Study of Tall Building With Tuned Mass Damper & Friction Damper: A Review

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Abstract- *the present scenario in the construction industry demands lighter and taller structures having high strength and maximum flexibility. This is facilitated by the advancements in the construction technology and material science. From the serviceability point of view, the increase in failure possibly provides a threat to this. The main theme in civil and mechanical structural design is the vibration control techniques relating to the structures subjected to environmental dynamic loads. Different policies have been proposed in this field which considers the structural safety and the random natural vibrations caused by natural or artificial loads such as sea waves, traffic vibrations, earthquakes etc. The alleviating responses of civil engineering structures to environmental loads such as winds and seismic has fascinated many researchers in recent years. Passive, semi active and active vibration control devices have been developed. Friction dampers is one of the simplest and the most reliable passive control devices among the available ones. This study deals with the efficacy of friction dampers as a passive device in controlling vibration of structures. Typical multistoried composite buildings consisting of normal, shear wall building, TMD building and FD building were considered. Braced frame building and FD building are connected by different configurations.*

Keywords- Seismic analysis, Tuned Mass Dampers, Friction damper, High rise building, Wind Analysis.

I. INTRODUCTION

The most feasible and effective solution for the housing needs of rapidly increasing urban population are the high rise buildings. It is possible to construct high rise building with the development in the construction technology and use of different type of construction material. The major engineering concern is the safety of high rise building against the environmental forces such as wind and earthquakes. Ductility, strength and stiffness are the major factors which depends on the response of these high rise building structures. The overall lateral response is affected by the structural used in tall buildings. The vibrations produced by the seismic and wind forces can cause failure for the building and produce discomfort to the occupants. This can be controlled by the enhancement of damping, mass, shape, and rigidity of the structure.

DAMPING - Damping is the process by which mechanical energy is dissipated in dynamic systems. It reduces the structural response on buildings. Vibration amplitude, materials used in the construction, fundamental periods of vibration, mode shapes and structural configurations are the parameters that depends the damping of the structure. Vibration control technique depends on many factors like efficiency, compactness and weight, capital cost, operating cost, maintenance requirements and safety. The damage produced on the structural system can be reduced by dissipation of input energy due to earthquake and wind through special devices which can be replaced if necessary after the occurrence of earthquake. Three types of external dampers that can be added to a mechanical system to enhance its energy dissipation characteristics. They are

A. *Active control devices*

An active system uses a power source to produce an additional force between the dampers and the structure, and still uses a damper to dissipate energy. This system includes a smaller mass but contains large amounts of energy. However, another major problem with active control system is that they can only be used on smaller buildings due to economic impact of the huge amount of energy consumption; the power needed to dampen the oscillations of huge structures is enormous. This high amount of energy not only has a negative consequence on overall operational charges, but it also produces a gigantic mark on the environment; active control devices do not conserve energy resources and emit exhaust that convert to environmental pollution. Examples of active control devices comprises of tuned mass damper and tuned liquid damper.

B. *Passive control devices* –

A passive system is the frequently used vibration control technique. This method is not only the inspected and most acknowledged but is also the age oldest configurations of Vibration control technique and it is presently the productive devices in high-rise buildings. Passive control devices dissipate the energy with no external power source. This system simply comprises of a mass, a damper and a spring. The force that act on the building due to the external force is directed through this device and thus dissipated takes place with the help of damping device. Examples of passive control devices comprises of viscous fluid dampers, viscoelastic solid dampers, friction dampers, and metallic dampers.

C. Semi Active control devices *–*

Semi-active control devices are hopefully the most promising devices, with lower performance costs and more energy efficient components. Semi-active control devices can be potentially activated fully by batteries if needed making them superior to active systems in the area of power interruption. The prime idea of a semi-active system is the amalgam of a passive and active system. The basic passive system operates as it always does, but in between outward disturbance force intakes, a valve is turned on. This valve sends a signal to a computer, which in exchange gives the active part of the system a bump of energy. This added energy then builds on to the dampening effect of the passive component of the system. Though this is a rather systematic method of dampening structural oscillations, the actuality remains that an external power supply is still needed in the semi-active tuned mass damper's performance. The totality of environmental impact caused by this power source may be much lesser than that of an active tuned mass damper system, but semi-active tuned mass dampers still rank below passive systems with regards to its sustainability. Passive control methods are quite usual vibration control method in tall building structures. Among numerous passive control devices, tuned mass dampers are used systematically to bring down the dynamic response of structures due to wind or seismic induced excitations. Some models of semi-active dampers include variable-orifice dampers, magneto rheological dampers, and electro rheological dampers.

