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Use of Dampers in Vertical cities: Effective Method to Control Seismic Vibrations

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Abstract: Modern high rise buildings, vertical cities, sky scrapers are popular due to its advantages in terms of consuming less foot print area of site; however this vertical development should be verified to safeguard the structure. To achieve this considering various parameters like structural systems, seismic vibration controlling systems and maintaining overall ductility of the structure are most important. This paper mainly reviews and discusses one of such method to control seismic vibrations i.e. use of dampers. Dampers of various types and mechanisms are studied. Case studies of top 5 skyscrapers in the world are discussed which includes Jeddah Tower, Burj Khalifa, Taipai tower, Shanghai Tower and International Commerce Centre. Concluding remarks are made with possible use of these dampers considering their suitability and requirement under various circumstances.

Keywords: **Skyscrapers, Dampers, Types of dampers, Ductility of structure, Case studies**.

Introduction:-

Skyscrapers are getting popularity due to rapid urbanization and adaptable nature for multiple purposes which save area of the footprint of a building. To achieve this structural stability should be given the topmost priority. Seismic forces, wind forces are critical in the high rise and skyscrapers which need to be taken care by providing different safety majors like introducing out-rigger structural systems, provision of dampers to absorb the vibrations, etc. Outrigger systems are getting obsolete and dampers are taking over their place due to the effective seismic control through externally attached devices. Dampers are the devices used in the buildings to absorb the vibrations which occur due to the seismic forces, wind forces etc. used in the building in modern age. There are different types of dampers available based on their mechanism, use which includes viscous dampers, friction dampers, visco-elastic dampers, hysteretic dampers, buckling restrained dampers, tuned liquid dampers, tuned mass dampers, etc.

Literature Review:-

Dampers are the devices which reduces the energy generally used in high rise buildings in which base isolation technique is not effective. Different types of dampers are discussed below-

1. Fluid Viscous Dampers**:** They consist of a stainless steel piston with bronze orifice head. It is filled with silicon fluid. The damper is usually filled with viscous fluid which gets compressed by a piston to absorb the energy. [1]

2. Friction Dampers: They use metal or other sources and energy is absorbed by rubbing against each other. Usually they consist of steel plates which are separated by shims of friction pad material. Friction dampers can be used in moment frames, diagonal frames along with many other applications.[1]

3. Visco-elastic dampers: It is a damper which stretches elastomer in combination with metal parts. The energy is absorbed by controlling shearing of solids. [1]

4. Hysteretic Dampers: They are also known as yielding dampers which are generally used in the frame buildings. They consist of metal parts which absorb energy by yielding. Steel is generally preferred material. They have the potential to be used to yield in bending, tension or compression. [1]

5. Buckling Restrained Braces (BRB): It is a special type of hysteretic damper; here the energy dissipation is carried out by built-in tension or compression brace. The brace is designed in such a manner that it can yield in both axial compression and tension under revised cyclic loading. The advantage of using this damper is that it spreads the absorbed energy over long spans which reduce the strains due to cyclic loading. [1]

6. Tuned Liquid Dampers: It is a special type of damper which relies on the motion of the liquid in U-shape to counteract the effect of external forces acting on the building. [II]

7. Tuned Mass Dampers: It consists of a secondary mass which attached with a tuned spring and damping attachment. They are preferred in buildings to absorb wind forces. [II]

Case Studies:-

To understand the behaviour of following top five skyscraper case studies are carried out-

1. Kingdom Tower, Jeddah:-
Location- Saudi Arabia,
Height: 1000m+,
Design Architect: Adrian Smith and Gordon Gill Architecture,
No of floors: 167,
Structural Engineer: Thormton Tomasetti
Tuned mass dampers are used in the design along with high grade concrete of 115MPa, Shear walls, and reinforcement bars of 720 MPa. Here to maintain the ductility of structure, the vibrations are only minimised rather than eliminating it and provision of tuned mass dampers helps effectively in such cases

by snapping in opposite direction of wind or seismic vibrations. This would help in avoiding catastrophic d\failure of structure.

