Improvement The Seismic Behavior Of Existing Steel Structures In Iran By TADAS Damper Modern Technology

Yousef Shirnejad , Gradutae Student of Structural Engineering , Islamic Azad University Dezfoul Branch,Dezfoul,Iran,Yousef-shirnejad@hotmail.com

Panam Zarfam ,Ph.d Research Affiliate,Civil Engineering Department , Sharif University of Technology,Tehran,Iran,Iran,Pzarfam@gmail.com

Reza Tajalifard ,Gradutae Student of Structural Engineering , Islamic Azad University Dezfoul Branch,Dezfoul,Iran,R-tajallifard@Yahoo.com

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Abstract

Strong earthquakes induce high amount of energy to the affected structures. If this energy can be controlled and dissipated in a manner independent of the structural components, the seismic performance and response of the structure will be substantially improved. This objective can be achieved by using passive control of the structures such as Tadas damper or base isolation techniques. This study presents the analysis of building structures equipped with TADAS system and subjected to strong earthquake excitation. In this study, the effect of the using of Tadas Damper for improving the seismic performance of an existing 9- story steel structure in Iran has been investigated by nonlinear dynamic analyses. The analysis was carried out by considering several nonlinear dynamic analysis . In nonlinear dynamic analyses, the response of the structure to seven scaled earthquake records matched to the design spectrum has been obtained. Initially, static analysis of the structure has been performed and the results such as stress state are stored as initial condition then structure was analyzed under earthquake vibration. In order to demonstrate the effect of TADAS damper system in the structures, an attempt has been made to compare its structural response in terms of story drift and base shear , displacement and dissipated energy in the structural members with and without TADAS damper. It was observed that structure equipped with TADAS damper system, have the potential to improve the seismic behavior of full-scale civil structures.

Key words: Dissipated Energy , Modern Technology , Nonlinear Dynamic Analysis , Seismic Rehabilitation, TADAS Damper

1.Introduction

Development and subsequent implementation of modern protective systems, including those involve passive energy dissipation the entire structural engineering discipline is now undergoing major changes. The control of structural vibrations induced by earthquake or wind excitation can be done by various means such as modifying rigidities, masses, damping, or shape and also the ductile structure is capable of absorbing forces. In general, structural control devices can be divided into 3 classes: passive control, active control and semi-active control [1]. An active control device is defined as a system which typically requires a large power source for operation of actuators which supply control forces to the structure. A semiactive control system is similar to the active control systems but the external energy requirements are orders of magnitude smaller than typical active control systems [1,3]. A passive control system is defined as a system which does not requires an external power source for vibration response.

2.The PassiveControl System

Passive energy dissipation systems for seismic applications have been starting with base isolation for low-rise buildings and number of implementation increase in passive damper control. Passive damper control have been widely adopted to reduce dynamic response due to minimal maintenance requirements also the cost of installment damper devices is about 1% of the overall cost of the structural frame. Various types of manufactured dampers are available which based on level of stiffness, damping and variety of materials. These include viscous fluid, viscoelastic, friction and metallic yield dampers and etc [2]. Serious efforts have been undertaken to expand the concept of energy dissipation or supplemental damping into workable equipment and a number of these devices have been installed in structures throughout the world.

3.TADAS Damper

Among passive energy dissipation systems, metallic dampers have some advantages: no complicated technology is needed to manufacture them, they can easily be integrated in structures, and they show stable behavior in earthquakes and no environmental (temperature, humidity, etc.) factors affect their performance. These dampers, increase damping and stiffness of structures and increase energy dissipation capacity in them. Adding metallic dampers to the structures can cause concentration of energy dissipation in the dampers. After earthquakes,dampers can easily be replaced for strengthening structure for future earthquakes. Using steel plates for absorbing and dissipating energy was first used exclusively in nuclear installation [1]. Kelly et al. 1972, tested X-shaped energy dissipaters in a 3-storey building on the earthquake simulator at the University of California at Berkeley [4]. Whittaker et al. 1989, at University of California at Berkeley, conducted a more elaborated test [7]. Xia et al. 1992, studied various aspects of X-shaped (ADAS) dampers by numerical simulations [8]. Tsai et al. 1993, have conducted some numerical and laboratory tests on TADAS dampers [5].

