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A Review on Retrofitting of Masonry Reservoir under Static Loads

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Abstract **–** Nowadays, the devastating effects of natural disasters and methods of protection from these effects are very popular. In the field of civil engineering, the issue of protecting structures against natural disasters has always been on the agenda. For this reason, research on the protection of all building types against natural disasters is of vital importance. It seems that masonry reservoirs, especially those used for irrigation purposes, are negatively affected by earthquakes. As a result of this situation, problems are encountered in accessing clean water and storing clean water. Post-disaster modal performance levels of masonry reservoirs should be examined and as a result, appropriate retrofitting techniques should be applied according to the structure type, damage and regional conditions. Various retrofitting methods are available to increase the seismic performance and stiffness of masonry reservoirs. The retrofitting method with GRC (Glass Fiber Reinforced Concrete) also stands out as an alternative. For all these reasons, this study focused on retrofitting masonry reservoirs with GRC. A masonry reservoir model was created with the finite element method and modal analysis was performed. Then, the same model was retrofitted with GRC and modal analysis was performed. When the results obtained were compared, it was seen that retrofitting with GRC significantly increased the masonry reservoir rigidity. In light of all these findings, it is recommended to retrofit GRC to ensure that the legacy of masonry reservoirs reaches the future.

Keywords –Grc, Masonry Reservoir, Retrofitting, Modal Analysis, Static Loads

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. Various proven popular retrofit methods are available to solve such problems. The use of GRC retrofitting is one of these retrofit methods which popular method [5].

Glass fibre reinforced concrete (GFRC) is a type of fibre-reinforced concrete. The product is also known as glass fibre reinforced concrete or GRC in British English [6]. Glass fibre concretes are mainly used in exterior building façade panels and as architectural precast concrete. Somewhat similar materials are fibre cement siding and cement boards. Glass Fiber Reinforced Concrete, also known as Composite Cement, CCV, Fiber Concrete, Fiber Reinforced Concrete and Glasfaserbeton (GFB), GRC and GFRC in various parts of the world, is a mixture of cement, fine aggregate, water, chemical additives and alkali resistant glass fibers. Glass Fiber Reinforced Concrete is a material that makes great contributions to economy, technology and construction aesthetics all over the world today. Glass Fiber Reinforced Concrete has been continuously developed since it was first produced in 1960, 50 years ago, and today's construction designers have a choice of matrix modifiers such as acrylic polymer, quick-drying cement and various additives to improve the long-term stability of the material depending on performance needs. Extensive independent testing and performance data are available on all elements of the matrix formula. In the production of prefabricated products produced in the factory, generally 2-5% alkali resistant glass fiber is used by applying spraying method or conventional concrete casting methods. This material is also used in the reinforced factory fiber in the form of a mixture applied in the field at a rate of 1-2%, as well as preventing cracking due to plastic shrinkage. In the GFRC production method by pre–mixture and casting, cement matrix is firstly produced and pre–cut glass fibers, between 2-4 % (usually 3.5 %) weight, are then mixed. The length of the pre–cut fiber is usually 6-12 mm, however, longer fibers lead to restrict to the mixture workability. Respectively, the matrix is produced in a high-shear mixer and chopped fiber strands are incorporated in a low-speed mixing regime because of maximum workability. This facilitates their dispersion at the highest practical volume content with a minimum damage to the fibers. Production with pre-mix GFRC may involve several procedures such as injection and vibration, pressing, or shotcreting [7]. Also, researchers have conducted studies [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22] about GRC which also contributed to this study.