II. TUNED MASS DAMPER

A tuned mass damper (TMD) is a device consisting of a mass, a spring, and a damper that is attached to a structure in order to reduce the dynamic response of the structure. The frequency of the damper is tuned to a particular structural frequency so that frequency is excited, the damper will resonate out of phase with the structural motion. Energy is dissipated by the damper inertia force acting on the structure. The Tuned Mass Damper (TMD) concept was first applied by Frahm in 1909 (Frahm, 1909) to reduce the rolling motion of ships as well as ship hull vibrations. A theory for the TMD was presented later in the paper by Ormondroyd and Den Hartog (1928), followed by a detailed discussion of optimal tuning and damping parameters in Den Hartog's book on Mechanical vibrations (1940). The natural frequency of the TMD is tuned in resonance with the fundamental mode of the primary structure, so that a large amount of the structural vibrating energy is transferred to the TMD and then dissipated by the damping as the primary structure is subjected to external disturbances. Consequently, the safety and habitability of the structure are greatly enhanced. From the field vibration measurements, it has been proved that a TMD is an effective and feasible system to use in structural vibration control against high earthquake loads, as shown in Figure 1.

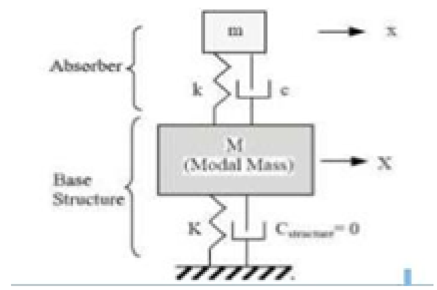

Fig: 1 A schematic representation of damped vibration absorber suggested by Den Hartog

III. FRICTION DAMPERS

Friction dampers [FD] are devices that use dry friction to dissipate energy of a system in order to limit its vibratory response. They work by keeping in contact two surfaces that move relative to each other in order to generate friction. When compared to other means to attenuate vibration, friction dampers stand out by their noteworthy advantages. To name a few, they work in harsh environments and in the absence of electric or hydraulic power they adapt to a wide excitation bandwidth without tuning; and they can act simultaneously along multiple directions. Consequently, they are used in a variety of applications. Their most common use is in buildings, as a means to prevent damage caused by earthquakes. Their use is also common in the transportation sector, such as for truck and train damping of road-induced vibrations. Friction damping is also extensively used in turbo machinery, especially on turbine blades and bladed disks.

Friction damping can be referred to as frictional damping or Coulomb damping. When the damping comes from the material itself or from a system about which no clear information of the inner dynamics is known, the terms hysteretic damping, complex stiffness, and structural damping may refer to the same phenomenon of dissipation by friction. The friction damper consists of 3 steel plates rotating against each other and in between these plates, there are two circular friction pad discs, in order to have dry friction lubrication in the unit, ensuring stable friction force and reducing noise of the movements.

The damper main parts are the central plate and two side plates. The central plate holds and connects the damper device to the girder of frame structure by a hinge in order not to introduce moment in the girder. The hinge connection will increase the amount of relative rotation between the central and side plates, which in turn increases the amount of energy dissipation in the system. The two side plates connect the damper to the bracing system and in this work, inverted V-bracing was used. This bracing consists of pretension bar members in order to avoid compression forces and therefore buckling. The bracing bars are pin-connected at both ends to the damper and to the column bases.