One of most effective mechanisms for dissipating input energy to the structure during an earthquake is on-elastic deformation of metals. During earthquakes, the inter-story drifts cause movement of the upper end of TADAS damper relative to the lower end. This causes yielding of metallic plates of the damper and as a result, the energy is dissipated. Fig (1) show the behavior of TADAS damper during earthquake .

The load-deformation curve in shear of the TADAS damper can be idealized as an elastic-perfectly plastic curve (Fig (2-a)), or as a bilinear one with strain hardening (Fig (2-b)) [7]. In this paper,a bilinear curve (with strain hardening of 5%) is used.

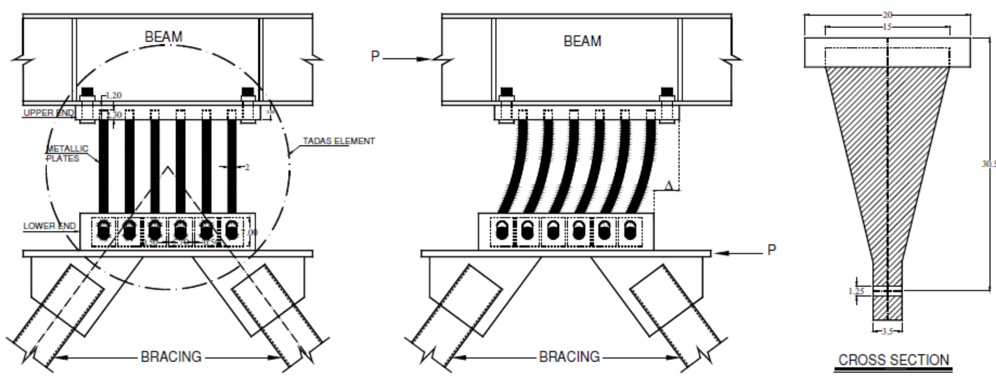


Fig 1: The behavior of TADAS damper during earthquake

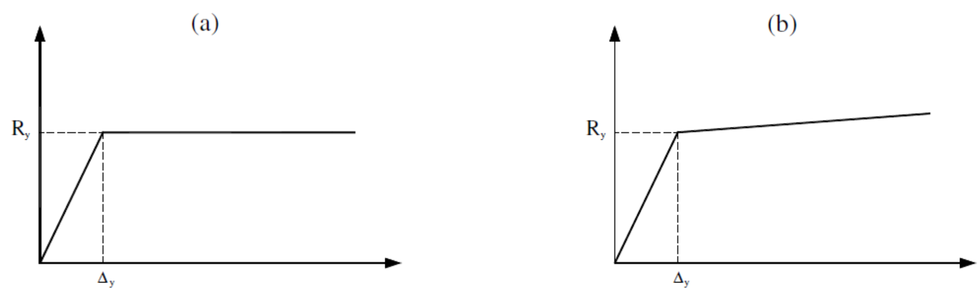


Fig 2: Proposed load-deformation for TADAS damper
a) Elastic-perfectly plastic curve, b) Bilinear curve with strain hardening

4.Introduction Of The Investigated Structure

The investigated existing structure in this research is a nine story steel building located in Shiraz-Iran.In Figure 3 the plan of the structure is presented. The structure In the Y direction consists of four spans of 4m .Connections in this direction are of a specific type which was prevalent in Iran in the past (1960-1990). In this type of connection, which is known as the saddle or the bypass connection, the beams directly pass in pairs from the both edges of column and they are connected to the columns by means of angles at top and bottom. Previous researches on the behavior of these connections indicate that these type of connections act like semi-rigid connections that are continuous over the node of the connection. A bilinear moment-rotation model can be used for this connection. The plastic moment and rotational stiffness of the connection can be calculated with regard to the depth of the beams and the length of the connection angles. The saddle connections in this structure include angles at the top and the bottom of the size L120x20mm with the length of 35cm. The beams in axes of 1,2,6 and 7 are IPE220 types, and in axes 3and 5 are IPE220 and in the axe 4 are IPE270, according to the German standard. In the other direction the structure has six spans of 6m. The beams in this direction are IPE200 with restrained connections. The beams at center and edges include steel reinforcement plates. In modeling of the structure, to deal with the effects of variation in the beam cross sections, additional nodes have been defined. Also, the columns are double INP profiles with strengthening top and bottom plates. The 3D View of the existing structure are shown in figure 4.