The elevated storage tank or reservoir offers advantages because it provides a reserve supply of water which is quickly available and also because it is adapted to intermittent windmill pumping. Farm fires constitute a serious economic problem, and the losses therefrom may be reduced with adequate water supply on the farm [23]. Water storage is a difficult problem on most farms, and few land holders are lucky enough not to be confronted with the problem of construction of storages on their properties. Where large quantities of water are to be stored and evaporation, seepage and muddiness are minor considerations, the earthen dam in best. But where such a dam is undesirable or the site is unsuitable, some other form of storage must be considered. The circular tank is the most economical to build. It requires the least material and offers the minimum in structural problems. The reinforced brick, or block, reservoir described below requires little skill beyond the ability to lay a row of bricks and follow the recommendations. Naturally the reservoir should be built where the best use can be made of it, the actual site depending entirely on the purpose of the storage. But the site must be level, firm and uniform. Any large stones, stumps and so on must be removed and the holes back filled with gravel well rammed in. Uniformity is more important than firmness, the idea being that, if settlement should occur, it will be uniform. On clay soils that are subject to expansion or contraction with wetting or drying, a minimum of four inches should be well rammed over the whole site, including the bottom of the foundation, which, in such cases, should be taken well down into the soil [24]. Also, researchers have conducted studies [25], [26] about masonry reservoir which also contributed to this study.

The aim of this study is to contribute to the retrofitting of masonry reservoir according to their stiffness conditions. It is known that there are many retrofitting methods available for the masonry reservoirs to increase masonry reservoir stiffness. In this study, the effects of the GRC retrofit method on masonry reservoir's stiffness and mode shapes are investigated.

II. Materials and Method

In this study, masonry reservoir model was created and modal analysis was carried out with the finite element method. The masonry reservoir model was retrofitted with GRC retrofitting and two masonry reservoir 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 was used. In this study, [25], [26], [27] studies in which the finite element method was used for retrofit were used.

A. *Description of Masonry Reservoir Model*

The model masonry reservoir is a cylindrical reservoir with a diameter of 5 m and a height of 10 m. Wall thickness is 0.20 m. The mechanical parameters of masonry material in model are; poisson's ratio: 0.2, modulus of elasticity: 2 GPa, density: 20 kN/m^3. The masonry reservoir finite element model was created using the SAP2000 software. The finite element model of the masonry reservoir is given in fig. 1.

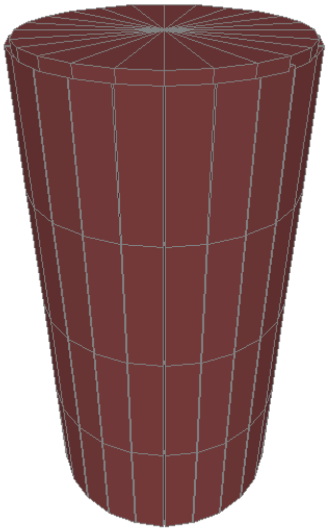

Fig. 1 3D Finite element model of the masonry reservoir

B. *Description of Masonry Reservoir Retrofitted Model*

The existing masonry reservoir model is coated internally with 0.025 m GRC. Thus, a retrofitted model was created. Mechanical properties of the applied GRC materials; poisson's ratio: 0.24, modulus of elasticity: 15 GPa, density: 20 kN/m^3.

III. Findings and Discussion

The masonry reservoir model and masonry reservoir retrofitted model were analysed (modal) using finite element method by SAP2000 software. The models were designed assuming there is no water in it. The period and mode shapes obtained for both models are obtained for each mode.

A. *Modal Analysis Results of Masonry Reservoir Model*

The modal analysis of the masonry reservoir model was performed. 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.

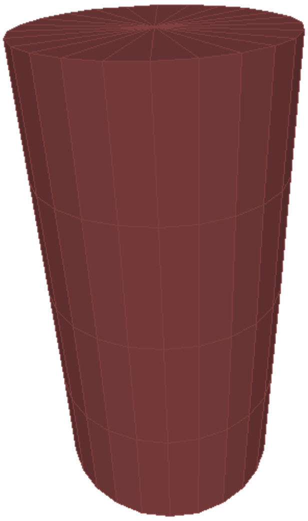

Fig. 2 1. Mode shape (Period value = 0.163 s)

Fig. 3 2. Mode shape (Period value = 0.112 s)