Fig. 1 Kingdom Tower, Jeddah, Saudi Arabia
https://en.wikipedia.org/wiki/Jeddah_Tower

2. Burj Khalifa:-

Location: Dubai, United Arab Emirates
Height: 863m
Design Architect: Adrian Smith
No of floors: 211

Burj Khalifa is a unique structure not only for its height but also due to the several records which are established on its name. One interesting parameter which i found is absence of tuned mass damper. The structural designers used the concept of 'confusing the wind' which is entirely based on the shape and integrity of structure. The unique Y shape of building reduces the wind forces along with the tubular variation in the heights reduces the effect. Variation in heights is a novice idea which will reduce the possibility of large deformations which are rather impossible to occur simultaneously. In addition to these structural braces are introduced at the periphery of building to reduce uneasiness which may be experienced by the occupants along with to reduce the other damages like windowpanes, outer facades, stress building joints, cracks, etc.

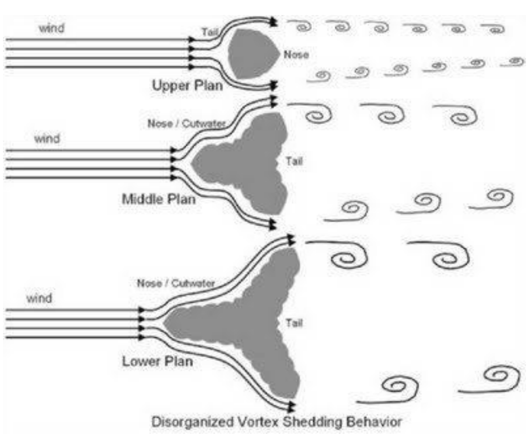

Figure 13. Wind behavior

Fig 2 Burj Khalifa wind behaviour based on shape
(Source: https://qph.ec.quoracdn.net/main-qimg 1baf963fea7c92be948cf899fefcaf66-c)

3. Taipai Tower:-

Location: Xinyi, Taipai,Taiwan
Height: 508m
Design Architect: C.Y. Lee and Partners
No of floors: 101 above ground + 5 basement floors

Taipai tower has a gigantic suspended mass which prevents motion against earthquake and wind vibrations. I has a total weight of 730 tons which spans across four stories.

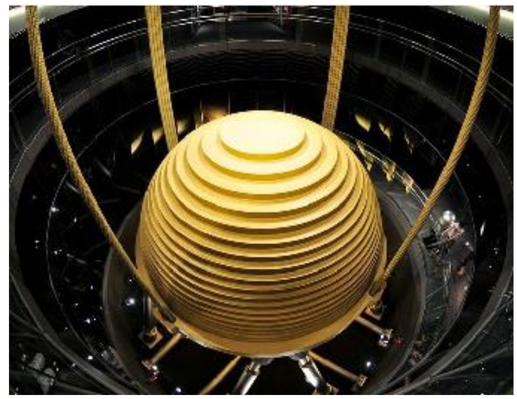

Fig. 3 Tuned mass damper installed in Taipai Tower
(Source: http://lh6.ggpht.com/-MuRQF5bTV88/U-NGbSnBodI/AAAAAAAA09U/R7_2sePwXw4/taipei-101-damper-6%25255B6%25255D.jpg?imgmax=800)

A tuned mass damper of 660 tonne steel pendulum is attached at the floor from 92nd floor to 87th floor. Damper consists of steel plates which are welded together to avoid the strong winds. Along with the big sphere two small spheres are also attached at the spire to avoid the wind forces.

4. Shanghai Tower:

Location: Lujiazui, Pudong, Shainghai
Height: 632m
Design Architect: Jun Xia and Gensler firm
No of floors: 128