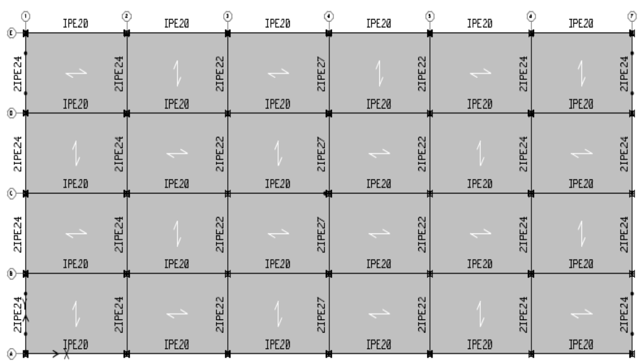


Fig 3: The typical floor plan of the existing structure

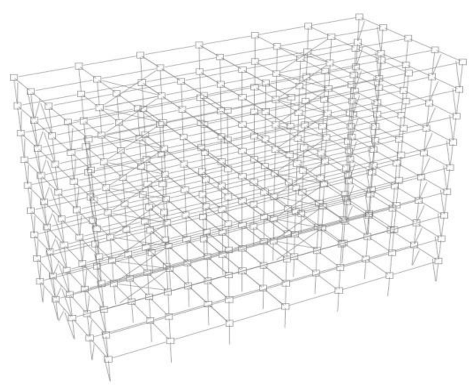


Figure 4. 3D view of existing structure

5. The Assumptions For The Nonlinear Analysis Of The Structure

The existing structure was modeled in three dimensions in Perform-3D software and several nonlinear static analyses were performed on the model. The evaluation of the structural elements was undertaken according to provisions given in FEMA356. In this regard the structural elements are divided into two main groups, namely: deformation-controlled and force-controlled elements (FEMA356, 2000).The initial nonlinear static analyses of the original structure in the Y direction, demonstrate that the plastic hinges were formed in the axes 1 and 7 beams in the region between two reinforcing plates at the web of the beams, where there was no infill plates available. Hence there was no expectation for the beams to resist large plastic deformations without web buckling or the formation of avierendeel type of mechanism at this region. Therefore, in the proposed model, the region with no infill plates was onsidered as a force-controlled region under the applied forces .So when the applied moments in these regions exceed elastic limits, the beam at these points is conservatively assumed to lose its strength .

Regarding to the results obtained in this stage, The remarkable strength loss was seen in the capacity curve that causes increase in the target displacement of the structure. Even in life safety performance level, columns have not sufficient capacities; in addition, the target displacement of the structure is far more than the permissible displacements. Also, in the most of the connections, plastic deformations exceed from the acceptable limits and the link beams in the eccentric bracings have not enough capacity while their plastic rotation violate the limitation given in FEMA356 instruction manual; therefore, in accordance with FEMA356 guidelines , the structure is vulnerable and need to be rehabilitated. Also, in the X-direction, some weaknesses are found in the bracings, columns and beams that even in the life safety performance level,result in large deformations in the structure.

5-1.The Characteristics of the Spectrum

In this work, the three-lined spectrum was used based on ATC40 and FEMA356 with the assumption of soil type S_D. Also C_V and C_A were considered at BSE-1 Earthquake Hazard Level as 0.32 and 0.50 respectively. For BSE-2 Earthquake Hazard Level these values were determined as 0.51 and 0.71 respectively (Applied Technology Council, ATC40, 1996).

5-2.The Locations of Bracings or Dampers

In all of the models used with the consideration of the building limitations, it was found that in the Y direction, the addition of new bracings was only possible at the 1 axe. The bracings were set at the span between the B-C axe . In the X direction, the bracings were set in axe A at spans between the axes of 3-4 .

5-3.The Modeling of the Saddle (Bypass) Connections

The saddle connection can be modeled using panel zone element that acts like a semi rigid connection. In this model the rigidity effects and connection strength is considered nonlinearly and the continuity of the beam at the joints can also be modeled. The moment-rotation diagram for this connection is considered to be bilinear. With the attention to the previous test results and the existing relationships for this connection, the rigidity and strength of this type of connection has been estimated (Moghadam, 2005). The rotational stiffness of connections for the beams No. 220, 240 and 270 are considered as 35000, 38000 and 43000 KN.m/rad respectively. Also the yielding moments of these connections are assumed to be of the order of 110, 130 and 160 KN.m respectively. Figure 5 shows a typical saddle (bypass) connection.

