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A PATH FOR HORIZING YOUR INNOVATIVE WORK

P DELTA EFFECT ON TALL BUILDING

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Abstract

Structural engineers aim to increase the building height simultaneously they also want to control the deflection for lateral load in tall buildings. The rigid frame system, shear wall frame system, outrigger belt truss system are generally used for reducing the lateral deflection in tall buildings. The P-Delta effect is the lateral movement of a storey mass to a deformed position is generating second order overturning moments. This second order behaviour has been termed the P-Delta. In this paper the two dimensional 10 storey tall building frame for rigid frame system, shear wall frame system and outrigger belt truss frame system is studied for P-Delta effect. It is found that by providing shear wall frame system maximum lateral deflection reduction is 89.29% with respect to rigid frame system. It is also found that by providing outrigger frame system maximum lateral deflection reduction is 93.75% with respect to rigid frame.

Introduction:-

The developments and construction of tall buildings has become need of progress in India. As per Council of Tall Building and Urban Habitat (CTBUH) there is no specific definition of tall building. The criterion of height selection is totally based on urban norms. Traditionally the functions of tall building have been as commercial office buildings. Scarcity of land led to the other usages, such as residential, mixed-use, hotel towers etc. The tall buildings continue to be built due to their significant economic benefits in dense urban area.

Due to the great height of these tall buildings, the lateral forces acting on the face of building lead to lateral deflection of building. Control of this lateral deflection is an issue on which the structural engineers are concerned now-a-days. It is very important for structure to have sufficient strength against vertical loads and adequate stiffness to resist lateral forces. There are several structural systems. Out of these shear wall frame system is one of the alternative system used for reducing the lateral deflection. Shear wall frame is consist of beams, columns and reinforced cement concrete wall (shear wall). Ali and Moon [1] describe the history of tall structural system and technology from 19th century to the current state of developments. They have given new guideline for better classification of structural system as shown in Fig. 1 and Fig. 2.

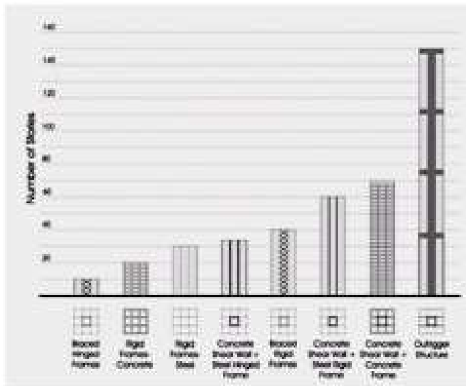

Fig.1 Interior structures [1]

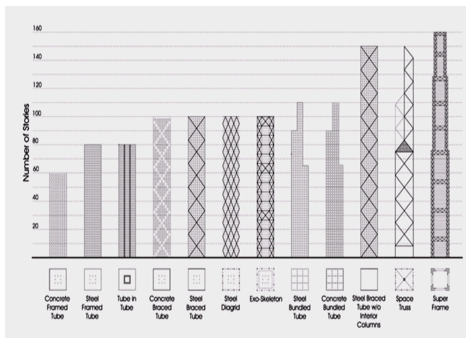

Fig. 2 Exterior structures [1]

Gunel and Ilgin [2] have studied and briefly discussed many structural systems that can be used for the lateral resistance of tall buildings. They suggested structural system for different heights of tall building.

Leithy, Hussein and Attia [3] have investigated the most common structural systems that are used for reinforced concrete tall buildings under the action of gravity and wind loads. Shear wall frame is combination of shear walls and rigid frames. It is suited for reinforced concrete building as well as steel building.

Taranath [4] has described total historical development in steel, concrete and composite building from ancient times to the current state. He has also described the detailed formulation on the different structural system.

Sullivan, Pham and Calvi [5] are studied that 45 storey reinforced concrete frame wall for P delta limit within modal response spectrum analysis procedure of Eurocode 8. And found that strength of the structure is dictated by P delta limit for seismic action.

Moghadam and Aziminejad [6] are studied that P delta effect in elastic and inelastic ranges for asymmetric building. Four building 7, 14, 20 and 30 storey are studied for with and without P delta effect. It found that type of lateral load resisting system plays an important role in degree that torsion modifies the P delta effect.

Negi [7] gives the recent updated steel table with all sections and its properties. From this steel section are uses in this paper.

SAP 2000v14 [8] manual describes detailed procedure of modeling, different type of analysis, results for model. It also described the P delta effect on building.

P-delta effect

The P-delta effect is generally occurs on high rise or tall building. The lateral movement of a storey mass to a deformed position is generating second order overturning moments. This second order behaviour has been termed the P-Delta. The additional overturning moments on the building are equal to the sum of storey weights multiplied by the lateral displacements. Fig. 3 shows overturning loads due to translation of storey weight.