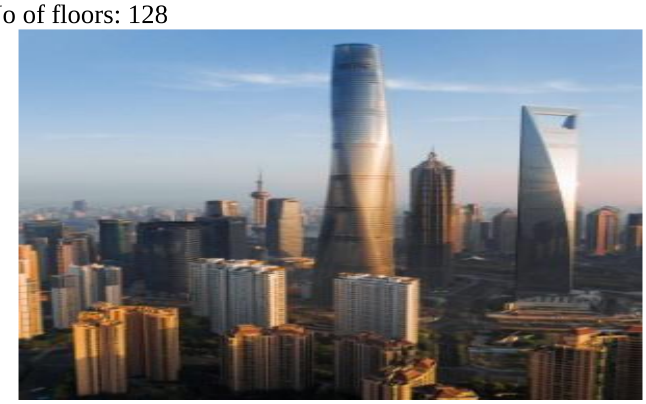

Fig.2 Shanghai Tower
(Source:https://www.google.co.in/url?sa=i&rct=j&q=&esrc=s cd=&cad=rja&uact=8&ved=0ahUKEwjA5ZnExJfYAhVFp48K HYvbB1AQjRwIBw&url=http%3A%2F%2Fwww.skyscrapercenter.com%2Fbuilding%2Fshanghai-tower%2F56&psig=AOvVaw1mlQJQi3FQ6e200iKOGW_c&ust=1513822904835897)

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An eddy- current damper is used which is very simple in design. It consists of copper base plate on which 125 magnets mounted below the mass damper.. It has the advantage of low maintenance and eliminates the requirement of manual change in the vibration frequencies. Whenever the building is subjected to wind forces, 1000tons weight creates electric current in the field and thus creates opposite magnetic field which reduces the effect of motion and automatic damping is achieved.

5. International Commerce Centre:-

Location: West Kowloon, Hong Kong
Height: 484m
Design Architect:
No of floors: 108 above ground + 4 basement

International commerce centre has outrigger system to control the seismic vibrations. Outrigger is made up of steel plates which offer flexibility to the structure. However damping which is achieved due to provision of structural systems is considered as uncertain and therefore external damping devices are considered to be reliable and therefore rapidly getting replaced over structural systems.

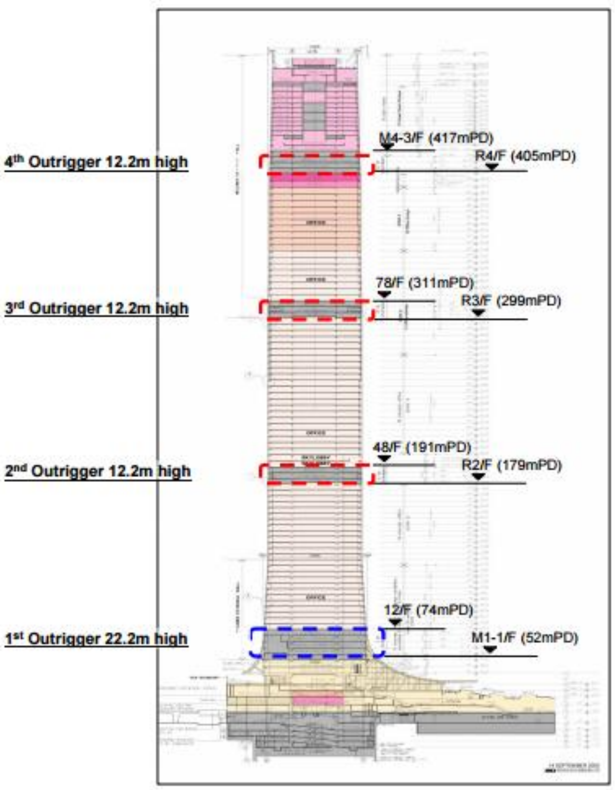

Fig. 5 International Commerce Centre Outrigger system provided (Source:http://personal.cityu.edu.hk/~bswmwong/pl/pdf/icc_full_jun_08.pdf.)

Conclusion:-

From the above study it is clear that the top skyscrapers use different mechanisms to control the seismic vibrations, wind forces. Some skyscrapers use tuned mass dampers in traditional and hybrid ways which are essential to minimize the effect of wind and earthquake vibrations. Also Burj Khalifa sets an exclusive example where structural plan, shape itself acts as a damper while the International Commerce centre used outrigger structural system in steel and concrete to control the vibrations. Dampers could be used for high rise buildings, skyscrapers effectively. Further study could be carried out for structural health monitoring and the other methods of damping which could be adopted for different typologies of buildings

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