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Review of Failure Analysis of Ground Level Reservoir and Remedial measures

T.Vijila[1], N.Sakthieswaran[2], G.Shiny Brintha[3], O.Ganesh Babu[4]
[1,2,3,4]*Department of Civil Engineering*
[1,2,3,4]*Anna University Regional Campus, Tirunelveli, TN, India.*

Abstract - This paper presents failure analysis of ground level reservoir. During operation one side wall of the Ground Level Reservoir collapse. The detailed study involves preliminary assessment of structural conditions, detailed analysis of causes of failure. A major part of the civil Engineering infrastructure will need significant repairs. This innovative rehabilitation and strengthening method of reinforced concrete ground level reservoir can be done after assessing the failure reasons due to the stresses developed in extremely loaded condition.
Keywords – Reservoir collapse, Failure, Shear wall, Rehabilitation, Failure.

I. INTRODUCTION

This report deals with analysis and design of water tank. TTPS is one of the major Electricity generating station which caters the needs of Tamil Nadu grid. Raw water required for generation is received from the TWAD Board and stored at TTPS site. This ground level RCC reservoir is of size 150x150m with three compartments each of 50x50m size. Each compartment is square in cross section and made of reinforced concrete. The depth of water stored is 3m with free board of 0.3m. The capacity of the water tank is 22,500 KL which is used for power generation as well as for mulsifire system. The total storage capacity of GLR available is 1,60,000KL. On 12.07.2015 one of the GLR wall for a length of 21.50mtr has collapsed. It is very urgent to rectify the damaged wall, since raw water is the main source for power generation. Hence this project deals with the causes of failure of GLR wall and remedial measures to be undertaken to put GLR into service.

The GLR was constructed during 1976 to 1979. The size of the GLR is 150 x 50 x 3.60 mtr. and wall thickness is 200mm at top and 610mm at bottom tapered outside. It is found that inner face of the wall is provided with 20mm dia. rod at 140 C/c and outer 10mm dia at 140 c/c. It has three compartments which are interconnected at delivery point. The size of the each tank was approximately 50m x 50m and the delivery point area is approximately 4 mtr. x 2 mtr. The wall is provided with raft slab with outer side protection of 600mm and inside 200mm projection. Also the raft in the inner wall of narrow channel and also the wall of the middle compartment connected with the raft of the outer wall in the diversion cannel portion.

The copy of plan and section of the GLR drawing is enclosed. The water from the two end compartment has to flow through a 90^0 diversion channel before the delivery point.

On 12.07.2015, a portion of the wall toppled as a rigid body near the beginning of diversion channel. The separation occurred at the raft and side wall connection. At the time of collapse, the level of water is approximately 90% of its capacity.

This water tank was out of service after one side wall was collapsed. After several failed visit to assess the damages “in situ” in the walls of the ground level reservoir a diagnoses was made which permitted the cause of the failure to be established. These included an analysis of the stability of the walls by the finite element method. The collapsed wall was broken at three locations using Air compressor concrete breaker and found that the vertical wall collapse was due to shear in all three locations. Also samples were collected. It is found that the quality of concrete is good as well as the reinforcement is also good.

This indicates that the pressure all along the wall is higher than the design pressure at the time of failure. The higher pressure causes the shear failure of rods and the wall was collapsed. The photograph shows the collapsed wall and three places where the concrete and rod samples collected. The higher dynamic pressure may be due to the sudden drawl of water from the compartment.

The paper also describes the solution chosen to stabilize the tank, the tests carried out on the full tank to check the effectiveness of the solution and the construction process. In examining the reports of the earthquake and investigation on the existent ground level water tank in the regions, the failure modes of these types of tanks classified.

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Figure 1 : Collapsed Ground level reservoir Photos

II. LITERATURE REVIEW

F.Trebuna, F.Sicak, J.Bocko – Jan'2009 has studied failure analysis of hot water storage tank. During operation, one of the two tanks has been damaged by collapse of its roof. consequently, analytical, numerical and experimental analysis of possible failure reasons was performed. Extreme stresses in the structure during its operation were determined taking into account shape and geometry imperfections as well as corrosion influence. These values were verified numerically by the finite element method. Extensive experiments performed by strain gauge measurements on the second tank of the same design helped us determine time-dependent stresses in extremely loaded locations during the chosen regimes of operation. The results of analysis allowed us to assess the failure reason and to express the recommendations for further analysis of the non-damaged tank.

