

Design of Prestressed Concrete Tank : A Review

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Abstract : Start from history of prestressed concrete tank present work focus on different conditions (i.e. leakage, crack of member) and behavior of Prestressed concrete tank which can be used for storing the high temperature liquid. The main components of prestressed concrete tank is divided into 3 parts- Tank floor, Tank wall, Roof slab. This paper presents advance research made on components prestressed concrete tank which helps for designing the tank as it is not included in IS 3370. This paper also deals with seismic effect on prestressed concrete tank.

Keywords : Prestressed concrete, seismic effect, tank components.

INTRODUCTION

To provide a detailed review of the literature related to modeling of structures in its entirety would be difficult to address in this chapter. A brief review of previous studies on the application of the prestressed concrete tank is presented in this section. This literature review focuses on recent contributions related to prestressed concrete tank and past efforts most closely related to the needs of the present work. Some of the historical works which have contributed greatly to the understanding of the concept of prestressing in structures are also described. First, a brief review of the historical background is presented. This literature is very useful in understanding the design of prestressed concrete tank by considering various condition and different types of loading.

HISTORICAL WORKS

Circular prestressed concrete tanks have been in various stages of development and perfecting for decades. Early systems used in the United States called for the use of cast-in-place concrete in the core wall of the tank and steel rods with turnbuckles as the prestressing elements. Although theoretically this approach to circumferentially prestressed concrete tanks was sound, deficiencies in placement of concrete together with insufficient residual compression in the core wall brought about modifications and improvements. In the early 1930's, the matter was fully understood when J.M. Crom, Sr. began the development of what was later to become the composite system of tank wall construction, using a steel shell cylinder with shotcrete encasement for the core wall, and high strength wire for the prestressing elements. Successors to Mr. Crom have over the years improved and perfected the

composite system for tank wall construction. These improvements have included the selection of better construction materials, together with ever-improving design and construction procedures. Consideration was given to:

1. Ready-mixed concrete and pneumatically applied shotcrete in combination with a steel shell diaphragm.
2. Prestressing rods, cables and high-strength wire.
3. Emulsion type sealants, polysulphides, polyurethanes, and epoxies for sealing the steel shell membrane.
4. Wall base joints using conventional waterstops; special bearing pad and waterstop combinations; and monolithic floor-wall joint connections.

Emerging from all of these was the development of the prestressed concrete tank:

1. The steel shell diaphragm was found to be the most foolproof means for making the core wall watertight.
2. Shotcrete with its high cement factor and low water/cement ratio had greater corrosion inhibition, impermeability and strength than conventional concrete.
3. High-strength wire could be used to more accurately apply prestressing forces and could be better protected from corrosion and mechanical damage.

In the early 1950's, J.M. Crom, Sr. and three associates, Ted Crom, Jack Crom, Jr., and Frank Bertie, established The Crom Corporation, with headquarters in Gainesville, Florida, for the prime purpose of perfecting the design and construction techniques for prestressed concrete tanks. Since then, their successors have continued the tradition of excellence initiated by the company's founders. The company has constructed in its own name and with its own forces over 3,300 circular and elongated prestressed concrete tanks.

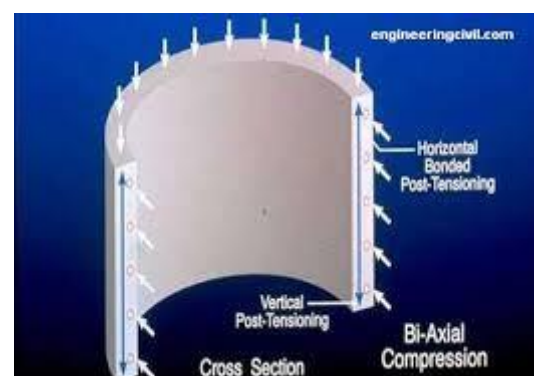


Fig 1: Cross Section of Prestressed concrete tank

TANK FLOOR

A.Rashed, David M. Rogowsky & A.E.Elwi [1] carried out an experimental phase of research program that aims to investigate the concept of partial prestressing in liquid containment structure. Partially prestressed specimen showed improved crack width & distribution under both pure flexure & pure tensile loading over the fully prestressed members & reinforced concrete members which prevent the leakage & crack of the members.

In prestressed concrete structures, such as storage tanks for liquefied gases, the thermal restraint was determined with the mechanical strains and FEM results using non-linear elastic cross-section analysis according to EN 1992-1-1:2011. The results obtained from above was compared by Sander Meijers Johan Van Sloten, Jaop Strik, John Kraus to those resulting from staggered heat flow and non-linear elastic FEM analysis with smeared cracking.