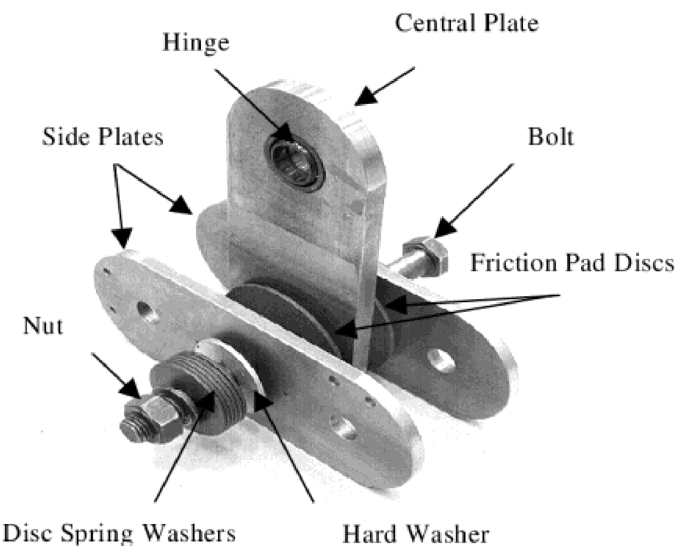

Fig. 2 Details of the FD device

The reason for using two side plates instead of one was to increase the frictional surface area and to provide the necessary symmetry in to obtain plane behavior of the device. The bolt connects the three plates of the damper to each other. This adjustable bolt is used to control the normal force applied on the friction pad discs and the steel plates. In order to keep a constant clamping force, several discs spring washers (Belleville washers) are used. Hardened washers were placed between these springs and steel plates to prevent any marks on steel plate due to the disc springs when they were in compression. When a lateral external force excites a frame structure, the girder starts to displace horizontally due to this force. The bracing system and the frictional forces developed between the frictional surfaces of steel plates and friction pad materials will resist the horizontal motion. This process of moving from phase to phase is repeated upon reversal of the direction of the force application.

IV. LITERATURE REVIEW

The following research papers are studied under the study of analysis of a Structure containing the different Damper such as TMD & FD. The summarized reports of different researchers are as follows:

A.U.Weerasuriyan and M.T.R.Jayasinghe. [1998] in this research they analyzed for 183 m tall building. The governing load observed for load combination of 1.2DL+1.2Q+1.2W and for this combination, bending moment has maximum about 35% in column and about 48% for the beams. However, column maximum axial load variation is in the range of 10%. This value is as high as 17% when wind load is governing as in load combination 1.0DL+1.4W. The bending moment value is higher as 50% for the column and more than 55% for beam bending moments for load combination 1.4DL+1.4W. For the governing load case 1.2G + 1.2Q + 1.2W, all wind loading standards gave almost the same wind load except wind loads for the Australian standards in zone 1. Australian Standards gave higher wind loads in zone 1 because of them used higher terrain-height multiplier and an importance factor for cyclonic region, zone1. The use of higher terrain height multiplier in cyclonic region can be justified because of higher risk level are required to design buildings in cyclonic regions. However, the use of importance factor 1.1 may leads to more conservative wind load design and thus it is recommended not to use it with higher terrain height multiplier. Euro code also derived higher wind loads due to higher pressure coefficient values used by the code.

M.D.Wijeratne and M.T.R.Jayasinghe. [1998] In this analysis they applied the wind force 33m/s and 38m/s on building structure in Shri-lanka. The structure consist of 40, 50 and 60 story having 160m 200m and 240 m height respectively range with height breath ratio. They found the maximum deflection for 40storey - 239mm, 50storey - 340 mm and for 60storey - 478mm. they observed that deflection was too large so they applied some shear walls and tried to reduce the maximum deflection 96mm to 212 mm. Design of high rise building with unusually low design wind speeds will allow the designers to select less rigid structural forms which may have unacceptably high acceleration even at lower wind speeds. for high rise building for the post disaster wind speed given for zone 3.The use of a higher wind speed will automatically constrain the structural designer to select sufficiently stiff structure forms with low drift indicates.

Bogusz Bienkiewicz, Munehito Endo, Joseph a. Main,and william p. Fritz.[2001] In this research they analysis paper of two building for wind force, having the different dimensions that wind induced internal force (bending moment) in the frame geometry. That force produced the 90% peak bending moment in the two frames. In a first building bending moment comes 31.2 KNm at the height of 6.1m and in second building it was 32.4 KNm at the height of 9.45m.which is maximum in both structure. Results of an ongoing inter-laboratory comparative study of approach flow, wind pressures on low buildings and internal wind- induced loading are presented. The largest variability in the laboratory wind pressures and in the associated (computed) wind-induced internal loading (bending moment) in structural frames Review of Critical Analysis of Frame Building Structure by Wind Force of generic low buildings was found for suburban wind exposure. This variability was primarily attributed to differences in the approach flows employed in physical modeling of wind pressures on tested buildings, carried out by the participating laboratories. The variability in the approach flows resulted in a large measure from the differences in the along-wind turbulence intensity implied by different empirical models, defining the target wind exposures and used by the laboratories. A follow-up comparative inter-laboratory study is planned to address a number of issues identified in the ongoing efforts.

Li Jian Zhou, Ming Kang Shan, Jin Zhou He, Yuan Gang Fan, [2012],This paper established three-dimensional calculation modal of three large space shear wall structures of different thickness, using finite element software ANSYS to analyze the wind load and vertical loads of the internal force. And analyze the displacement, internal force distribution pattern. Under the wind loads and vertical loads of three different thickness wall of the larger space wall structure.