Pedro A. Calderon, Jose M Adam, Ignacio Paya-Zaforteza – 2009 has presents failure analysis and remedial measures applied to a RC water tank. An analysis of the failure of a 150,000 m3 reinforced concrete drinking-water tank bult on a hillside. The facility, close to a town of 63,000 inhabitants, was take out of service soon after being filled for the first time after excessive movement was detected in its retaining walls, which threatened collapse. After several field visits to assess the damage "in situ", a diagnosis was made which permitted the causes of the failure to be established. These included an analysis of the stability of the retaining walls by the finite element method considering both the whole soil-structure system and the construction process. The paper also describes the solution chosen to stabilize the tank, the tests carried out on the full tank to check the effectiveness of the solution and the construction process. The paper also describes the solution chosen to stabilize the tank, the tests carried out on the full tank the check the effectiveness of the solution and the lessons that have been learned from the experience.

P.Tiago, E.Julio has studied the Damage of an RC building after a landslide – inspection, analysis and retrofitting. In 2000, due to a substantial landslide, the reinforced concrete (RC) structure of a residential building located in Coimbra, Portugal, was severely damaged. The Firs two levels of three columns were completely destroyed and, as a result, part of the building supported by these, with a dimension in plant of 9.50 x 6.7 2, became a 7.0 m span cantilever with 12 stories.

In this paper, the authors describe the following: the accident; the preliminary assessment of structural conditions: the immediate intervention; the strategy adopted to consolidate the damaged structure; the repair and strengthening works: the loading procedure of the rebuilt part of the structure; and the finishing operations. Some final remarks are also presented, including a proposal for robustness analysis.

This paper describes the response of a residential building erected in the beginning of the 1980's in Coibra, Portugal, subjected to an unforeseen event-the impact caused by a landslide, and describes how it was retrofitted. Lastly, some remarks are presented and a possible approach to enhance the robustness of this type of building is proposed.

The observed low level of damage was attributed to the joint behavior of the RC structure with the outer (non-structural) masonry walls that allowed a strut-tie system to materialize in order to resist the gravity loads. More specifically, in the damaged part of the building, the loads previously supported by the destroyed columns became equilibrated by compression stresses (struts) at the outer masonry walls and by tension stresses (test) at the slabs. In the remaining part of the building, this system originated: a tension

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resultant force at the top slab; a compression resultant force at the bottom slab; and an additional compression at the existing foundations.

In order to assess the safety of the damaged body, it was necessary to quantify the stress state in the resulting structural system. This represented a major difficulty due to the existence of two sets of openings in both lateral walls. Therefore, and since a fast response was requested, it was decided to build a plane linear elastic finite elements model of these walls, including the columns common to the rest of the building.

In the case of an earthquake, tension stresses between the retrofitting steel frame and the original structure will appear, it was decided to strengthen this connection. The destroyed slab was rebuilt adopting a solid concrete slab supported by steel beams normal to the plane of the steel frame. Finally, non-structural finishing operations were carried out and the building was painted. Later, the 2-story parking garage located in the backyard that had vanished was also rebuilt and the building retrofitting was completely accomplished.