TANK WALL

An efficient numerical method of analysis for environmental (thermal, shrinkage and swelling) effects in circular, concrete, liquid storage thin walled tanks under conditions of axial symmetry studied by Edmund S. Melerski [3] The interaction wall & plate elements was introduced in FORCE METHOD – type procedure by utilizing conditions of compatibility of displacements at the wall- plate junctions. The analysis technique was applicable to a wide range of circular cylindrical tank systems in contact with a variety of support media.

Navakumar Poologasingam, Hiroshi Tatematsu, Diasule takuwa & Augusto Duque [7] dealt with full- containment liquefied natural gas (LNG) storage tank concrete outer wall under a spill condition was performed using a nonlinear finite element analysis technique. The design criteria included a serviceability limit state (SLS) condition considering reinforcement stress, crack width, compression zone thickness & compression zone stresses. This parametric study also focused on tension softening & tension stiffening of reinforced concrete as well as modeling reinforcement discontinuities.

ROOF SLAB

Bryan P. Strohman & Atis A. Liepins [2] investigated stability of the roof of prestressed concrete wastewater treatment tank. The roof was designed by considering 1/6 rise to span ratio, 2ft thickness & 18 ft diameter central opening at its pole. Bifurcation from the symmetric deformation to a nonsymmetric buckling mode below the limit point was investigated with a different finite element model using NASTRAN & results were compared to form the design equation for dome thickness in ACI 350 which was used to calculate dome load capacity.

In the precast prestressed concrete tank the temperature of heated water storage could be increased from 30 to 95° c by adopting some recommendation and consequent design suggested by Michael j. Minehane and Brian D.o'Rourke [6]. The feasibility & implications of thermal storage using cylindrical concrete reservoirs was investigated. Creep of concrete, bond strength & stress relaxation are most important factors considered when temperature of heated

liquid exceed 30°C in any instance.

SEISMIC EFFECTS ON PRESTRESSED CONCRETE TANK

Based on two international well accepted design standards, Eurocode 8 part-4 Tank, silos & pipelines & API standard 650 – seismic design of storage tanks, the structural response of seismically excited vertical circular cylindrical tanks was analysed by Ingolf Nachtigall, Norbert Gebbeken, Jose Luis Vrrutia-Galicia [4] from a novel perspective. The basic assumptions made for design that tank containing liquid behaves like a cantilever beam without deformation of its cross-section was obsolete. Emphasis was laid on the analysis of the fundamental frequencies for the tank-liquid system. But from the examples it observed that most of the failures was caused by resonance effect which were not considered in EC-8 nor API-650 standard.

Jie Li, Hua- Ming Chen, Jian- Bing Chen [5] tested a 1:8 scaled model of prestressed concrete egg- shaped digester for seismic response considering different conditions. The natural frequency, seismic responses including the amplification factor of acceleration (AFA), the relative displacement & the strain stress of the empty model digester (EMD1), model digester filled with half volume of water (WMD) & empty model digester with water (EMD2) were investigated based on the test results.

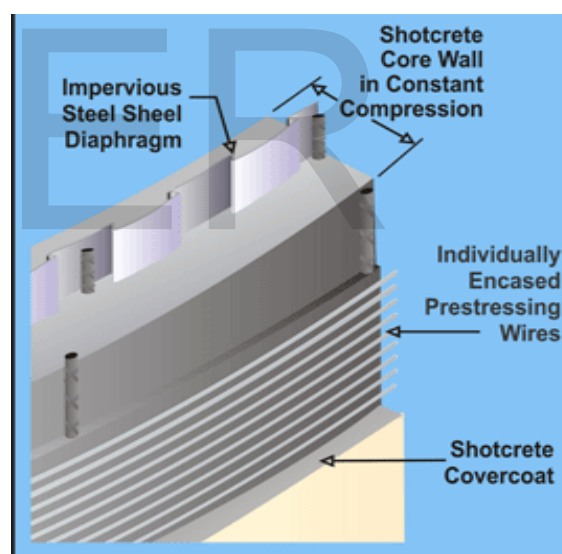


Fig 2: Details of Prestressed concrete tank

SCOPE OF IS CODE

IS-3370 standard does not cover the requirements for concrete structures for storage of hot liquids and liquids of low viscosity and high penetrating power like petrol, diesel, oil, etc. This standard also does not cover dams, pipes, pipelines, lined structures and damp- proofing of basements. Special problems of shrinkage arising in the storage of non-aqueous liquids and the measures necessary where chemical attack is possible are also not dealt with. The recommendations, however, may generally be applicable to the storage at normal temperatures of aqueous liquids and solutions which have no detrimental action on concrete and steel or where sufficient precaution are taken to ensure

protection of concrete and steel from damage due to action of such liquids as in the case of sewage.

CONCLUSION

The detail review of the research work pursued by the various researchers till date is presented. From this literature it is conclude that prestressed concrete tank can use for storing the liquids in high seismic region. Partial prestressing is effective for improving the crack of the member in the tank over reinforced concrete tank. The high temperature liquid can be store in prestressed concrete tank.

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