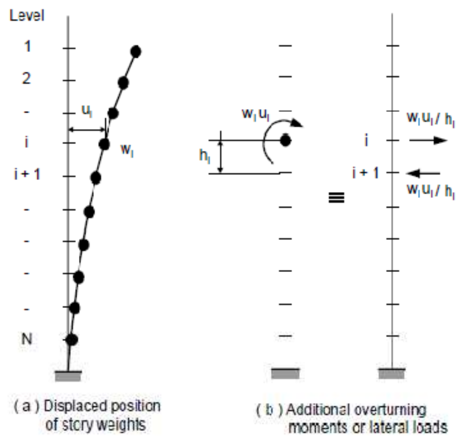

Fig. 3 Overturning loads due to translation of storey weight

The P-delta effect refers specifically to the nonlinear geometric effect of large tensile or compressive direct stress upon transverse bending and shear behaviour. A compressive stress tends to make a structural member more flexible in transverse bending and shear, whereas a tensile stress tends to stiffer the member against transverse deformation.

The basic concept behind the P-delta effect is illustrated in following cantilever beam example. Consider a cantilever beam subject to an axial load P and transverse tip load F as shown in Fig. 4 (a) The internal axial force through the member is equal to P. If equilibrium is examined in the original configuration (using the undeformed geometry), the moment at the base is $M = FL$, and decreases linearly to zero at the loaded end if, instead, equilibrium is considered in the deformed configuration shown in Fig. 4 (b), there is an additional moment caused by the axial force P acting on the transverse tip displacement Δ. The moment no longer varies linearly along the length; the variation depends instead upon the deflected shape. The moment at the base is now $M = FL - P\Delta$ due to tensile load. The moment at the base is now $M = FL + P\Delta$ due to compressive load. Tensile forces tend to resist the rotation of elements and stiffen the structure, and compressive forces tend to enhance the rotation of elements and destabilize the structure. It required a moderate amount of iteration. The moment diagrams for various cases shown in Fig. 4 (c) to Fig. 4 (e)

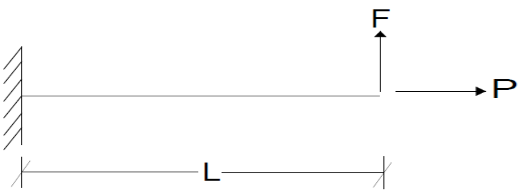

Fig. 4 (a) Original configuration

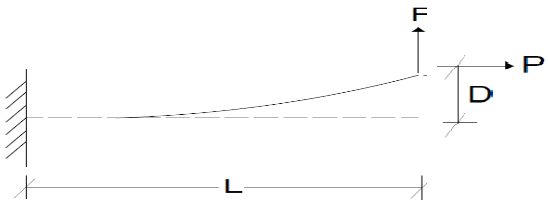

Fig. 4 (b) Deformed configurations

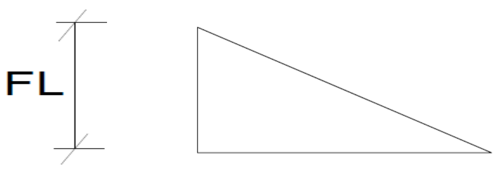

Fig.4 (c) Moment diagram in original configuration without P-Delta

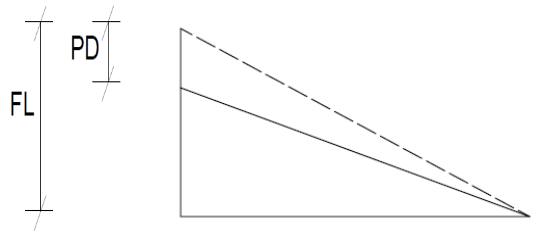

Fig. 4 (d) Moment diagram for tensile load P with P-Delta

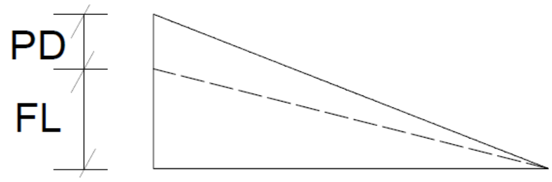

Fig. 4 (e) Moment diagram for compressive load P with P-Delta

Fig. 4 P-Delta effect on cantilever beam

Rigid frame system

Rigid frame is used in steel and reinforced concrete building. Lateral stiffness of a rigid frame bent depends on the bending stiffness of the columns, girders, and connection in the plane of the bents. Rigid frame systems for resisting lateral and vertical loads have long been accepted for the design of the buildings. For a rigid frame, the strength and stiffness are proportional to the dimension of the beam and the column dimension, and inversely proportional to the column spacing. rigid frame of a typical scale that serve alone to resist lateral loading have an economic height limit of about 30 stories, as for more than 30 stories the rigidity of the frame system remains mostly insufficient for lateral sway resulting from wind and earthquake actions. Fig 5 shows Lever

House, New York is an example of rigid frame system.

