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A Review on Effect of Actual Site Specific Response Analysis of Tall Building with Viscous Damper

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Abstract: This paper deals with a state of art review onsite-specific ground response analysis of tall building with viscous dampers. Earthquakes are natural hazards under which disasters are mainly caused by damage or collapse of buildings and other man-made structures. During an earthquake, seismic waves radiate away from the source and reach the ground on which these seismic waves produce shaking. The surface ground shaking causes severe damage to the structures, which depends on characteristic of subsurface soil. Therefore for a realistic design of earthquake resistant structures site-specific detailed investigation is necessary. Site specific response spectra are developed using ProSHAKE software.

The site specific response spectra are used to evaluate response of tall building frame structures with viscous dampers using ETABS software. Using viscous dampers to dissipate energy and reduce building response to dynamic inputs is gaining worldwide acceptance. The use of supplemental damping to control structural deformations and forces due to seismic ground motions has been demonstrated in overseas applications to be a very effective means of improving building performance. The combination of structural frames with energy dissipation provided by Viscous Dampers (VD) is a surprisingly cost efficient means to achieving Low Damage Design (LDD) that is effective at both serviceability and ultimate limit states. This paper presents an application of viscous dampers in a tall structure to suppress the anticipated earthquake induced accelerations. The viscous damper system proves to be a very cost-effective method to reduce earthquake and wind motions.

Keywords: Site Specific Response, Viscous Dampers, Proshake, Low Damage Design.

I. INTRODUCTION

Past earthquake have given significant evidence that amplification of seismic waves transfer large acceleration to structure and cause destruction particularly when the resulting seismic wave frequency matches with the resonant frequencies ofthe structures. Amplification of groundmotion is highly dependent on local geological, topographical and geotechnical condition, therefore it is essential to perform site specific ground response analysis.

The estimation of strong-motion characteristics is important for engineering design. Such characteristic includes peak ground acceleration and spectral ordinates. The main input in engineering design are loading conditions which must satisfy certain conditions regarding their level and frequency of occurrence during the lifetime of a structure. Loading conditions appropriate for a particular type of structure are expressed in terms of ground motion in the frequency or time domains.

II. SITE SPECIFIC GROUND RESPONSE ANALYSIS

Site specific ground response analysis is required to determine the response of a soil deposit to the motion of the bedrock immediate below the soil. It also determines the effect of local soil conditions on amplification of seismic waves and hence estimating the ground response spectra for future design purposes.

The term site specific is used because as the seismic waves travel from bedrock to the surface, the soil deposits that they pass through change certain characteristics of the waves, such as amplitude and frequency content. Soft deposits of soil amplify (increase) certain frequencies of ground motion thereby increasing earthquake damage. Thus local soil conditions have significant role on amplification of seismic waves. This amplification can be measured by performing ground response analysis which refers to the determination of the response of the soil to the motion of the bedrock below the soil. This response of a soil is dependent on the frequency of the ground motion and the geometry and material properties of the soil layer above the bed rock.

The phenomenon where the local soil acts as a filter and modifies the ground motions characteristic is known as soil amplification problem. Soil amplification transfers large accelerations to structures and causes destruction particularly when the resulting seismic wave frequency matches with the resonant frequencies of the structures.

According to the site location, it is necessary to know the local soil conditions and topographic conditions. Depending on the subsurface characteristics, seismic waves might undergo amplification and create more severe strong ground motions at the surface.

The seismic hazard is assessed by means of expected ground response of the seismic waves for a given earthquake for a specific site. As the local site has significant effect on seismic waves, "Site Specific Ground Response" is important aspect for earthquake resistant design of structure.

III. VISCOUS DAMPERS FOR TALL BUILDING

Structural control systems increase the energy dissipation capacity of structures during an earthquake by convertingmechanical energy into heat energy. Different kinds of dampers systems are:Tuned Mass Dampers (TMDs), Tuned Liquid Mass Dampers (TLDs), Friction Dampers, Metallic Dampers,Viscous Dampers,Elasto Plastic Damper used. But here Viscous Dampers are used for tall building seismic analysis.

Viscous dampers (VD) have been used in the last 30 years in major civil structures to mitigate the effects of earthquakes. Their use in high-rise buildings built in seismic areas is a challenge for the designers, since they should reduce the vibrations induced by both strong winds and earthquakes, and the optimal behavior in these two situations is not usually the same. Consequently, the design requirement for VD to be used in high-rise buildings is often that they should have two different behaviors in the different range of velocities corresponding to wind and earthquake.

Viscous dampers operate on the principle of fluid flow through orifices. A stainless steel piston travels through chambers that are filled with silicone oil. The silicone oil is inert, non flammable, non toxic and stable for extremely long periods of time. The pressure difference between the two chambers cause silicone oil to flow through an orifice in the piston head and input energy is transformed into heat, which dissipates into the atmosphere.

Fluid viscous dampers can operate over temperature fluctuations ranging from -40°C to + 70°C.