Soheil Soroushnia, S. etc has studied Seismic Performance of RC Elevated Water Tanks with Frame Staging and Exhibition Damage Pattern. The current designs of supporting structures of elevated water tanks are tremendously vulnerable under lateral forces due to an earthquake and the Bhuj (India) earthquake provided another illustration when a great number of water tanks with frame staging suffered damage and a few collapsed. Liquid storage tanks and particularly elevated reservoirs including structures with very high significance and elements of the main arteries are considered. In the past earthquakes, it has been identified that the reinforced concrete water tanks under lateral earthquake loads have been extremely susceptible, so that in some cases, these tanks had suffered collapse. According to the studies it was found the current detriment in frame staging, creating plastic hinges n beams and columns and created deep cracks in the columns which are in place to connect container. In this paper, at first by studying the losses occurred in reservoirs during past earthquakes, the reasons for these occurred damages studied and then so provide patterns for these damages in structures. In comparison with reinforced concrete elevated water tanks with shaft staging, the reinforced concrete elevated water tanks with frame staging have shown better seismic behavior to resistant against lateral loads. Considering the fact that damage pattern recognition is necessary to te appropriate analyze in reservoirs in the methods of nonlinear and dynamic, so the main objective of this paper is to obtain the damage pattern in reservoirs for using in analytical methods. A sample of a reinforced concrete elevated water tank, with 900 cubic meters under one earthquake record have been studied and analyzed using dynamic time history analysis. It was determined which failure modes of shear forces in beams and also, failure modes of axial force are dominant in this reservoir.

According to field studies and published reports of earthquakes, it specified that the failure modes of reinforced concrete elevated tanks with frame staging are shear and bending modes in beams, axial mode in columns, cracks in joints and torsion mode. By numerical studies in a reinforced concrete elevated tank with a capacity of 900 cubic meters, it was determined which failure modes of shear forces in beams and also, the failure mode of axial force are dominant in the reservoir. The results showed that there is a good implementation of numerical studies with field studies.

Kurt W. Henkhaus, West Lafayette, IN, spujol@purdue.edu has studied the Simultaneous Shear and Axial Failures of Reinforced Concrete Columns. Axial failure of columns can lead to collapse of a building. Reinforced concrete columns in buildings constructed before modern seismic design codes were enforced may contain inadequate transverse reinforcement. Columns with these ties may experience simultaneous shear/axial failures when subjected to displacement reversals similar to those caused by earthquake ground motions.

In order to prevent the collapse of buildings during an earthquake, engineers must be able to identify columns that may experience simultaneous shear / axial failures. The standard for evaluation of existing buildings, ASCE/SEI 41-06, outlines guidelines to estimate drift levels associated with axial failure for reinforced concrete columns. However, when the procedure outlined by this standard was used to evaluate the reinforced concrete column specimen of several research studies it was found that the standard failed to identify columns prone to simultaneous shear / axial failures. Due to the limited number of known specimens n the literature that have suffered simultaneous failures there is a need for additional testing of specimens that will exhibit this type of behavior.

Primo Allan T ALCANTARA' And Hiroshi IMAI[2] has studied a new approach in the classification of the resulting failure mode, whether shear, bond splitting or flexure, for reinforced concrete columns is presented. Particular emphasis is placed on the analysis of the strain distribution in the main reinforcement based on the truss and arch model theory. The proposed alternative method is compared with results from several series of column experiments. The proposed method is shown to provide a high precision n classifying failure modes with consideration of the presence of inner rows of main bars and axial loading.

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This study is focused on the determination of the resulting failure mode based on the truss and arch model theory. Using the experimental strains the main reinforcement and with proper consideration of the presence of inner main bars and axial loading, it can be concluded that the classification of the resulting failure mode is generally accurate for both the qualitative and quantitative aspects. In the case of shear and flexural failure, results show that the use of the main bar strain distribution is fairly good. On the other hand, for the bond splitting type, an improvement in the calculation of the reinforced concrete column capacity with proper consideration of the inner rows of main reinforcement is deemed necessary.

After several field visits to assess the damage "in situ", a diagnosis was made which permitted the causes of the failure. An analysis of the stability of the walls by the finite element method considering both the whole soil-structure system and the construction process. The paper also describes the solution chosen to stabilize the tank, the tests carried out on the full tank to check the effectiveness of the solution and the construction process. The paper also describes the solution chosen to stabilize the tank, the tests carried out on the full tank the check the effectiveness of the solution and the lessons that have been learned from the experience. The results of analysis allowed us to assess the failure reason and to express the recommendations for further analysis of the non-damaged tank.

