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INVESTIGATION OF THE TUNED LIQUID WALL DAMPER CONTRIBUTION TO THE DYNAMIC PARAMETERS OF THE PRESTRESSED REINFORCED CONCRETE STRUCTURE USING FEM

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ABSTRACT

The destructive effects of seismic loads on structures are known. Earthquake engineers have taken many precautions in their building designs to protect and minimize these destructive effects. In this way, many new design and reinforcement methods have been developed against seismic loads. The use of a tuned liquid wall damper (TLWD) is one of the developed methods. Therefore, in this study, the effects of TLWD on dynamic performance in a 6-storey prestressed reinforced concrete building model were investigated. For this, two models with and without TLWD were created by the finite element method and modal parameters were compared. As a result of the data obtained, it has been observed that the building model makes more balanced displacements, as can be understood from the mode shapes, without increasing the period of the building to a dangerous level. TLWD reduced the seismic effect by on the structure. It can be used in TLWD prestressed reinforced concrete structures.

Keyword: Tuned liquid wall damper, prestressed reinforced concrete structure, mode shapes, dynamic performance, finite element method

INTRODUCTION

Most of the structures found in earthquake hazardous areas are subject to various destructive effects caused by seismic loads.[1],[2],[3],[4],[5]. Buildings located in seismically active regions are under high risk of severe damages caused by harmful earthquake loads. [6]. In recent years, in the world and our country, the determination of the effect of vibrations on structures and structural behavior has become very important.[7]. The TLWD (Tuned Liquid Wall Damper) is a device that absorbs structural vibration energy by sloshing fluid at a frequency that is matched to the structural frequency. Wind-induced vibrations in civil structures are commonly controlled by TLWD. When there is an error in tuning between sloshing and structural frequencies, or when the structure is subjected to non-stationary stimulation, its performance degrades. As a result, the design of a tamed sloshing system is critical for extending its lifespan and lowering maintenance costs. The effectiveness of a tuned liquid wall damper for wind-induced vibration in composite laminated beams was examined in this work. The performance of large-scale constructions was hampered by the complex size of beams, single-material fabrication, and shrinkage during curing and forming cycles. Furthermore, the damper performance was harmed by the lack of appropriate compensating mechanisms and the inadequate adhesion between sloshing and structural frequencies. In composite laminated beams, TLWD is used to reduce the occurrence of building settling owing to wind-induced vibration. The sloshing frequency is adjusted to the structural frequency for an analogous frequency delivered to the structure at a given damping ratio. Sloshing frequencies of composite laminated beams after experimental loading with plastic encasing, steel cages, plastic bags, and felt pads were used to evaluate the TLWD's performance. In addition, the simulation results of the design models based on both damper conditions were analyzed, as were the variations in the outcomes of two separate damper design circumstances, namely the pad type and the out-of-plane damping ratio. Using a single-mode optical sounder and the impedance spectroscopy approach, the performance of sloshing and the structural frequencies of composite laminated beams were examined. The TLWD's damping ratio was set to 100% of the structural frequency, and then the sloshing frequency was recorded at 3000–3000 Hz, 3000-3500 Hz, 3500-4000 Hz, 4000-5000 Hz, and 5500-6500 Hz. For each frequency tuning, the unweighted average of the three data sets yielded a fit of the sine function (half), and the relative increase (R) in structure performance with raising the damper frequency as compared to the structural frequency was found. By introducing nonlinearity into the system, the control of the resistance to the force applied to the damper can be further improved. When the amount of the resistance to a force provided to the damper through one side differs from that applied through the other side, the system becomes nonlinear, and the damper requires a lower resistive force to adjust to the force. Because the damping ratio is primarily a measure of the damper's response to the applied force, adding a nonlinear element to the system can significantly increase the damper's response to the applied force, which is critical for the optimal performance of composite laminated beams. This method is identical to the resistance-type damping method. A force is applied to the damper by applying a force to the noncontact plate in the noncontact technique, and the damper adapts to the force in a frequency controlled manner. The frequency of sloshing is also adjusted by changing the frequency of force transfer to the damper, which is derived from the transferred load. Thus, the damper adjustment may be efficiently regulated in a frequency-controlled way using this technology. Similar to the resistance-type damping method, the noncontact damping method only applies a direct resistance to the applied force. However, this produces an erroneous response, necessitating the employment of a passive device to regulate the frequency. Noncontact damping has the disadvantage of being difficult to optimize the damper's damping ratio. An adjustable resistor, on the other hand, is a useful tool for accomplishing this. The damping ratio can be accurately regulated by adjusting the resistor to fit the individual application and force supplied to the damper. The damper's resonance frequency can be adjusted to fit the application. The noncontact element's speed can also be adjusted. The load created by the damper, for example, can be more precisely regulated if the noncontact element's speed is altered. This approach can also be combined with a dual control system to improve the damper's frequency response. The adjustable resistor and dual control system can be combined with a torque or resistance-type control system, which can turn the noncontact damper into a real time-domain damping control system. Dampers must also be able to tolerate pressures, strains, twisting, and flexing in order to provide consistent function. As a result, certain composite laminated beams are supported by a passive device that absorbs flexing in these places. This passive element contains a compression (or cushion) bearing and a transition at its base, allowing it to endure compression stresses. Only the load created by the damper in the longitudinal direction is controlled by this passive device. Compressive pressures, on the other hand, are extremely high in particular situations. To regulate the forces in these applications, the beam must be extremely rigid. That means the damper must have a high tensile strength, but the composite laminated beams must have a low friction coefficient in order for the beam to flex and flow. In most cases, the tensile force must be roughly equal to the compressive force. The reason for this is because, even though the compressive force is large, a high-tensile damper can handle the load far better than a low-tensile damper. As a result, for some applications, a high-tensile damper is a good choice. The damper can control cracks and break-up in beams because of its low friction coefficient. It is critical to ensure that the damper is strong enough to sustain the force while designing it. It must, however, be flexible enough to allow the beam to flow and flex while still controlling material defects. As a result, a compromise is required. The stiffer the damper, the more difficult it is to manage material flaws and fracture formation. It is preferable to use a damper with a lot of flexibility in these applications. Flexibility and flow aren't as important in other applications. In these cases, a flexible damper with a very low friction coefficient is ideal. This very flexible damper can withstand large compressive and tensile forces. As a result, a flexible damper with a low coefficient of friction is an excellent choice.

