Investigating the Applicability of Inertial Amplification Mechanism - Tuned Mass Damper in MDOF Structure

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***Abstract* - The technologies for seismic response reduction have been developing for years. In past few decades the studies over dampers have achieved much pace and thus the effectiveness and the capability of dampers have improved accordingly. An inertial amplification mechanism (IAM) is a developing one in the field of seismic dampers. An IAM make use of the inertia of a mass to dissipate energy from a system. The mechanism cut the energy of a moving or vibrating system down in each cycle of movement. This work looked into the applicability of an IAM as an additional damper along with a conventional tuned mass damper (TMD) in a high-rise building, here the whole mechanism was named as IAM-TMD. A comparative study of a building; without dampers, with TMD, and with multi degree of freedom IAM-TMD have been made as part of this work.**

***Index Terms* - Damper, Inertia**

I.INTRODUCTION

An earthquake is the shaking of Earth surface resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves. This in fact can affect the buildings stability depending upon the intensity of earthquake, earthquakes are natural vibrations of the ground which cannot be controlled by humans but its impact on structures can be controlled by incorporating various techniques while design and construction. During earthquakes, the buildings are terrifically affected by the vibrations of underlying soil layers. The seismic response of building cause disturbance to normal life, functionality of structure and safety of public. Here comes the relevance of seismic dampers, which is a device operates mechanically to dissipate the kinetic energy of seismic waves entering a building structure. The design of various techniques to suppress the seismic vibration depends upon several parameters related to the structure and area of construction like zone of seismicity, height of the building, importance factor, mass etc.

TMD is a commonly used seismic damper in skyscrapers. TMD is preferred to place where deflection is more. The frequency of damper is tuned to a particular structural frequency so that when that frequency gets excited, damper will resonate out of phase with the structural motion. It consists of a mass which is supported by springs or strings. Tuned mass dampers are used to reduce the maximum amplitude of the object while weighing very much less than it. But TMD does not always gives the expected outcome, so enhancing the performance of TMD by coupling any other mechanism becomes a research area.

IAM-TMD is an efflorescing one in the field of seismic dampers. Past studies reveal that IAM coupled with TMD is effective in mitigating the vibrations in TMD as well as building by dissipating energy quickly. IAM enhancing the performance of TMD in buildings. From the proposals till now IAM or either called as inerter, which is a non-elastic system made by joining steel bars, and an appropriate mass/ weight is placed in the linked structure. The whole system is responsible for dissipating energy from the TMD and building by their relative motion during earthquake. Adding more mass to the system will increase inertia but it will ultimately result in the failure of springs supporting TMD, hence in IAM a series of mass is added and when the TMD and building oscillates it have to deform and reform the linked system that is IAM connected in between them. Since it is a non-elastic structure, for the deformation and reformation TMD and building have to spend more energy hence kinetic Investigating the applicability of inertial amplification mechanism tuned mass damper in MDOF structures energy loss equivalent to the Inertial force of the IAM get dissipated. There by the whole system attains equilibrium as soon as possible. But it accounts only the single degree of freedom structures. The current study aims to identify the applicability of IAM-TMD in a multi degree of freedom structure through a comparative study.

II. MATERIALS AND METHODS

This project compares the seismic response of building in 3 stages. Three stages in the execution of project are Seismic response of building under consideration, Seismic response of building with TMD and Seismic response of building with modified IAM-TMD. Code books used for reference are IS 456:2000, IS 800:2007, IS 1893:2016, and IS 875:1987. Parameters chosen for analysis are storey drift and storey displacement. Selected study Location is seismic zone III, Kerala comes under this zone. Study Duration is November 2020 to June 2021.

III. METHODOLOGY

This work focuses on the comparison of the seismic response of building in three different conditions, i.e., building without damper, building with TMD, and building with multi degree of freedom IAM-TMD. The parameters chosen for the analysis and comparison are stroey drift and storey displacement. Storey drift is the lateral displacement of one storey relative to the storey above or below. Storey displacement is the total displacement of any storey with respect to ground.

a. Building without damper

A thirty-one storied framed building having plan dimensions 30 m × 30 m is taken for the analysis. The cross-section of framed elements are, 0.23 m × 0.5 m for beams and 0.3 m × 0.75 m for columns respectively. The seismic zone III is selected for the analysis. In India, seismic zone III comprises of Kerala, Goa, Tamil Nadu, Lakshadweep Island, remaining parts of Uttar Pradesh, Gujarat and West Bengal, parts of Punjab, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Odisha, Jharkhand, Chhattisgarh, Madhya Pradesh and Bihar. The seismic response of building is analysed in terms of storey drift and storey displacement.