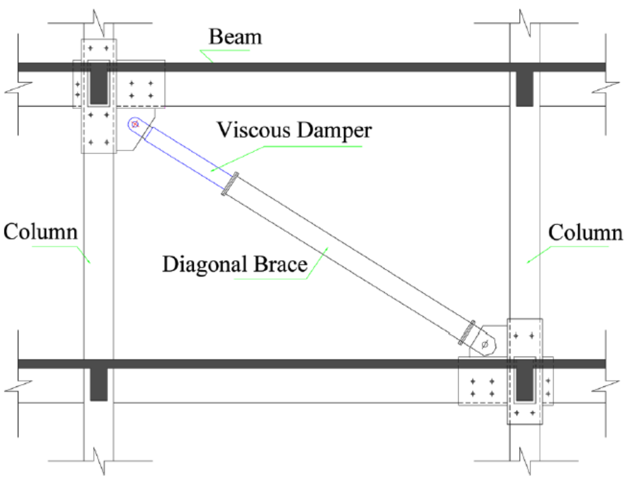

Figure 1: Viscous Damper

The damper decreases the response of a structure by adding energy dissipation to a structure, which significantly reduces response to any vibration or shock inputs. The absence of storage stiffness makes the natural frequency of a structure incorporated with the damper remain the same. This advantage will simplify the design procedure for a structure with supplemental viscous dampers.

IV. LITERATURE REVIEW

Various literatures have been referred for site specific response spectrum analysis and viscous damper for tall building brief review of literature is discussed below.

A. Site Specific Ground Response Analysis

L. GovindaRaju, G. V. Ramana, C. HanumanthaRao and T. G. Sitharam [1] review of various aspects of site-specific ground response analysis including its engineering importance, difficulties involved in conducting a complete ground response study and also the justification for widely used one-dimensional ground response analysis is highlighted. A case study on the ground response analysis in terms of settlement of soil deposit and soil amplification of a site close to Sabarmati river belt in Ahmedabad City during the earthquake in Bhuj on 26 January 2001 is presented. The soil conditions at the selected location represent deep alluvial deposits with partially saturated condition indicating very remote chances for occurrence of liquefaction. The ground surface settlement associated with the ground shaking alone is insignificant. The high degree of damage to multistory buildings is essentially due to the transfer of large accelerations to high rise buildings by soil amplification. Further, close matching of resulting wave frequencies with the resonant frequencies of the high rise structures is an added factor for their collapse. The 'seismic coefficient method' currently recommended by Bureau of Indian Standards Code is inadequate in dealing with the design of geotechnical structures and hence a performance-based design becomes imperative. There is a need to include guidelines on conducting ground response analysis in the case of geotechnical structures in the current IS Code.

Duhee Park and Youssef M.A. Hashash [2] Highlights the relevance of the compatibility between frequencies at which dynamic soil properties are measured and their use in site response analysis.

In laboratory tests show that the rate of loading alters the behavior of cohesive soils, with both shear modulus and damping ratio increasing with an increase in the rate of loading. A series of modified equivalent linear analyses were performed to characterize the effect of the rate-dependent soil behavior on site response analysis. The results indicate that the rate-dependent nature of the shear modulus has a limited influence on propagation of the seismic waves. However, the rate-dependent damping ratio has a more pronounced influence on characteristics of the propagated motion, filtering out high-frequency components due to the higher damping ratio at high rate of loading. The effect becomes relevant when propagating a motion with a significant high-frequency content and low in amplitude. If the soil curves are obtained at low frequencies, as in the torsional shear test, the effect of the rate dependency is pronounced. However, when using dynamic curves obtained at high frequencies, as in the resonant column test, the effect of the rate dependent soil behavior is less pronounced. Overall, the effect of the rate-dependent soil behavior is relatively limited, resulting in up to 20% difference in the computed response for very weak ground motions, but for most ground motions the effect of the rate dependency is within 10% of that from the rate-independent analyses.

Chi-Chin Tsai and Chun-Wei Chen [3] study performs a series of site response analyses that consider different input motions, intensities of input motion, depths of soil columns, and nonlinear properties.

The main conclusions are as follows.

1. The two approaches exhibit more differences for shallow soil columns and less for deep soil columns, which contradicts the general concept that time domain -nonlinear analysis is required for deep soil columns.

2. The PGA plots reveal more significant differences. SA at 0.2 s exhibits an intermediate difference, whereas SA at 1.0 s exhibits less difference. Engineers should be cautious when selecting an analysis approach that depends on the range of interest of the period.

3.No clear threshold peak ground acceleration that causes the nonlinear result to deviate from that of equivalent linear is found. The relative difference increases as the intensity of input motion increases. For the PGA case, the threshold PGA of input motion is 0.2 g for shallow soil columns and 0.4 g for deep soil columns, given that 20% of relative difference is acceptable. For the 0.2 s SA case, 0.2 g is probably the threshold for shallow cases. For the 1.0 s SA, the relative difference is within 20%.