Researchers have carried out many studies using both the finite element method and the finite element method. There are many studies by the authors using the finite element method before. In this study, studies [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19] on the use of the finite element method were used. In addition, the authors have comparative studies [20], [21], [22], [23], [24], [25] using more than one method, including the finite element method. In these studies, the effect of the finite element method was compared with the operational and experimental modal analysis method. With all this knowledge, this new study has been carried out. Researchers have conducted studies [26], [27], [28], [29], [30], [31], [32], [33] about tuned liquid wall damper (TLWD).

The aim of this study is to observe the effects of tuned liquid wall damper (TLWD) contribution to the dynamic parameters of prestressed reinforced concrete structure with the finite element method. For this purpose, a prestressed reinforced concrete structure model was created and a modal analysis of the building model created by the finite element method was carried out.

Description of Model Prestressed Reinforced Concrete Structure

Model prestressed reinforced concrete structure is a 6-storey reinforced concrete building with two spans (6 m) in x and y directions, with a floor height of 3 m. Columns and beams are 40x50 cm, floor thickness is 20 cm. The finite element model (FEM) of the reinforced prestressed concrete structure is given in figure 1.

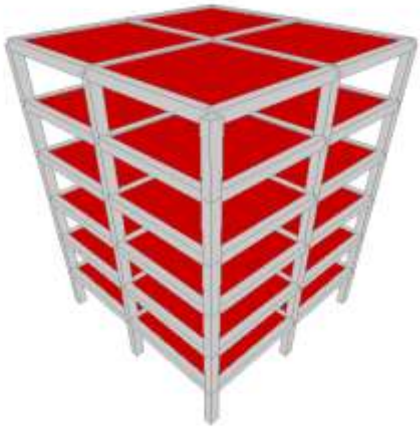

Figure 1: FEM model of reinforced prestressed concrete structure

Description of Tuned Liquid Wall Damper

Tuned liquid wall damper is placed in two planes on each floor. Tuned liquid wall damper has a mass of 1 kN, fixed in the x-y-z axes, has a stiffness of 1000, 100, 100 kN/m and a damping of 100, 10, 10 kNs/m, respectively. Location of tuned liquid wall damper is given in figure 2.

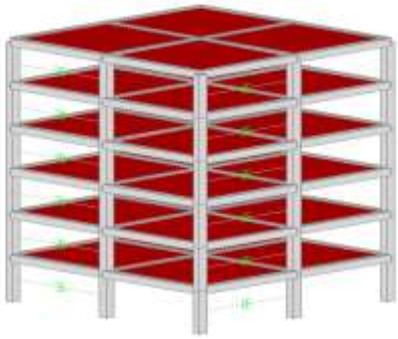

Figure 2: Location of tuned liquid wall damper

ANALYSIS AND RESULTS

The building was first analysed in its current state using SAP2000 with the finite element method, then TLWD was added to the frames and the same analysis was repeated and the results were compared.