Fig. 4 3. Mode shape (Period value = 0.092 s)

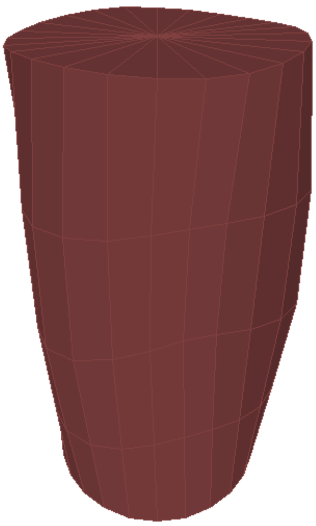

Fig. 5 4. Mode shape (Period value = 0.077 s)

Fig. 6 5. Mode shape (Period value = 0.067 s)

B. *Modal Analysis Results of Masonry reservoir Retrofitted Model*

The modal analysis of the masonry reservoir retrofitted model was performed. 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 = 0.119 s)

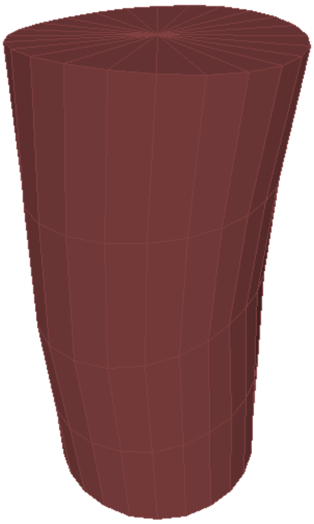

Fig. 8 2. Mode shape (Period value = 0.063 s)

Fig. 10 4. Mode shape (Period value = 0.043 s)

Fig. 9 3. Mode shape (Period value = 0.049 s)

Fig. 11 5. Mode shape (Period value = 0.037 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	0.163	0.112	0.092	0.077	0.067
Retrofitted	0.119	0.063	0.049	0.043	0.037
Difference (s)	0.044	0.049	0.043	0.044	0.030
Difference (%)	26.99	43.75	46.74	57.14	44.78

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	Translational	Translational
3	Torsional	Torsional
4	Torsional	Torsional
5	Torsional	Torsional

In the mode 1, the period difference between non-retrofitted and retrofitted status was obtained as 0.044 s. The effect of period retrofitting with GRC retrofitting as a percentage was determined as 26.99.

In the mode 2, the period difference between non-retrofitted and retrofitted status was obtained as 0.049 s. The effect of period retrofitting with GRC retrofitting as a percentage was determined as 43.75.

In the mode 3, the period difference between non-retrofitted and retrofitted status was obtained as 0.043 s. The effect of period retrofitting with GRC retrofitting as a percentage was determined as 46.74.

In the mode 4, the period difference between non-retrofitted and retrofitted status was obtained as 0.044 s. The effect of period retrofitting with GRC retrofitting as a percentage was determined as 57.14.

In the mode 5, the period difference between non-retrofitted and retrofitted status was obtained as 0.030 s. The effect of period retrofitting with GRC retrofitting as a percentage was determined as 44.78.

With the retrofitting, no change was observed in the mode shapes from torsion to translation or from translation to torsion. However, some minor change in translation and torsion was observed.

IV. CONCLUSION

As a result of this study, it is clearly seen that the stiffness of the masonry reservoir model increases by retrofitting the masonry reservoir model with GRC. In the 1st mode, in other words, there is a decrease of 26.99 percent in the dominant period value. The maximum decrease in period values was observed in the 4th mode with 57.14%. The maximum period value decrease was received very positively. In general, masonry reservoir retrofit with GRC, a period reduction of between 26.99 percent and 57.14 was observed. It is known that this is a very positive situation in terms of retrofit. In this case, a significant increase in stiffness can be mentioned as the effect of retrofitting. In addition, no transformation was observed in the mode shapes. In the light of all these results, it is recommended to retrofit masonry reservoir with GRC, taking into account the existing state of the masonry reservoir.

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