

THE IMPACT OF SYSTEM STIFFNESS ON DISPLACEMENTS OF BUILDING CONSTRUCTIONS WITH MECHANICAL DAMPERS

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ABSTRACT

The installation of dampers into building constructions and their positive effect on the construction's responsiveness to dynamic loadings, especially earthquakes, became a subject of even more detailed research in the last decades. The functioning of dampers systems set outside the intersection, which have an effect of decreasing construction displacements and increasing its stiffness and capacity of critical sections because of their deformation characteristics will be given in this paper. With their deformation in the field of linear and nonlinear deformations, mechanical dampers have an effect of increasing the capacity of critical sections, primarily compared to bending moments, as well as an effect of decreasing the oscillation period which further causes an increase of the construction's stiffness and lowering its displacements. This system is more suitable for strengthening and dissipation of energy in the process of building new constructions, as well as strengthening structural elements of existing constructions. The system is suitable because of its simplicity and low price compared to other systems used for building earthquake-resistant constructions usually used.

Keywords: energy dissipation, dampers, dynamic loading, earthquake, bending moment, stiffness

1. CONDUCTED CONSTRUCTIONS

In the earthquake engineering, the level of design spectrum has been increasing after every stronger earthquake, starting with the first technical standard on seismic design developed in Japan in 1925. Currently, in the technical standards of the leading industrial nations such as USA, Japan, EU and others, the level of design spectrum, depending on the type of soil and for periods less than 1,0 sec. reaches the values of 0,7-0,8 g. Such a level of the design spectrum requires massive constructions, which generates strong inertial forces during earthquake. These forces cause damages in construction, even partial or total failure. In other words, the increase in seismic input does not always lead to stable and safe object. Today, the problem of stability control and the object safety is assured by systems which control the construction stiffness or construction damping. The most widely used are the solutions that use devices or systems for control and dissipation of seismic energy and systems with large energy absorption capacity.

Different solutions for the control of the construction dynamic response can be found in the literature, depending on the excitation source such as wind, earthquake, explosion or other dynamic excitation sources. Couple of classifications of these systems can be found in the literature, depending on the excitement sources, construction systems and technological solutions.

The simplest classification of constructive systems [1] is in those that do not use additional external energy, known as passive systems and those which require external energy known as the actively

controlled systems. There are solutions that combine both systems (active + passive) known as hybrid systems. There are actively controlled solutions which use partial control known as the semi-actively controlled constructions. The control of such constructions require little additional energy, as it controls the magnitude of additional energy which increases the energy absorption capacity.

2. RESULTS OF THE NUMARICAL ANALYSIS

In this paper the results of numerical analysis of the seismic, reinforced concrete wall of the object of the six storey building [2]. By using numerical simulation the principle of construction control through usage of mechanical energy dissipation systems is analyzed in a simple way. The simulation and numerical analysis was performed using software SAP 2000. The energy dissipation system is represented by round steel rebar. The number of rebars and their eccentricity was varied in the analysis. The model is represented by a cantilever in which rebars are positioned outside the cross-section. Thereby the rebars act as an additional bracing, decreasing forces in the critical cross-section. This is passively controlled construction in which the system for control of its stress and strain characteristics is represented by dampers positioned outside the cross section. The dampers dissipate the energy of the dynamic loads through their deformations. The system is provided with a device which compensates for any dilatations in a oscillation cycle of the wall. In this way the energy dissipaters (dampers) always remain in tension during the earthquake [3].

In the numerical simulation of the cantilevered wall, the response of the wall with increasing magnitude of horizontal forces (push-over analysis) was performed and dynamic loads originating from the real earthquake (El Centro). The cross-section forces that influence the behaviour of the construction during earthquake were obtained in the analysis. These forces are represented by bending moments in the clamping and forces in the reinforcement bars. The cross section capacity of the system with dampers in the clamping area, expressed by the bending moment in the elastic state of the cantilever increases from approx. 3% for 1ø20 with eccentricity $e=0$ up to 13,4% for 4ø20 with the eccentricity $e=0,4$ m from the edge of the wall. The period of wall oscillation decreases in the case of dampers positioned at different eccentricity relative to the edge of the wall. The results of the first 12 eigen modes (*Table 1.*) were obtained using numerical analysis. The decrease of oscillation period is evident for the wall with and without dampers. The largest decrease is obtained in the first eigen mode (*Figure 1.*).The oscillation periods in the higher modes, starting with the second one are equated. The decrease of the construction oscillation period with dampers leads to increase in its stiffness. According to well known expressions for the oscillation period:

$$T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow k = \frac{4\pi^2}{T^2} m \quad \dots (1)$$

with constant mass of the system:

$$k = F \cdot m \quad \dots (2)$$

The increase in stiffness, dependent on the eccentricity for the dampener 4ø20 is shown graphically in the (*Figure 2.*). The increase of the factor F from the equation (2) is provided in the (*Table 2.*).The factor F is directly proportional to the decrease in oscillation periods for different damper eccentricity.