Results of the Building without TLWD

The building was analysed without adding tuned liquid wall damper (TLWD) by finite element method. The first 5 modes were taken into account in the analysis. Obtained results are presented in figures 3,4,5,6,7 as periods and mode shapes.

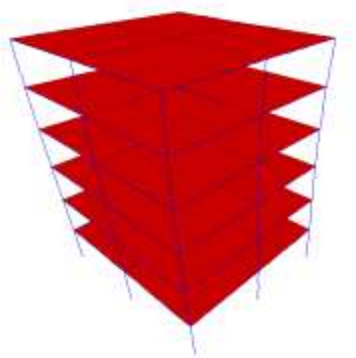

Figure 3: 1. Mode shape (Period = 0.7922 s)

It is seen that Mode 1 is translational mode shape. The period value was obtained as 0.7240 second in mode 1.

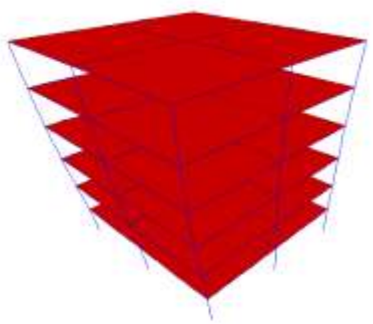

Figure 4: 2. Mode shape (Period = 0.7133 s)

It is seen that Mode 2 is translational mode shape. The period value was obtained as 0.7133 second in mode 2.

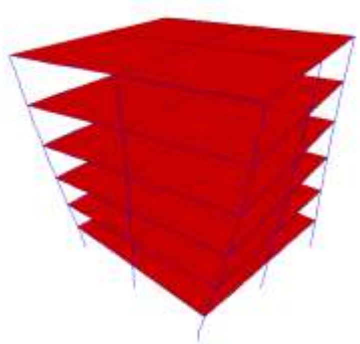

Figure 5: 3. Mode shape (Period = 0.6871 s)

It is seen that Mode 3 is torsional mode shape. The period value was obtained as 0.6871 second in mode 3.

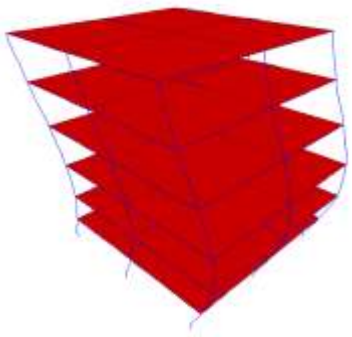

Figure 6: 4. Mode shape (Period = 0.2591 s)

It is seen that Mode 4 is translational mode shape. The period value was obtained as 0.2591 second in mode 4.

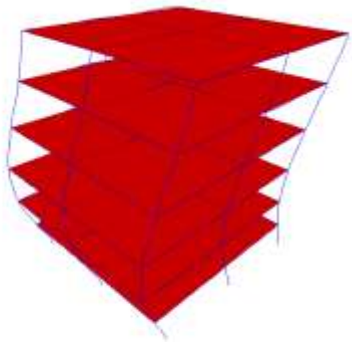

Figure 7: 5. Mode shape (Period = 0.2303 s)

It is seen that Mode 5 is translational mode shape. The period value was obtained as 0.2303 second in mode 5.

Results of the Building with TLWD

The building was analysed with adding tuned liquid wall damper (TLWD) by finite element method. The first 5 modes were taken into account in the analysis. Obtained results are presented in figures 8,9,10,11,12 as mode shapes.

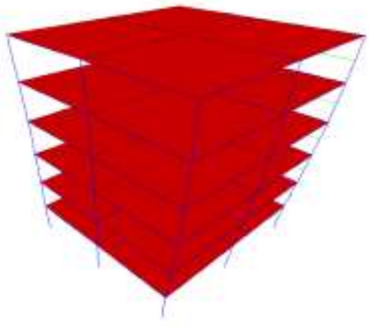

Figure 8: 1. Mode shape (Period = 0.8115 s)

It is seen that Mode 1 is translational mode shape. The period value was obtained as 0. 0.8115 second in mode 1.