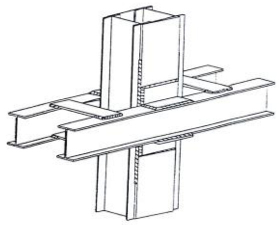


Fig 5: Typical saddle (bypass) connection

6.The Use of the TADAS Metallic Damper

This damper consists of some triangular steel plates (Fig.6). The characteristics of these dampers (SR and U values) for structure in X and Y directions are determined regarding to guidelines in Reference 6 (Tsai, Chen, Hong, and Su, 1993). SR and U values are defined as the relative strength and stiffness of the metallic TADAS dampers to the original frame of the structure respectively. Also the strain hardening effect of the damper is considered by taking the slope of 5% in its bilinear forcedisplacement model. Therefore by calculating the relative yielding displacements of the floors of the frame (Δy2) and the stiffness of each floor, the stiffness and yielding force of the TADAS damper can be obtained and considered in the computational model.

Fig 6: TADAS damper (Tsai, Chen, Hong, and Su, 1993)

7. The Nonlinear Dynamic Analyses

Based on the above, the structure a realistic model has been prepared and several nonlinear dynamic analyses have been performed on the model. The nonlinear dynamic analyses were performed using seven scaled earthquake records matched to the spectrum under consideration. These records include Naghan (Iran, 1977), Tabas (Iran, 1978), Rudbar (Iran, 1991), Elcentro (1940), Northridge (1966), Kobe (1952), and Chi Chi (1971) earthquakes.
In the Figure 7 the roof displacments of the structure for the use of various values of designing parameters is presented. By the comparison of these diagrams one can find out that the Tadas damper redcue the roof displacements in two direction. In the Figure 8 ,comparison between various value of U&SR to reach of optimization dampers plates is presented.In the Figure 9 the base shears of the structure for the use of various U&SR is presented. Figures 10 to 11 show the average percentage of dissipated energy in the structural elements in response to the 7 earthquake records. Dissipated energy in the structural elements has been used as a damage index parameter that reflects the damages in the elements. In this regard, the more dissipated energy in the elements, the more damages are expected.