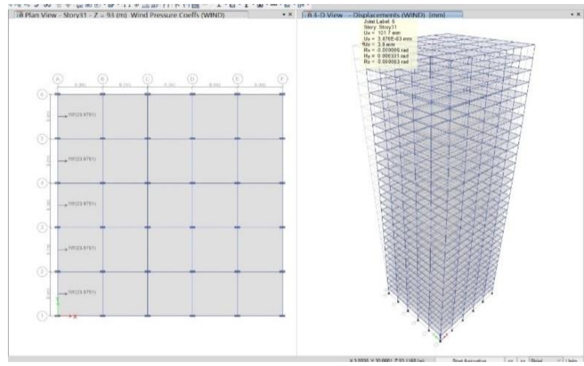

Fig. 1. Plan and 3D View of Building

b. Building with Tuned Mass Damper (TMD)

TMD as a welded steel structure hanging by using springs from the thirty first floor of the building taken for the analysis. The values obtained are, Mass of steel work= 4.4x 10^5 kg Stiffness of springs= 3960.86 N/m Coefficient of damping= 8857.44 The storey drift and storey displacement of building with TMD is taken for the comparative study.

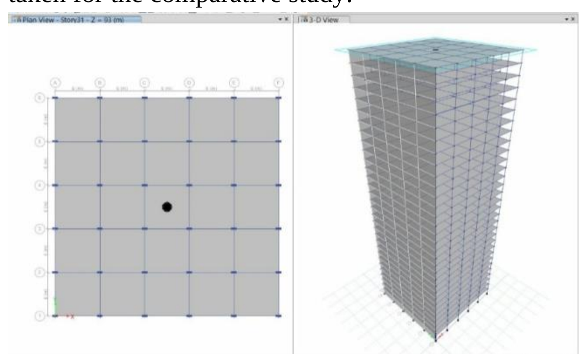

Fig. 2. Plan and 3D View of Building with TMD

c. Building with Inertial Amplification Mechanism-Tuned Mass Damper (IAM-TMD)

This paper proposes an IAM system which having multi degrees of freedom. Two links are connected by using hinged joints in between TMD and columns of building. First link makes an acute angle with horizontal plane as well as vertical plane, whereas the second link creates an angle only with the vertical plane. The links itself provides mass for attaining inertia. Totally four links are made in the similar manner. Here we assumed a Fe500 HYSD bar having diameter of 50 mm, hence the total weight of one set of links is 839.18 N.Storey drift and storey displacement of building with IAM-TMD is taken for investigating its feasibility in a high-rise building

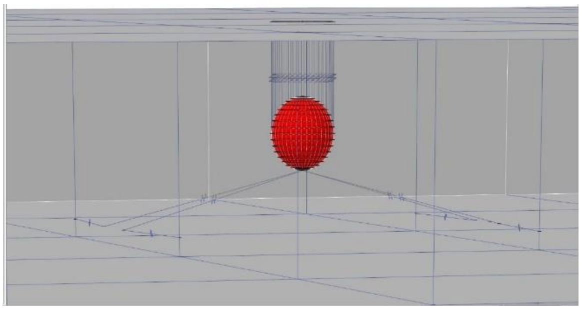

Fig. 3. 3D View of IAM-TMD

IV. RESULTS AND DISCUSSIONS

Analysis and comparison are made on the parameters storey displacement and storey drift obtained for building without damper, building with TMD and building with multi degree of freedom IAM-TMD.

While analysing the building without damper, storey drift increases from the bottom storey and it reaches a maximum value 0.034025 between storey 3 and storey 5. Then it starts decreases slowly till it reaches the top story. And the displacement increases gradually from the bottom storey to a maximum value of 267.016 at the 31st storey. So, the structure may get destructed due to earthquake loads.

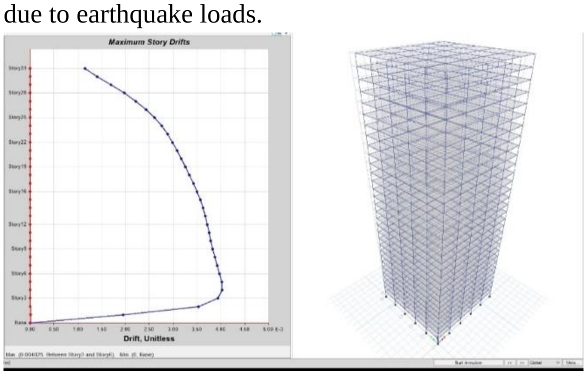

Fig. 4. Maximum Storey Drift of Building Without Damper

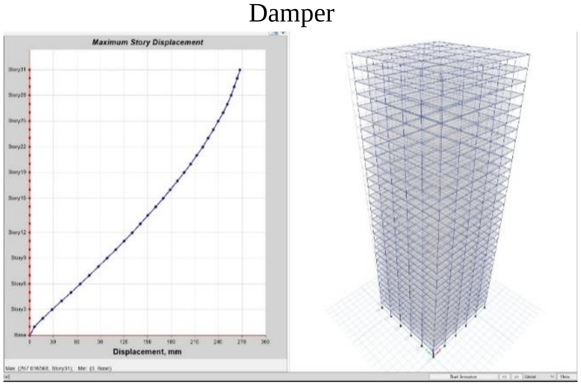

Fig. 5. Maximum Storey Displacement of Building Without Damper

TMD is an effective damper which reduces the seismic response of the building. It is tuned to a particular natural frequency of building resting on seismic zone III. While analysing the building with TMD, the storey drift is negligible and its value 0.150E-8. But there is a sudden displacement of maximum value 3.123E+15 at the top storey. So, when applying TMD to the building, the building can resist seismic waves. The displacement observed at the 31st storey is due to the movement of the absorber. Which is not harmful to the building, since the TMD is effective in reducing the storey drift to zero.