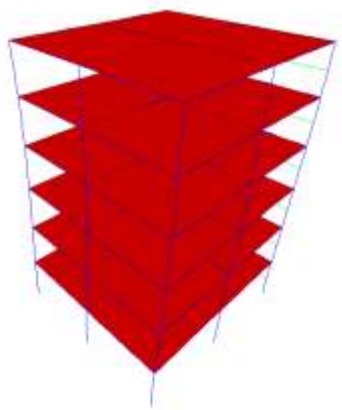

Figure 9: 2. Mode shape (Period = 0.7228 s)

It is seen that Mode 2 is translational mode shape. The period value was obtained as 0.8115 second in mode 2.

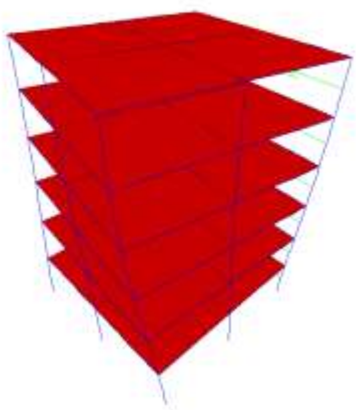

Figure 10: 3. Mode shape (Period = 0.6923 s)

It is seen that Mode 3 is torsional mode shape. The period value was obtained as 0.6923 second in mode 3.

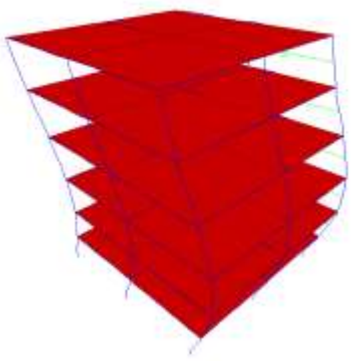

Figure 11: 4. Mode shape (Period = 0.2863 s)

It is seen that Mode 4 is translational mode shape. The period value was obtained as 0.2863 second in mode 4.

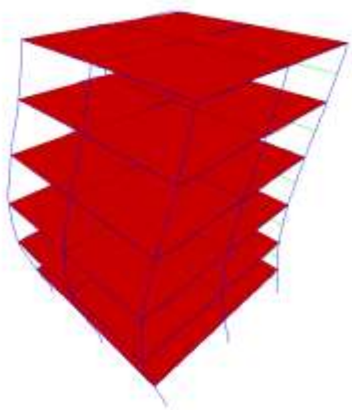

Figure 12: 5. Mode shape (Period = 0.2611 s)

It is seen that Mode 5 is translational mode shape. The period value was obtained as 0.2863 second in mode 5.

The comparison of period and mode shapes of the model with TLWD and without TLWD model is given in Table 1.

Table 1. Comparison period and mod shapes of without TLWD model and with TLWD model

Mode	1	2	3	4	5
Without TLD Period (s)	0.7922	0.7133	0.6871	0.2591	0.2303
With TLWD Period (s)	0.8115	0.7228	0.6923	0.2863	0.2611
Difference of Period (s)	0.0193	0.0095	0.0052	0.0272	0.0308
Difference of Period (%)	2.44	1.33	0.76	10.50	13.37
Without TLWD Mode Shapes	Translational	Translational	Torsional	Translational	Translational
With TLWD Mode Shapes	Translational	Translational	Torsional	Translational	Translational

CONCLUSIONS

The percentage changes in the parameters of the building are listed below;

In the mode 1, the period difference between non-TLWD and TLWD status was obtained as 0.0193 s. The effect of TLWD reinforcing as a percentage was determined as 2.44%.

In the mode 2, the period difference between non-TLWD and TLWD status was obtained as 0.0095 s. The effect of TLWD reinforcing as a percentage was determined as 1.33%.

In the mode 3, the period difference between non-TLWD and TLWD status was obtained as 0.0052 s. The effect of TLWD reinforcing as a percentage was determined as 0.76%.

In the mode 4, the period difference between non-TLWD and TLWD status was obtained as 0.0272 s. The effect of TLWD reinforcing as a percentage was determined as 10.50%.

In the mode 5, the period difference between non-TLWD and TLWD status was obtained as 0.0308 s. The effect of TLWD reinforcing as a percentage was determined as 13.37%.

As a result of the study, it has been observed that the building model makes more balanced displacements, as can be understood from the mode shapes. In addition, it was observed that TLWD increased the periods in a balanced way without increasing it excessively. In the third mode, it was observed that only about 0.76 percent increase in the period. TLWD reduced the seismic effect by acting in the opposite direction to the seismic effect on the structure. It can be used in TLWD prestressed reinforced concrete structures.

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