Fig. 5 Lever house, USA

Outrigger belt truss system

Outrigger belt truss system is modified form of braced frame and shear walled frame system. The outrigger belt truss system is briefly defined as the structural arrangement consists of main core connected to the exterior columns by relative stiff horizontal members commonly referred to as outrigger. The main core may consist of a steel braced frame or reinforced concrete shear walls. The outrigger beam (girder) may consist of concrete or steel brace. The outrigger girder is minimum one floor deep. The belt truss is provided at outer peripheral of building to reduce the further deflection [4]. The outrigger belt truss system is shown in Fig. 9. And building example of outrigger belt truss system is Wisconsin Centre in Milwaukee (USA) shown in Fig. 10 [2].

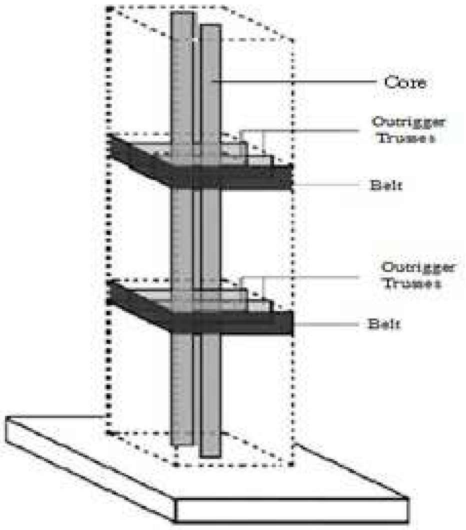

Fig. 9 Outrigger belt truss system

Fig. 10 Wisconsin centre, USA

Analysis and Result

For two dimensional frame three cases are studied as follows.

In case First, the two dimensional three bays of 10 storey tall building frame. The each bay width is 4 m and storey height is 3.1 m. The frame is fixed at base and total height of frame is 31 m. The steel column SC 250 and beam ISLB 250 is provided. The lateral load of 1 kN/m is applied on left column (X – direction) only.

In second case, all the data and loading are same as in first case. The M20 grade of concrete shear wall having thickness 150 mm is provided in centre bay.

In third case, all the data and loading are same as in second case. The outrigger beam ISLB 200 is provided at half height of frame (i.e. at 15.5 m from base respectively).

The above three cases are modelled and analysis in SAP 2000v14 software. The models for three cases are shown in Fig. 11, Fig. 12 and Fig. 13. The analysis type is "Nonlinear static with P delta effect". The variation of lateral deflection with height is shown in Fig. 14.

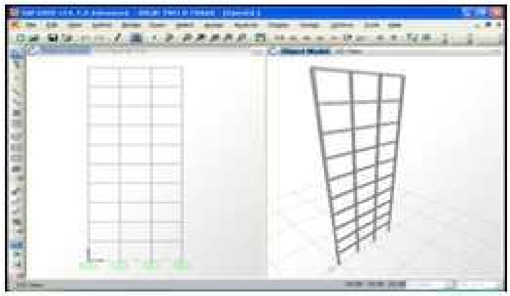

Fig. 11 Model of two dimensional rigid frame system

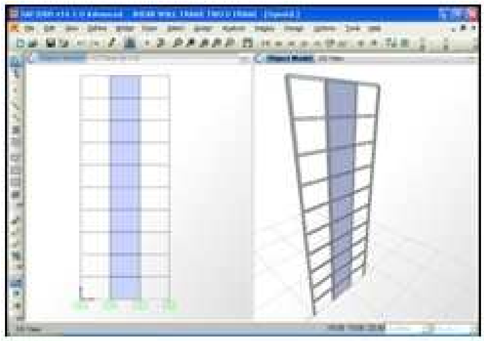

Fig. 12 Model of two dimensional shear wall frame system

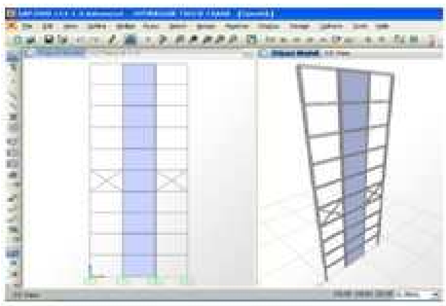

Fig. 13 Model of two dimensional outrigger belt truss frame system

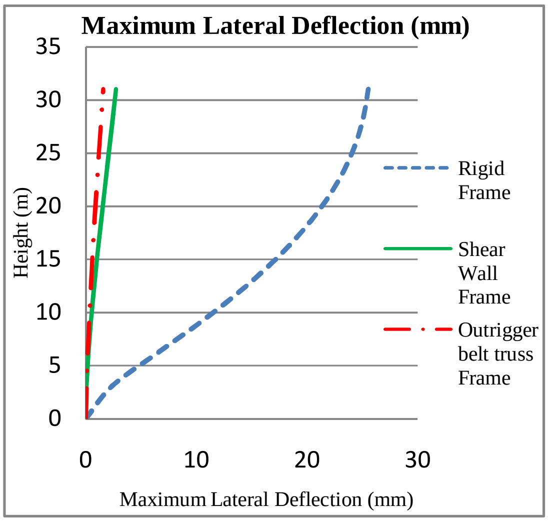

Fig. 14 Lateral deflection with height

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