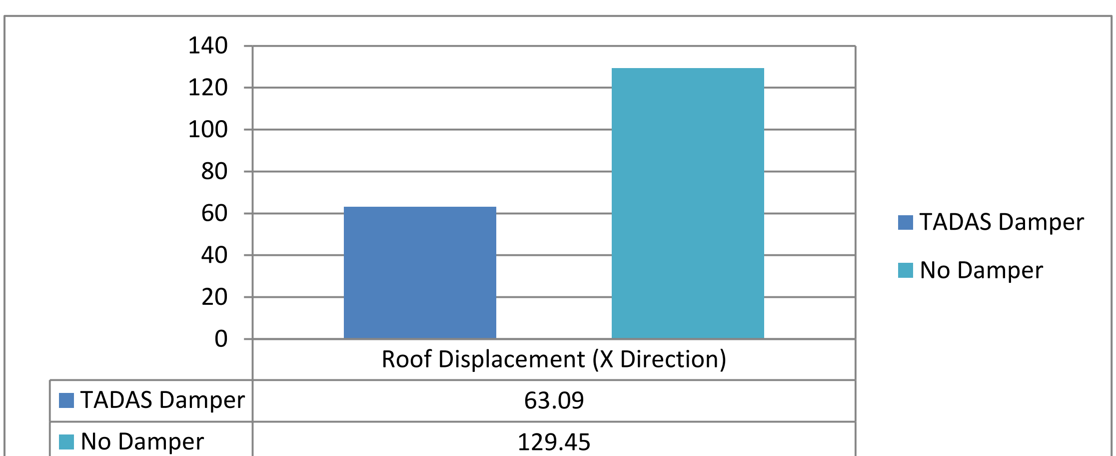


Fig 7: Comparison between Roof Displacement in X Direction

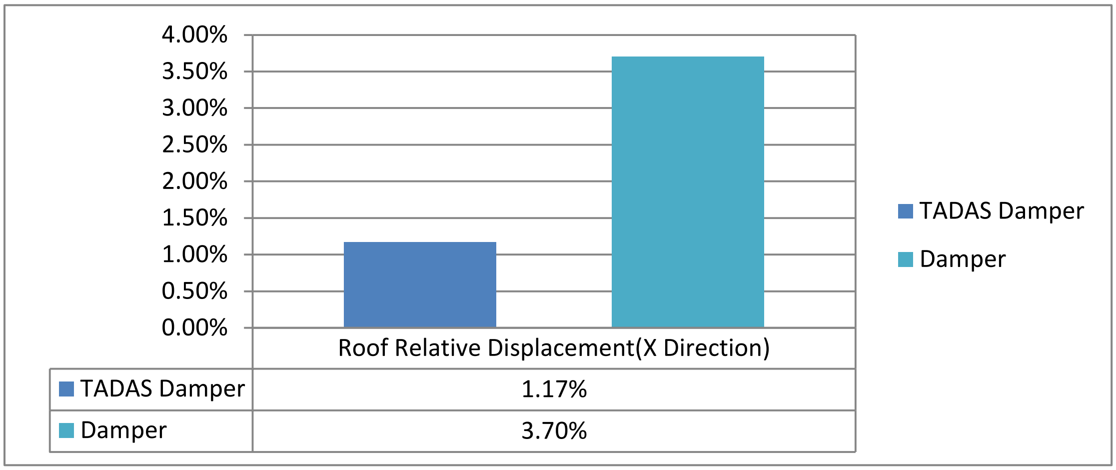


Fig 8: Comparison between Roof Relative Displacement in X Direction

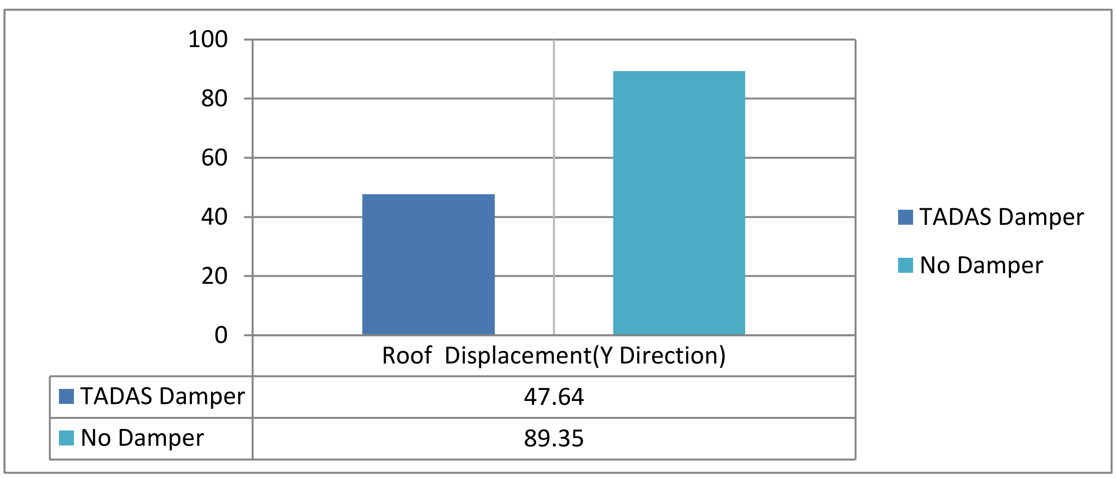


Fig 9: Comparison between Roof Displacement in Y Direction

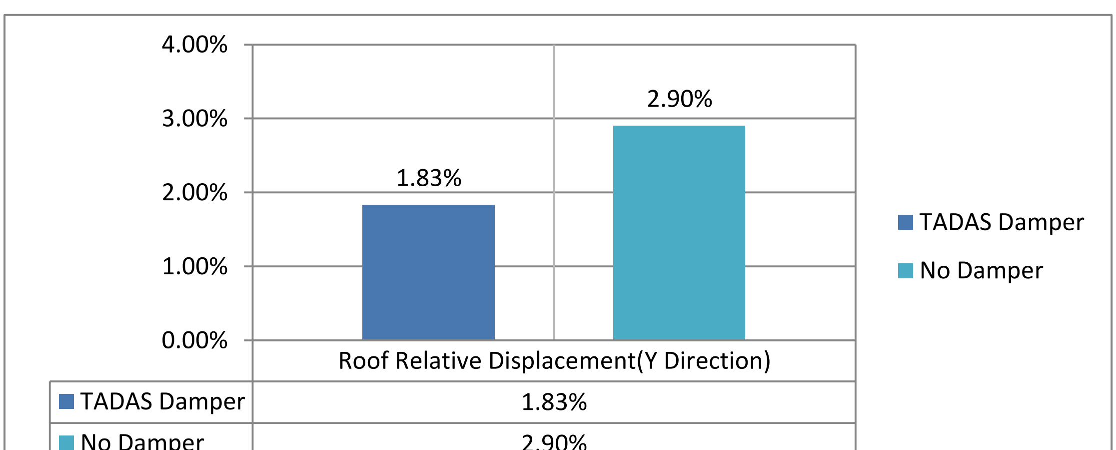
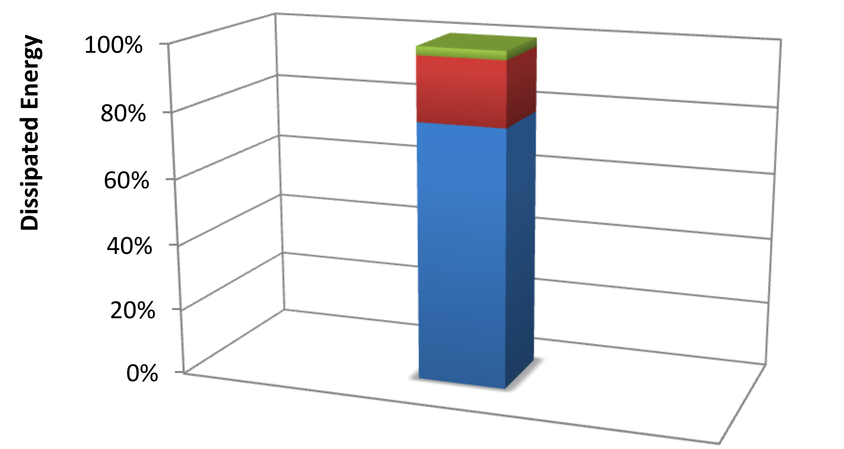
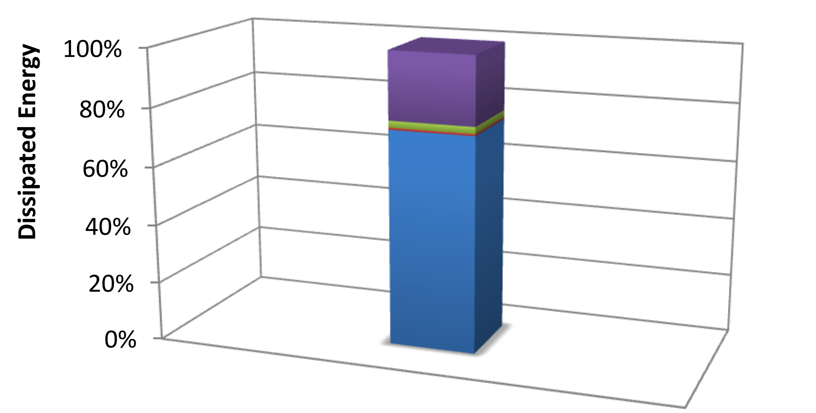


Fig 10: Comparison between Roof Relative Displacement in Y Direction



	X Direction
Columns	2.61
Beams	19.3
TADAS Damper	78.09

Fig 11: Comparison between Dissipated Energy in X Direction



	Y Direction
Saddle Connection	23.2
Columns	2.33
Beams	0.67
TADAS Damper	73.8

Fig 12: Comparison between Dissipated Energy in Y Direction

8. CONCLUSIONS

The results indicates that the Tadas damper for the purpose of the seismic rehabilitation of the existing structures is quite valuable. With the application of the TADAS damper in the structures, the earthquake energy is dissipated via that while the other structural elements can remain undamaged. On the other hand the comparison of the base shears,displacement induced in the structure, demonstrates that the use of the Tadas damper in the structures can substantially reduce the base shear,displacement and base moment and usually eliminates the expensive works on foundation strengthening or local retrofitting.

9.REFERENCES

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