Bianca R. Parv and Monica P. Nicoreac. [2012] In this analysis of structure they have analyzed 25floor building having the height of 87.5m for the horizontal uniformly distributed load, from wind, acting on both side direction is 28kn/m and 24 kn/m by equivalent column method and FEM method. They found max. Deformation at Umax is 1.3cmfor ECM and 1.2 for FEM and Vmax is 12.05cm and 10.70cm for ECM and FEM respectively.

Swati D. Ambadkar, Vipul S. Bawner [2012] in this paper they analyzed 40m storied building at 50m/s wind force is 65.322KN. Bending moment is 97.823 KN-M and deformation is 105.147 mm. As the wind speed increases My, Mz value also increases according to the category as compare to Mz values My values increases more rapidly. As the wind speed increases Fy, Fz value Fy value increased more rapidly. Displacement increases as the wind speed increases for various types of opening, category

Rajib Kumar Biswas, Md.Meraj Uddin, Md.Arman Chowdhury, Md.Al- Imran Khan, [2013] In this paper Comparative Analysis of a 15 Story Flat Plate Building with and Without Shear Wall and Diagonal Bracing Under Wind and Seismic Loads. To increase lateral stiffness of flat plate structure and to is also concerned about column axial load and to review our structure with special features like shear walls & diagonal bracing. In present work, a 15 storied flat plate garments building have been modeled using software package “STAAD Pro” for minimize the displacement of the structure under lateral loading. This paper earthquake zone II in Bangladesh .This model is considered in most vulnerable situation where we took wind speed as 26 kmph and Earthquake load has been taken as per Bangladesh National Building Code (BNBC).

R. Vijayasarathy, V. Finney H. Wilson, [2013] in this study Application of Tuned Mass Damper in Structures under Seismic Excitation. This paper makes an attempt to understand the present knowledge on Tuned Mass Damper in structural systems and their applications in earthquake engineering. The research work done by various researchers and their conclusions have been discussed in detail

Mohit Sharma, Dr. Savita Maru, [2014] Experimental study performed on G+ 30 storied regular building model in STAAD Pro. These buildings have the plan area of 25m x 45m with a storey height 3.6m each and depth of foundation is 2.4 m. & total height of chosen building including depth of foundation is 114 m. The static and dynamic analysis has done on computer with the help of STAAD-Pro software using the parameters for the design as per the IS-1893- 2002-Part-1 for the zones- 2 and 3 and the post processing result obtained has summarized.

Sandeep Tembhurkar, Dr. Valsson Varghese [2014], this paper present a study of wind loads to decide the design critical parameter of a multistoried building. The significant of this work is to estimate the design loads estimate based on the basic wind speed and other factors of a structure.

Said Elias and Vasant Matsagar,[2014] In this paper, a 76-storey benchmark building is modeled as shear type structure with a lateral degree of freedom at each floor, and tuned mass dampers (TMDs) are installed at top/different floors. Suitable locations for installing the TMDs and their tuning frequencies are identified based, respectively, on the mode shapes and frequencies of the uncontrolled and controlled buildings. It is concluded that the d- MTMDs are more effective to control wind induced vibration than the STMD and the MTMDs placed at top floor.

Farhana Naznin, Partha Pratim Das and Nayanmoni Chetia, [2015] this paper highlights a review on the principle and applications of base isolation and tuned mass damper. The vibration control concept with base isolators and tuned mass dampers is a passive way of controlling the response by providing horizontal flexibility, energy dissipation and rigidity against lateral loads.

Haruna Ibrahim, Daha S. Aliyu, Hafizu Hamza, [2015] this study was made to study the effectiveness of using Tuned Mass Damper for controlling vibration of a frames structure. This report proposes a passive control of vibration of single degree of freedom and multi- degree of freedom structural frames subjected to dynamic (wind) excitation and a general understanding of the structural dynamics through MATLAB simulations. Preliminary results on the passive control of the structural response of single degree of freedom (SDOF) and two dimensional multistoried frames using Tuned Mass Damper (TMD) are presented. At first a numerical analysis was developed to investigate the response of a shear building fitted with a tune mass damper. Then another numerical was developed to investigate the response of a 2D frame model fitted with a Tuned Mass Damper and then without Tuned Mass Damper (TDM). From the study it was found that, tuned mass damper can be effectively used for vibration control of structures. Tuned mass damper (TMD) was more effective when damping ratio of the structure is less. Gradually increasing the mass ratio of the tuned mass damper results in gradual decrement in the displacement response of the structure. It is also observed that due to increase in tuned mass damper damping ratio, the movement of tuned mass damper is also decreases.

