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Dynamic Performance of Concrete Pool Before and After Retrofitting Process

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Abstract – Earthquakes damage not only structures but also infrastructure and superstructure facilities. Therefore, the seismic performance of all structure types is of vital importance. It is known that seismic performance losses occur in various types of structures due to the earthquake effect. Various retrofitting methods are available for such structures to regain their former seismic performance. Appropriate retrofitting techniques should be applied according to the type of structure, its damage and the conditions of the region. In addition, the retrofitting process can be done to the entire structure or to some sections or parts of the structures. It is known that environmental and forced vibrations, especially in pools, increase the destructive effects by activating the water in the pool. In this type of situation, stiffness losses for pools increase even more. Their collapse becomes inevitable under the influence of the next forced and environmental vibrations. For this reason, this study focused on the technique of retrofitting concrete pools with UHPC (Ultra High Performance Concrete). A sample concrete pool model was created using the finite element method and modal analysis was performed. Then, the same model was retrofitted with UHPC and modal analysis was performed. When the results obtained were compared, it was seen that retrofitting with UHPC had a positive effect on the rigidity of the concrete pool. In light of all these findings, UHPC may be an option for retrofitting concrete pools.

Keywords –Uhpc, Retrofitting, Modal Analysis, Concrete Pool, Dynamic Performance

I. INTRODUCTION

Many types of structures are damaged as a result of natural disasters (such as floods, landslides, earthquakes). According to the degree of damage received, loss of life and property occurs with the collapse. In some structures, collapse does not occur as a result of disasters, but damage is observed [1], [2], [3], [4]. Various reinforcement methods are applied in such structures. Thus, the structures are restored to their former bearing strength and stiffness, thus avoiding possible collapse. It is known that the destructive effects of natural disasters also damage structures, thus damage may occur much more than expected. Concrete pools are also exposed to these destructive effects. Various proven retrofit methods are available to solve such problems. The use of UHPC (Ultra High Performance Concrete) is one of these retrofit methods.

Ultra-high-performance concrete (UHPC) has been developed for three decades and is considered one of the most promising construction materials for future sustainable and resilient infrastructure. Given its low water-to-binder ratio (w/b, 0.15-0.25), high particle packing density (0.825-0.855), high-volume of steel fibers (≥2%, by volume), and proper addition of chemical admixtures, UHPC exhibits good flowability (mini-slump flow ≥160 mm) and high mechanical properties (28-day compressive strength ≥120 MPa and tensile strength ≥5 MPa, under standard curing; 28-day compressive strength ≥150 MPa, under steam curing). Due to the use of high-volume fibers, UHPC exhibits strain-hardening behaviors after cracking. After 2000, instead of pursuing high strength, the focus of the UHPC development switched to reduce its CO_2 emissions and initial materials cost for eco-friendlier and more economical UHPC. To this end, various methods have been employed: reduce cement content (<850 kg/m^3) and silica fume content (<200 kg/m^3) by using a high volume of supplementary cementitious materials (SCMs) and fillers; reduce binder content (<1200 kg/m^3); replace finely grounded quartz sand by conventional concrete sand or quartz sand reduce fiber content by hybrid fiber systems use standard curing instead of heat curing for lower energy consumption [5]. Concrete is a composite building material that has many superior advantages such as versatility, usability and economy compared to other structural materials, and is widely used in our country and all over the world thanks to these features. It is expected that concrete, which is one of the most important building materials of the past and present, will continue to be widely used in the future. However, due to population growth, rise in living standards, advances in construction technology and urban transformation projects, traditional concrete cannot show the desired strength and durability properties in some cases. In order to meet the increasing demand and obtain the desired concrete properties, researchers in the construction sector have turned to designing different types of concrete. Ultra High Performance Concrete (UHPC) stands out as one of the most important of these different concrete types. Researchers have conducted experimental and theoretical studies [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18] about UHPC which also contributed to this study.