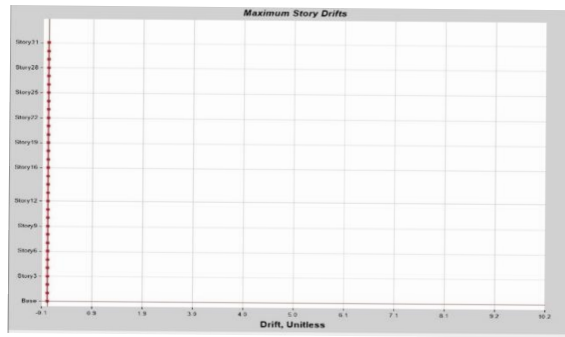

Fig. 6. Maximum Storey Drift of Building With TMD

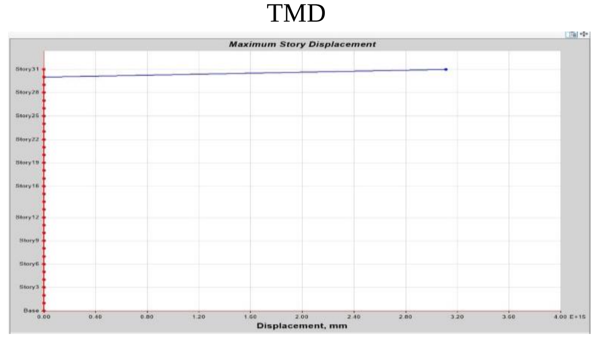

Fig. 7. Maximum Storey Displacement of Building With TMD

In order to reduce displacement, provide IAM to the system. While analyzing the building with IAM-TMD, it is observed that the storey drift is slightly increases from the bottom storey and it becomes maximum of 0.00165 in between first and second storey and then it reduces gradually to a value of 0.0003 at top storey. And the storey displacement increases from the bottom storey to 16th storey and it reduces to a minimum value then there is a sudden displacement after 28th storey and it reaches a maximum value of 0.033713 at top storey. While comparing with the displacement of building with TMD, here the storey displacement is lesser, but the storey drift has a slight increment.

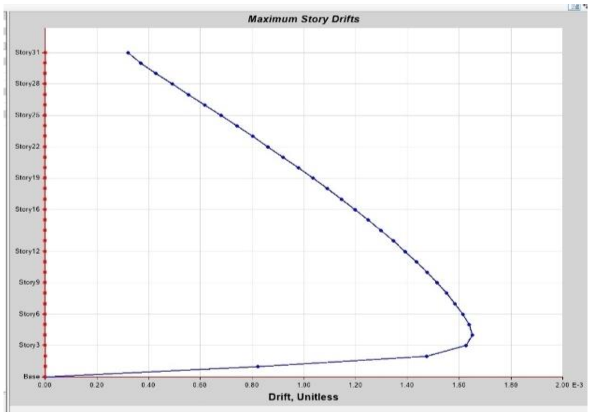

Fig 8. Maximum storey drift of building with IAM-TMD

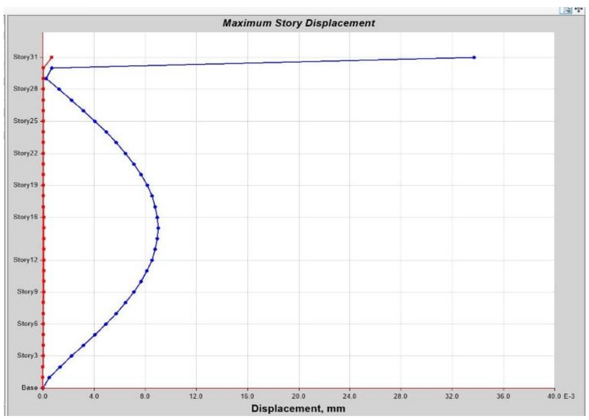

Fig 9. Maximum storey displacement of building with IAM-TMD

V. CONCLUSION

On analysing storey drift and storey displacement of building without damper, building with TMD, and building with IAM-TMD, both TMD and IAM- TMD are effective in reducing building's seismic response in terms of storey drift IAM is effective in reducing the displacement due to movement of TMD in the 31st storey. Drift is minimum while using TMD as compared to IAM. From the Results it can be concluded that when using the TMD, the response of primary structure is suppressed, but the responses of the absorber are relatively large. When using IAM-TMD the dynamic response of TMD is suppressed, and a slight increase in storey drift as compared to that in TMD occurs. The study reveals that IAM is efficient in mitigating the dynamic response of both the primary structure and absorber at the same time if it designed properly. The multi degree of freedom IAM-TMD model is feasible in multi degree of freedom structures like high rise buildings. Future studies are required for establishing IAM-TMD with maximum efficiency. The concept of IAM-TMD is elaborating day by day through the studies, researches etc. IAM-TMD is a newborn in the field of seismic dampers. This would be one of the greatest findings in future.

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