4. The nonlinear results are higher than the equivalent linear results between the periods of 0.1 s and 0.3 when more nonlinear soil properties are used. Therefore, if a site mostly consists of highly nonlinear soil, then the result of the equivalent linear analysis can underestimate ground response in a short period range.

5. SF by nonlinear exhibits more nonlinearity than that by equivalent linear, particularly for Fv because equivalent linear adopts an averaged module, whereas nonlinear actually models nonlinear behavior.

Anbazhagan P, Sitharam T.G and Divya C [4] Investigations have been carried out at a site in Bangalore opposite to international airport. The observed "N" value is corrected following general seismic "N" correction procedures. Multichannel analysis of surface waves (MASW) with SurfSeis has been used to calculate the shear wave velocity of soil profile in all the SPT locations. SHAKE2000 1D equivalent linear ground response analysis software has been used to determine the site specific response of the soil column by using SPT and MASW data separately. Response spectrum obtained from SHAKE2000 matches well with the shape of the spectral acceleration coefficient presented in IS1983, 2002 and uniform hazard spectrum. The obtained SHAKE2000 results from the both methods are compared. Relation between Gmax with corrected "N" value (N60) has been generated.

B. Viscous Damper for Tall Building

J.D. Pettinga1, S. Oliver2 and T.E. Kelly [1] Studied that to the use of viscous damping to control and improve building performance has been well demonstrated by numerous researchers and designers internationally. With the move towards Low Damage Design of structures in New Zealand, the combination of essentially elastic seismic resisting frames and fluid viscous dampers provide an opportunity to accurately achieve a high level of performance at multiple limit states, and for a wide range of building forms. This paper has summarized a practical design approach that takes a step towards true performance-based design. A simple three storey moment frame example has been included todemonstrate the method, with results that clearly identify the benefits of supplemental viscous damping in terms of controlling drifts and accelerations in the building.

Yongqi Chen, Tiezhu Cao, Liangzhe Ma And Chaoying Luo [2] Analysed the

1. Add Fluid Viscous Dampers to the bracing system can have an importan effect to reduce the overall seismic responses, including the inter-story displacement, the top displacement and acceleration, the base shear force and moment, the torsion of the structure, and the response of the secondary system.

2.The located dampers can play important role in reducing the located response, i.e. four dampers can reduce the top acceleration on the top cantilever truss obviously.

3. The damper's system of Pangu Plaza not only have significant effect for reducing seismic response, but also can save one-time investment and longtime maintenance cost.

Samuele Infanti, Jamieson Robinson, Rob Smith [3] Described the two examples that viscous dampers can be effectively used in different configurations to reduce the response of high-rise buildings to wind and earthquake.The addition of VDs, alongside the use of performance based seismic design, on the St Francis

Towers has also enabled a reduced superstructure, making a net saving on the structure of approximately $4 Millions of USD. Furthermore, it is interesting to note that the Taipei 101 TMD has already been put into operation by earthquakes in March 2005 and May 2008 (Sichuan Earthquake) and by many strong typhoons (especially throughout an active typhoon season in mid to late 2005). During some of these events, building performance data was obtained via the on-site monitoring system, and the TMD was observed to behave as the design intended. Some occupants of the tower who were present during many of the typhoons have commented that the building motion was barely perceptible with the TMD in operation.

P.P. Diotallevi1, L. Landi2 and A. Dellavalle [4] Introduced the supplemental damping ratio, due to the presence of the non-linear viscous dampers, can be assessed by a direct procedure. To this purpose a new dimensionless parameter, ε, has been proposed. The cases of study have shown that the direct procedure proposed leads to results very close to the ones obtained by the iterative procedure reported in literature. In order to get the direct procedure easily usable by structural designers, a method for defining the spectra of supplemental damping ratio for known values of α and ε on the basis of spectra provided by seismic codes has been proposed.

V. FUTURE SCOPE

- Site specific response analysis can be carried out for other important structures such as bridges, dams and industrial structures.
- Case study of real life problems can be studied in nonlinear domain considering site specific response spectrum.
- Seismic Capacity Evaluation of R.C Framed buildings can be carried out using Site Specific Response Spectra of different sites.
- Extended to study the effect of site specific response analysisIn place of concrete structure, steel and composite structural system can be studied.

CONCLUSION

- Site-specific ground motions analysis should simulate the controlling seismic events in amplitude, frequency distribution, and duration.
- Local sub-soillayers of varying characteristicshave considerable effects on acceleration timehistories on ground and response spectrum.
- Site factors developed empirically for weak to strong ground motion levels nonlinear (NL) is found to be better in capturing soil nonlinear behavior in site response analysis.
- The addition of a fluid viscous damping system in tall building resulted in a significant reduction in vibrations, deflection and floor accelerations were reduced by approximately 35%.
- The viscous damping system proved as a very cost effective method to effectively reduce earthquake and wind induced vibrations. For large force output at very low displacement, a motion amplification device has been included in the design in order to reduce the quantity and cost of the dampers.

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