The word pool is defined in the dictionary of the Turkish Language Association as "A place, usually open-topped, whose bottom and sides are made of marble, concrete, etc. and filled with water for the purposes of accumulating water, swimming, beautifying the environment, etc." Regardless of the purpose for which the pool is used, it is a bowl that can hold or flow water; It will operate smoothly by taking into account and solving environmental conditions, architectural and static facts, and infrastructure requirements in a full and timely manner; A whole of architectural, landscape, construction, mechanical, electrical and electronic systems; It is a work that brings together the sciences of chemistry, physics, biology and ecology.

The aim of this study is to contribute to the strengthening of concrete pools used for many different purposes according to their modal conditions. It is known that there are many studies [19], [20], [21], [22], [23], [24], [25], [26] using UHPC retrofitting methods to increase the rigidity of structures. In this study, the effects of the UHPC retrofit method on concrete pool modal periods and mode shapes are investigated.

II. MATERIALS AND METHOD

In this study, concrete pool model was created and modal analysis was carried out with the finite element method. The concrete pool model was retrofitted with UHPC retrofitting and two concrete pool model was created for comparison. Variables on the model should be minimized in order to better see the reinforcement effects. Therefore, it was emphasized that the models should be designed simply and symmetrically. Thus, it is aimed that the only variable between both models is the retrofitting method. In the application of the finite element method, the SAP2000 software, which is used in the field of academic and engineering applications all over the world, was used. In this study, [27], [28], [29] studies in which the finite element method was used for retrofit were used.

A. *Description of Concrete Pool Model*

The model concrete pool is dimensions in plan are 10x10 m and its height is 4 m. Wall thickness is 0.15 m. The mechanical parameters of concrete pool in model are; poisson's ratio: 0.2, modulus of elasticity: 30 GPa, density: 24 kN/m^3. The concrete pool finite element model was created using the SAP2000 software. The finite element model of the concrete pool is given in fig. 1.

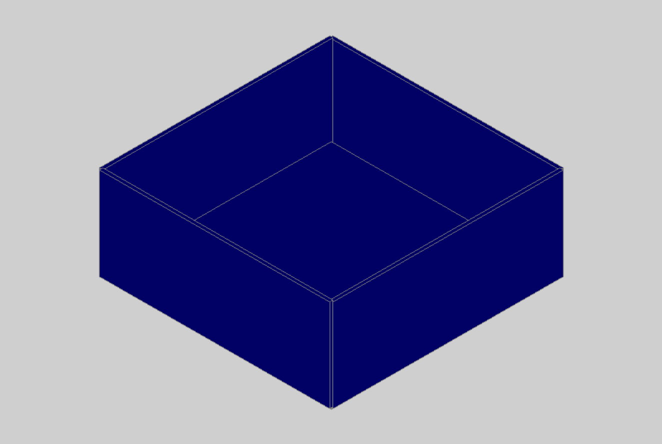

Fig. 1 3D Finite element model of the concrete pool

B. *Description of Concrete Pool Retrofitted Model*

The existing concrete pool model is coated internally with 0.025 m UHPC. Thus, a retrofitted model was created. Mechanical properties of the applied UHPC materials; poisson's ratio: 0.2, modulus of elasticity: 75 GPa, density: 29 kN/m^3.

III. FINDINGS AND DISCUSSION

The concrete pool model and concrete pool retrofitted model were modal analysed using SAP2000 software. The period and mode shapes obtained for both models are obtained for each mode.

A. *Modal Analysis Results of Concrete Pool Model*

The modal analysis of the concrete pool model was performed with finite element method. The first 5 modes were taken into account in the analysis. Obtained results are presented in figures 2,3,4,5,6 as periods and mode shapes.

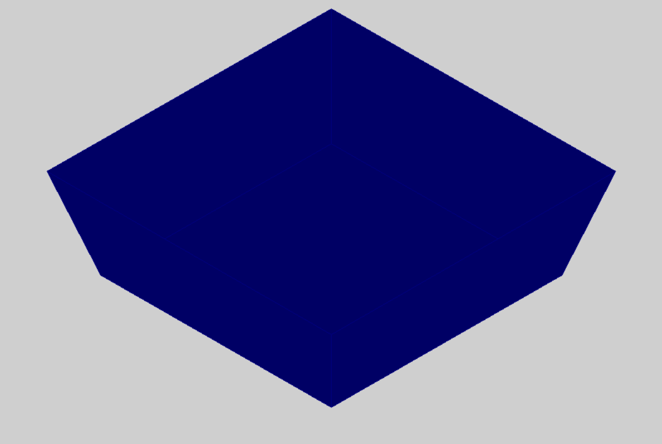

Fig. 2 1. Mode shape (Period value = 0.155 s)