A Kale, S. A. Rasal, [2015] in this paper study four different shapes of same area multistory model is generated & tested by the ETABS under the guideline of IS-875-Part3 & IS1893-2002-Part1. The behavior of 15, 30 & 45 story building has been studied. The Dynamic effects also find by Response spectrum method. All the parameters like Story displacement, Story drift, Base shear, Overturning moments, and Acceleration & Time period are calculated. After comparing the all building shape results we can conclude that which section is convenient & either seismic or wind effect is critical.

Ashwini S Gudur, Prof. H S Vidyandhar, [2016], In this paper author take six models of building heaving 25 story is considered having 8 bays in X and Y direction with plan dimension 40X40m and story height 3.5m. The building is kept symmetric in both direction are analyzed as special moment resisting frame using equivalent static analysis and dynamic response spectrum analysis. In model first bare frame model without bracings however masses of infill walls are included in the model. In second bare frame model with V bracings. In third model full infill model without bracings. In fourth model full in fill model with V bracings. In fifth model building has one gull brick infill masonry wall in all stores without bracing with ground soft story. As in sixth building has one full brick infill masonry wall in all stores with V bracing with ground soft story.

Priyanka Soni, Purushottam Lal Tamrakar, Vikky Kumhar,[2016], studied and analyzed of various research works involved in enhancement of shear walls and their behavior towards lateral loads. As shear walls resists major portions of lateral loads in the lower portion of the buildings and the frame supports the lateral loads in the upper portions of building which is suited for soft story high rise building, building which are similar in nature constructed in India, As in India base floors are used for parking and garages or officers and upper floors are used for residential purposes. Shear walls are structural systems which provide stability to structures from lateral loads like wind, seismic loads. These structural systems are constructed by reinforced concrete, plywood/timber unreinforced masonry, reinforced masonry at which these systems are sub divided into coupled shear walls, shear wall frames, shear panels and staggered walls.

Shaikh Muffassir, L.G. Kalurkar [2016], in this study total fifteen no. Of building model are prepared and analysis for wind wind load by using ETABS. 2015. The wind is performed for different height such as 20m, 50m, and 80m In addition, comparative study concludes that the composite structure are larger ductile and more susceptible as compare to RCC structure and the composite option is better than RCC multistory building. In addition the comparison of different configuration shows that the response of parameter such as displacement, story stiffness base reaction and the time pried under effect of wind.

S. Elias , R. Rupakhety , and S. Olafsson,[2016], Is study presents analysis of a benchmark building installed with tuned mass dampers (TMDs) while subjected to wind and earthquake loads. Different TMD schemes are applied to reduce dynamic responses of the building under seismic load.

Mahesh Ram Patel, R.C. Singh [2017] the effect of wind velocity and structural response of building frame on sloping ground has been studied. Considering various frame geometries. Combination of static and wind loads are considered. For combination, 10 cases in different wind zones are analyzed. STAAD-Pro v8i software has been used for analysis purpose. Results are collected in terms of axial force, Shear force, moment, Storey-wise drift and Displacement which are critically analyzed to quantify the effects of various heights of structure.

Nicola Longarini,1 Luigi Cabras,2 Marco Zucca,1 Suvash Chapain,3and Aly Mousaad Aly,[2017] In this paper structural improvements for tall buildings under wind loads comparative study heas been done on the basis of this analysis the behavior of a very slender building is investigated under wind load to satisfy both strength and serviceability design criteria. In this two procedures (i) pressure integration method (PIM) with finite element modeling, and (ii) high frequency force balance (HFFB) technique are used. The lift area and around the major stress plate parts.

Sonali Pandey, Dr.Krishna Murari, Ashish Pathak, Chandan Kumar, [2017], in this paper aimed to study the various research works done for improving the performance of shear wall and locating its best position in a building. Shear walls have proved to be very successful in resisting strong earthquake so far.

Vikrant Trivedi-1, Sumit Pahwa,[2018], This study focuses on static and dynamic analysis of a 20 story buildings by using STAAD-pro Vi8 under wind load to improve integrity and stability of structure.