III. CONCLUSION

The above report deals with the failure analysis of a 21.5 m section of a wall (eastern side compartment). The given model was analyzed for extreme failure cases (Maximum stress levels) in the structure during operation taking geometry imperfections into consideration using Finite element Methods. The most cost effective solution for re installation of the wall and preventing further failure has been proposed and discussed. Simulation results have validated the proposed design solution.

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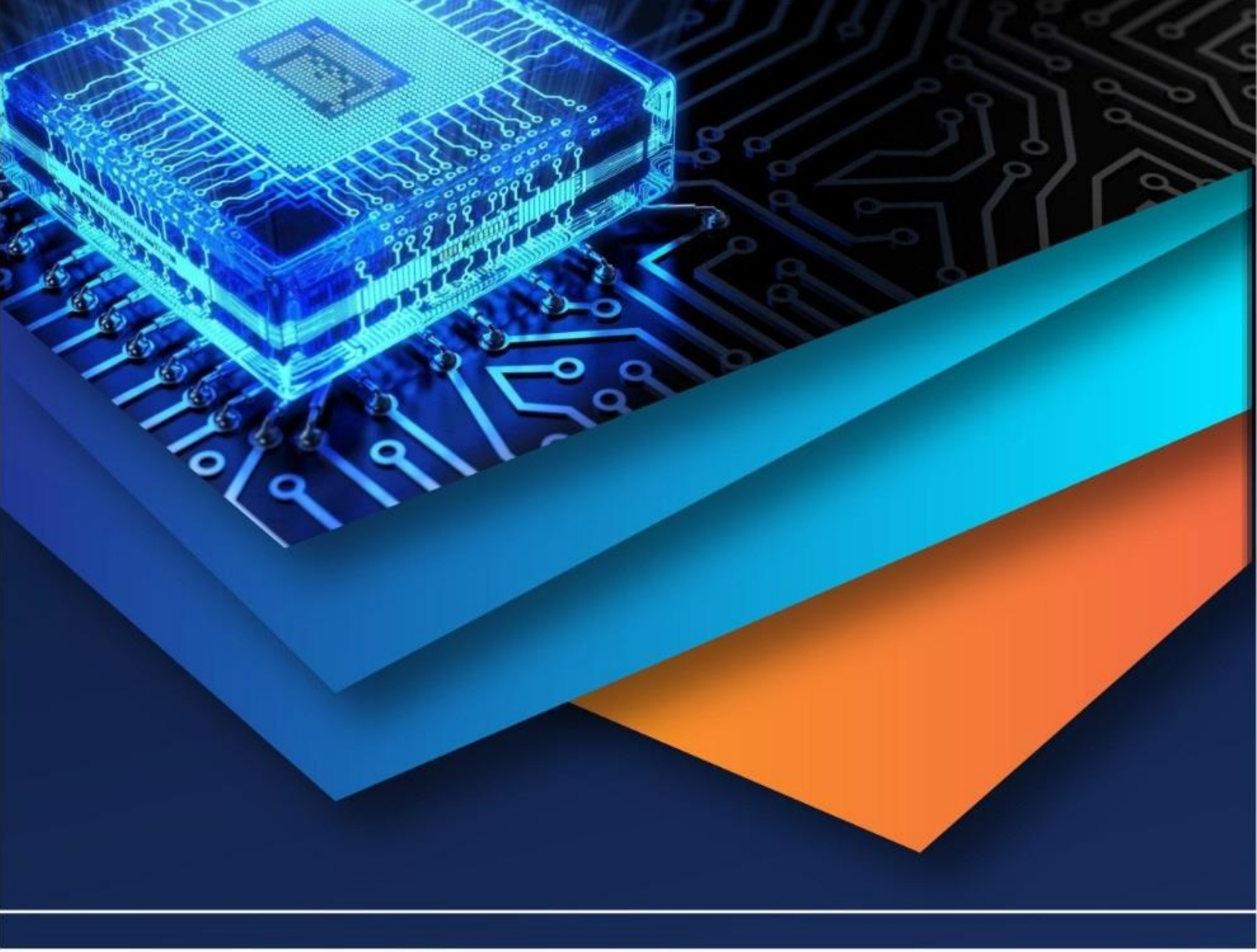

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