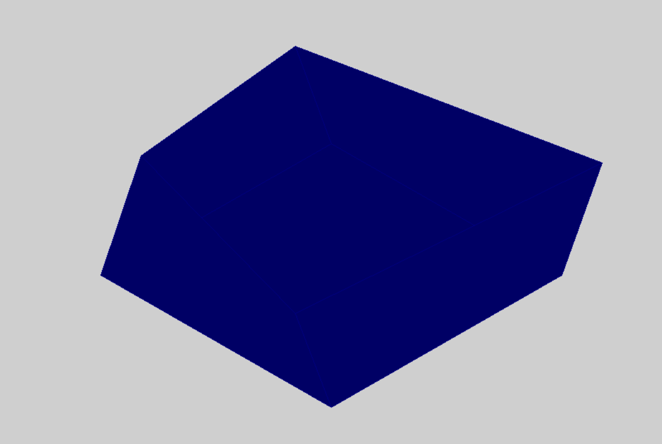

Fig. 3 2. Mode shape (Period value = 0.127 s)

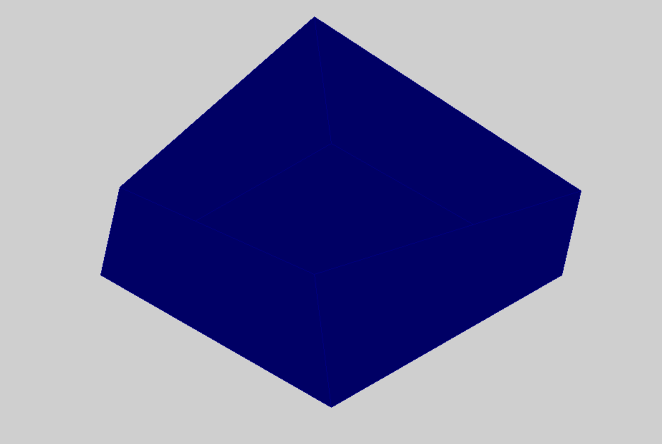

Fig. 4 3. Mode shape (Period value = 0.113 s)

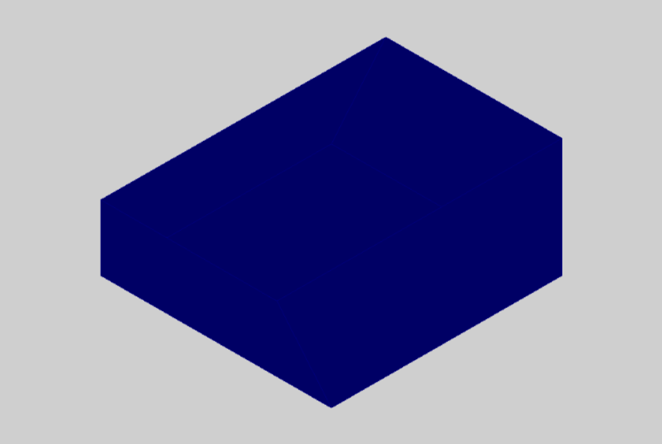

Fig. 5 4. Mode shape (Period value = 0.075 s)

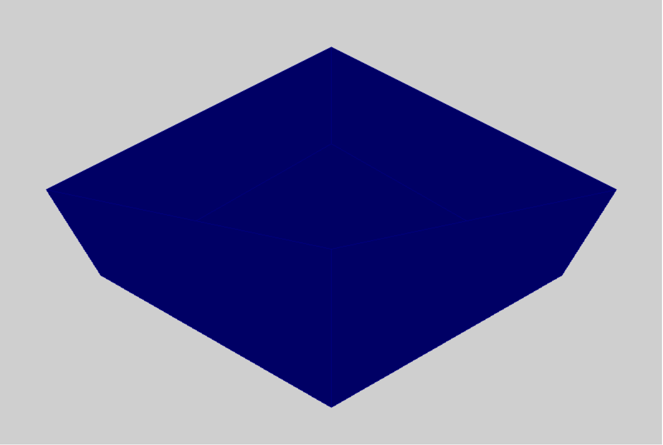

Fig. 6 5. Mode shape (Period value = 0.059 s)

B. *Modal Analysis Results of Concrete Pool Retrofitted Model*

The modal analysis of the concrete pool retrofitted model was performed with finite element method. The first 5 modes were taken into account in the analysis. Obtained results are presented in figures 7,8,9,10,11 as periods and mode shapes.