Md Ahesan Md Hameed Amit Yennawar [2018] this paper is to understand provision of international stander and compare them with Indian stander. In this paper a comparative study of wind load analysis of RC building using three different codes is done is done as per IS875 (part 3):1987, IS875(part 3):2015,ASCE 7-05, and AS\NZS 1170(part 2)-2011. Wind loads are determined based on gust factor method and critical gust loads are calculated.

Reşitpaşa Mahallesi, Katar Caddesi, Teknokent ,[2018], This paper,present a novel approach for easily developing mechanical models of buildings integrated with friction dampers to simplify their numerical simulation, and using the developed approach, friction damper-based passive control and then mass driver-based robust active vibration control strategies are applied on a seismically excited, three-story building simulation model, and the results are compared to assess the vibration attenuation level achieved by the passive control approach. The simulation results reveal that displacement and acceleration response reductions in active control are, in general, better than those in passive control but the difference is not that big. These findings, hence, encourage strongly the use of friction damper-based passive vibration control mechanisms as strong alternatives to active control methods in structural protection against earthquakes.

Mr.Madhu sudhan rao.kondapalli, [2018], this study aims at comparing various parameters such as storey drift, storey shear and storey displacement of a building under lateral loads based on strategic positioning of shear walls. Linear static analysis has been adopted in this paper. The software used is ETABS.

Aiswaria G.R., Dr. Jisha S.V. [2018] analyzed the effect of across and along wind loads acting on tall building as per IS 875 (Part-3):2015 located in terrain category IV, height varying from 90 m to 240 m by considering the effect of interference. From this study, maximum base shears and base moments induced by across and along wind loads were compared to compute the governing wind load component acting on tall RC framed building. Results shows that the in case of long body orientation for upto the height of 150 effect of along wind force is governing while for short body orientation across wind force is governing for all the buildings.

Mariyam1 , Sagar Jamle, [2019], In this paper Wind Analysis over Multistory Building Having Flat Slab-Shear Wall Interaction for this the different parameters should be checked as per the selection of different model cases Model case M1-Simple Flat slab model building with shear wall around the lift area. Model case M2-Simple Flat slab model building with shear wall around the lift area and around the major stress plate parts. Model caseM3- Flat slab added drop mode building with shear wall around the lift area. Model case M4- Flat slab added drop model building with shear wall around

Mohd Ismail Zabeeh, S. M. Hashmi, [2020], this paper Study on Seismic and Gust Wind Effects on G+30 Residential Mivan Structure Using Different Stiffness Modifiers for Structural and Non Structural Walls. Structures should be designed such that they can resist seismic tremor and wind gust effects actuated deflections and internal forces. Structural stiffness modifiers are important factors which gives the behavior of structure after cracking due seismic or wind forces on the structures. In this study, impacts of Stiffness Modifiers on structures, drifts, displacement, modal mass participation, time period, frequency are examined. Building models, which have same number of floors with different stiffness modifiers as per codal provision of IS 16700- 2017 are produced by a FEM PC program and calculations are made. Results are compared and safeguards are given with avoid harms caused by Stiffness Modifiers under seismic tremor loads are analyzed.

Fatemeh Rahimi, Reza Aghayari, Bijan Samali [,2020], This paper presents a active, passive, semi-active and hybrid control systems of TMD used for preserving structures against forces induced by earthquake or wind, and provides a comparison of their efficiency, and comparative advantages and disadvantages. Despite the importance and recent advancement in this field, previous review studies have only focused on either passive or active TMDs. Hence this review Covers the theoretical background of all types of TMDs and discusses the structural, analytical, practical differences and the economic aspects of their application in structural control

Ubair Gul Khan Mirza Aamir Baig, [2020], This paper presents an outline of cutting-edge measures to lessen basic reaction of tall structures, including a conversation of assistant damping gadgets for moderating the seismic tremor and wind-initiated movement of structures. To guarantee the useful execution of tall structures, different plan adjustments are conceivable, running from elective auxiliary frameworks to the use of aloof and dynamic control gadgets. Latent tuned mass damper (TMD) is broadly used to control auxiliary vibration under wind load yet its viability to lessen tremor-initiated vibration is a developing procedure.

V. CONCLUSIONS

On The basis of above study There are many technologies which is used to reduce wind effect on tall building with help of dampers previously, much work has been done with or without dampers and also with shear wall but there are more types to reduce wind pressure on tall building. There are some evaluation needs to be done on various responses of structure, which are described as follow:-

- Comparison of more than two damper in RC building under wind load.
- Check TMD & FD in RC building under wind load with calculation of gust factor.
- Checking optimum location of TMD in RC building.
- Applying more than one damper in a single building under wind load.

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