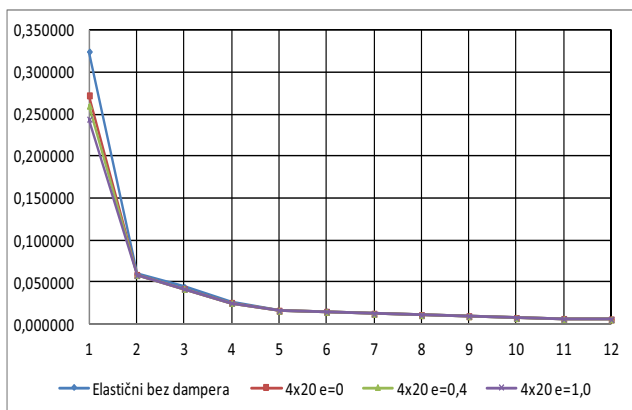


Figure 1. Diagram of decrease of oscillation periods for 12 eigen modes in a case of damper 4φ20 with different eccentricity

Table 1. Decrease in oscillation periods for different damper eccentricity [sec]

Flexible without dampers	4φ20 e=0	4φ20 e=0,4	4φ20 e=1,0
0,324818	0,272588	0,260217	0,244107
0,059231	0,058535	0,058301	0,057935
0,044310	0,041910	0,041910	0,041910
0,025273	0,025160	0,025122	0,025061
0,015977	0,015866	0,015828	0,015766
0,015062	0,014580	0,014580	0,014580
0,012244	0,012237	0,012234	0,012229
0,010637	0,010636	0,010636	0,010635
0,009402	0,009345	0,009345	0,009345
0,007136	0,007132	0,007132	0,007132
0,006032	0,006003	0,006003	0,006003
0,005501	0,005482	0,005482	0,005482

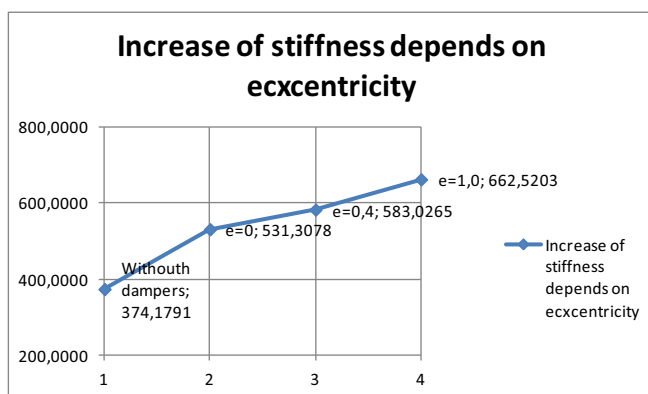


Figure 2. Diagram of stiffness increase in a case of damper 4φ20 with different eccentricity

Table 2. Increase stiffness factor F in a function of damper eccentricity

4φ20	F
Without dampers	374,1791
e=0	531,3078
e=0,4	583,0265
e=1,0	662,5203

The direct consequence of the oscillation period decrease of the damped construction is the increase in its stiffness. Therefore the lesser displacements are expected and less damage under dynamic loads. This conclusion is important in the earthquake engineering. By knowing the construction basic oscillation period, one can estimate the difference in fundament and mass displacements for the multiple damaging earthquakes in Montenegro and USA [4]. For the displacement comparison it is important to determine the oscillation period with and without damping. Having in mind that:

$$T^* < T$$

Where:

T*- is the period of oscillation with damped construction

T - is the period of oscillation of construction without dampers.

The lower displacements of construction are expected, (Figure 3.), [4].

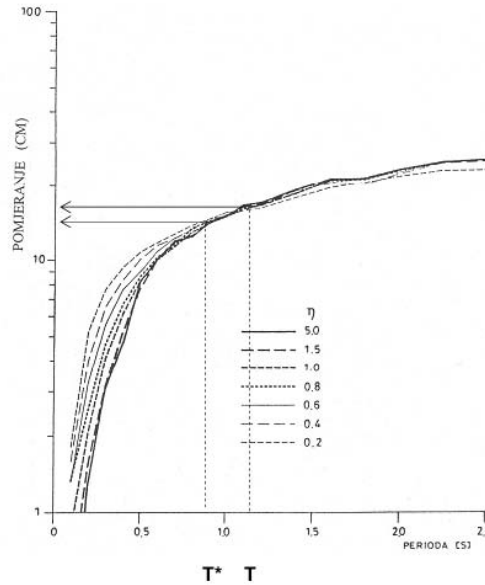


Figure 3. Decrease of construction displacements comparing to oscillation periods for different damping (x-axis – period (sec); y-axis– displacements (cm))

3. CONCLUSIONS

Based on the analysis of dynamic action, the system of energy dissipation for the building construction was proposed. According to its characteristics, this system is a passively controlled system. The proposed dampers can be provided with tensioning devices, which compensate for elongations due to material flow. It was proposed that this system partially dissipates energy that was put into system by forced displacements. The system consists of reinforcement steel bars position outside the cross section dissipates the energy by its deformation characteristics in the elastic and especially plastic zone. Critical cross-section forces in critical zones and construction displacements under dynamic load can be reduced by proper damper positioning. By applying basic laws of mechanics and dynamics of constructions the decrease of the damped construction displacement under earthquake load was demonstrated. Numerical analysis was used to show the reduction of bending moments in the critical cross-section and decrease in construction displacements, due to yielding dampers. Dynamic analysis of the cantilevered construction with and without dampeners was performed for the characteristic earthquake. The application of dampeners led to a reduction of the maximum displacements due to yielding of construction and bending moment reduction up to critical cross section yielding.

4. REFERENCES

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