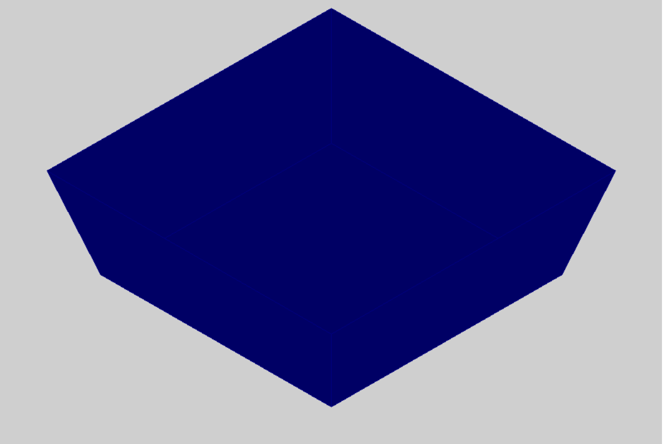

Fig. 7 1. Mode shape (Period value = 0.151 s)

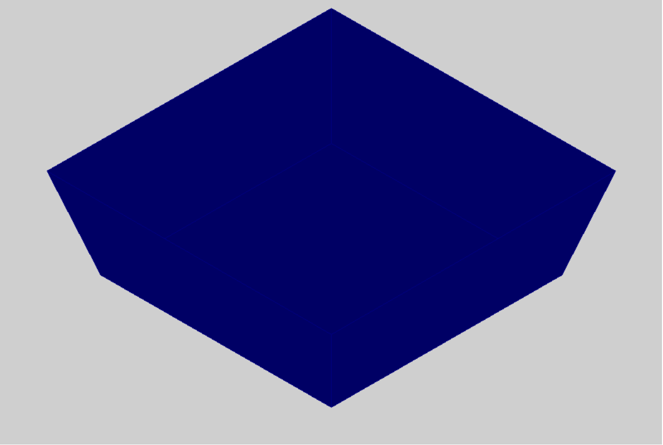

Fig. 8 2. Mode shape (Period value = 0.098 s)

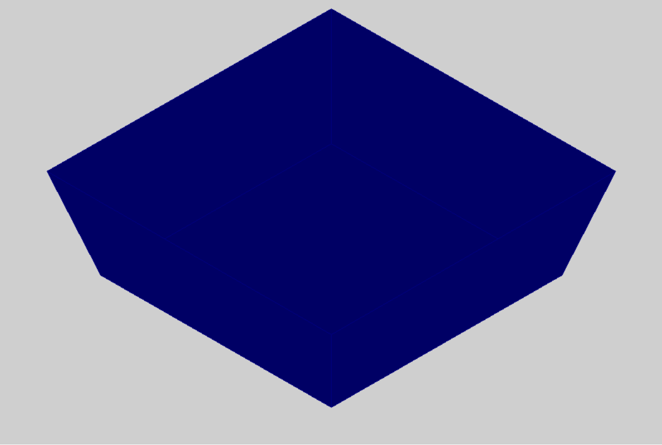

Fig. 9 3. Mode shape (Period value = 0.088 s)

