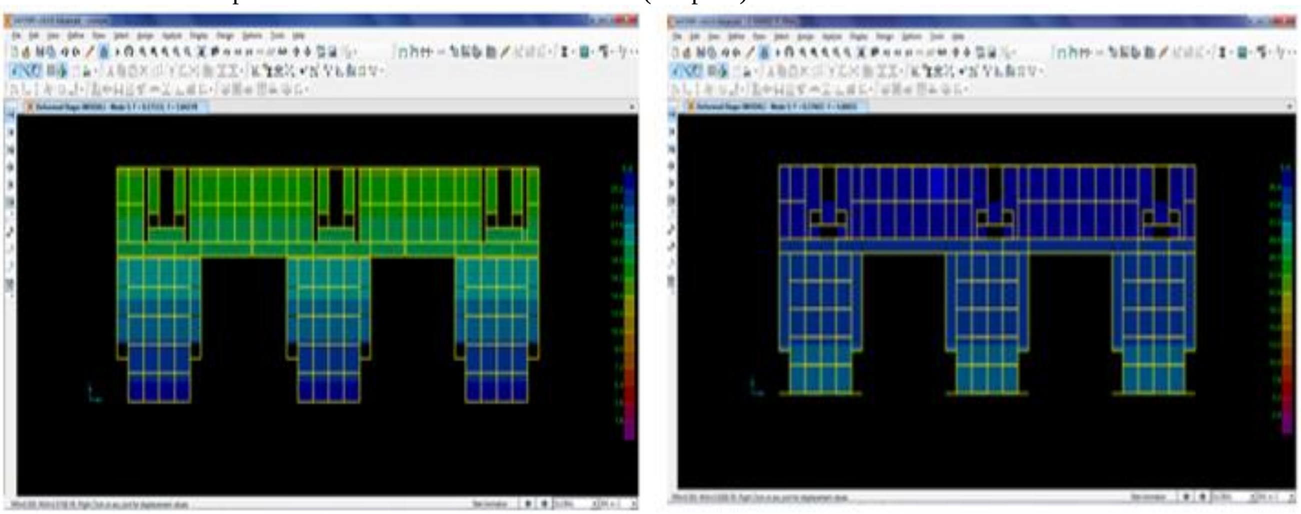


Fig. 7: Comparison of Time Period between Section with Crumple and Without Crumple (Sap: 2000)

Deformed shapes for various modes during Analysis represent the stress profile. An irregular shape building is highly stressed(Graph E)while same building provided with crumple section, all its separated parts behaves as individual unit and having their individual mode shapes results in less stress concentration.(Graph F)



Graph E Graph F

Fig. 8: Deformation Profile Section with Crumple and Without Crumple (Sap: 2000)

VI. CONCLUSION

- An irregular shaped structure does not promote easy load transfer for inertia forces generated due to earthquake.
- Due to which stresses and torsion effects are generated at re-entrant corners
- As a remedy crumple section is provided at required location to convert an irregular shape in to regular one with appropriate material which can be easily crumple down during ground shaking. By providing crumple section,
- The values of axial forces, bending moments, shear forces, torsion are reduced to remarkable extent.
- Reduction in joint displacement will result in to less story drift.
- Relative motion of separated parts during earthquake is accommodated which preclude Seismic Pounding effect.
- As mass is reduced in crumple section,$F = \frac{1}{2\Pi}\sqrt{\frac{K}{M}}$ Frequency increases and as $F=\frac{1}{T}$ Time period is reduced. As it is possible to reduce time period, damage also be reduced up to several extent.
- It is possible to plan and design less vulnerable multistoried building having irregularity in plan as well in vertical plane even in earthquake prone areas.

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