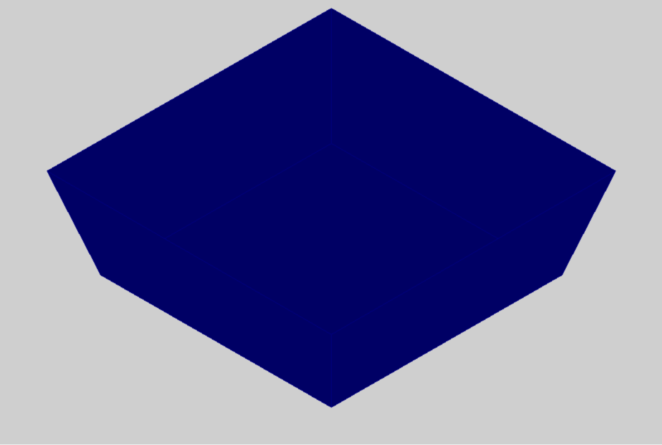

Fig. 10 4. Mode shape (Period value = 0.067 s)

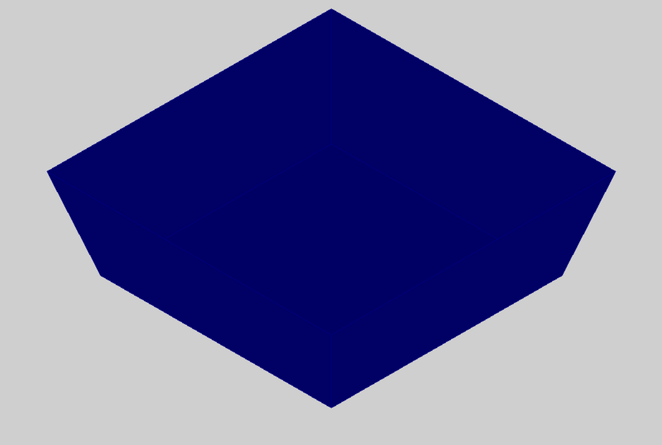

Fig. 11 5. Mode shape (Period value = 0.054 s)

C. *Comparison of Modal Analysis Results*

The comparison of periods of the model non-retrofitted and retrofitted are given in Table 1.

Table 1. Comparison of period values

Mode	1	2	3	4	5
Non-retrofitted	0.155	0.127	0.113	0.075	0.059
Retrofitted	0.151	0.098	0.088	0.067	0.054
Difference (s)	0.004	0.019	0.025	0.008	0.005
Difference (%)	2.58	14.96	22.12	10.67	8.48

The comparison of mode shapes of the model non-retrofitted and retrofitted model is given in Table 2.

Table 2. Comparison of mode shapes

Mode	Non-retrofitted	Retrofitted
1	Translational	Translational
2	Torsional	Torsional
3	Torsional	Torsional
4	Torsional	Torsional
5	Translational	Translational

IV. CONCLUSION

In the mode 1, the period difference between non-retrofitted and retrofitted status was obtained as 0.004 s. The effect of period retrofitting with UHPC retrofitting as a percentage was determined as 2.58.

In the mode 2, the period difference between non-retrofitted and retrofitted status was obtained as 0.019 s. The effect of period retrofitting with UHPC retrofitting as a percentage was determined as 14.96.

In the mode 3, the period difference between non-retrofitted and retrofitted status was obtained as 0.025 s. The effect of period retrofitting with UHPC retrofitting as a percentage was determined as 22.12.

In the mode 4, the period difference between non-retrofitted and retrofitted status was obtained as 0.008 s. The effect of period retrofitting with UHPC retrofitting as a percentage was determined as 10.67.

In the mode 5, the period difference between non-retrofitted and retrofitted status was obtained as 0.005 s. The effect of period retrofitting with UHPC retrofitting as a percentage was determined as 8.48.

With the retrofitting, some minor change in translation and torsion was observed. It is thought that these changes are not very important. No negative change was observed in terms of retrofit in mode shapes.

As a result of this study, it is clearly seen that the stiffness of the concrete pool model increases by retrofitting the concrete pool model with UHPC retrofitting. In general, it is seen that the decrease in the periods is between 2.58% and 22.12%. In the 1st mode, in other words, there is a decrease of 2.58 percent in the dominant period value. It is known that this is a somewhat positive situation in terms of retrofit. The reason for this situation can be shown as the single layer application of UHPC. It is estimated that with the thicker application of UHPC, the period decrease will be greater in 1st mode. The maximum decrease in period values was observed in the 3rd mode. In the light of all these results, the concrete pool can retrofit with the UHPC, taking into account the state of the pool and environmental factors.

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