International Journal of Scientific Research and Engineering Development-– Volume 2 Issue 4, July – Aug 2019
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Analysis and Design of Water Tank Employing STAAD. Pro for Cost Optimization

Himanshu Dwivedi
M.Tech. Scholar, Structural Engineering, Dept. of Civil Engineering, BIT, Durg (C.G.),India

Dr. M.K. Gupta
Prof. and Head of Department, Dept. of Civil Engineering, BIT, Durg (C.G.), India

Abstract – *Water is the basic need for all the living organisms to survive. Portable water is essential for good health of human beings. It is important to supply portable water to every individual and every community; hence it is very essential to store water. Water is generally stored in tanks and later the stored water is supplied to every community through pipelines.*
In this project, we have planned and designed an circular reinforced cement concrete tank. A circular water tank is manually designed. It is further analyzed using the premiere analysis software STAADPRO. The design and detailed drawings are presented in this project work.
Limit state design method for water retaining structure was not adopted so far as liquid retaining structure should be crack free. However, This edition of Indian standard adopts limit state method mainly considering two aspects. Firstly it limits the stresses in steel so that concrete is not over stressed and in second aspect it limits the cracking width. Structure has been designed using the LSM , as the LSM gives less area of reinforcement of steel and hence the check for crack width has been done. Further to make the structure most economical STAAD.Pro is used. For quick cost prediction of tanks, this study therefore examines the cost effectiveness in terms of amount of materials. At the end of the project it concludes that total amount of concrete and steel used for construction of circular tank.

INTRODUCTION - A water tank is used to store water to tide over the daily requirement. In the construction of concrete structure for the storage of water and other liquids the imperviousness of concrete is most essential . Liquid storage tanks are commonly used in industries for storing chemicals, petroleum products, etc. and for storing water in public water distribution systems. The petroleum product such as petrol, diesel oil, etc. are likely to leak through the concrete walls, therefore such tanks need special membranes to prevent leakage. Reservoir is a common term applied to liquid storage structure and it can be below or above the ground level.

Reservoirs below the ground level are normally built to store large quantities of water whereas those of overhead type are built for direct distribution by gravity flow. This project gives in brief, the theory behind the design of liquid retaining structure i.e. Circular tank (Elevated circular water tank with domed roof and conical base) using limit state method. The permeability of any uniform and thoroughly compacted concrete of given mix proportions is mainly dependent on water cement ratio. The increase in water cement ratio results in increase in the permeability .The decrease in water cement ratio will therefore be desirable to decrease the permeability, but very much reduced water cement ratio may cause compaction difficulties and prove to be harmful also. Design of liquid retaining structure has to be based on the avoidance of cracking in the concrete having regard to its tensile strength. Cracks can be prevented by avoiding the use of thick timber shuttering which prevent the easy escape of heat of hydration from the concrete mass. The risk of cracking can also be minimized by reducing the restraints on free expansion or contraction of the structure. Limit state design method, though semi-empirical approach, has been found to be the best for the design of reinforced concrete structures over the elastic theory of design where the level of stresses in concrete and steel are limited so that stress-deformations are taken to be linear.

Use of small size bars placed properly, leads to closer cracks but of smaller width. The risk of cracking due to temperature and shrinkage effects may be minimized by limiting the changes in moisture content and temperature to which the structure as a whole is subjected. The risk of cracking can also be minimized by reducing the restraint on the free expansion of the structure with long walls or slab founded at or below ground level, restraint can be minimized by the provision of a sliding layer.

This can be provided by founding the structure on a flat layer of concrete with interposition of some material to break the bond and facilitate movement.In case length of structure is large it should be subdivided into suitable lengths separated by movement joints.
Where structures have to store hot liquids, stresses caused by difference in temperature between inside and outside of the reservoir should be taken into account.The coefficient of expansion due to temperature change is taken as 11 x 10-6 /° C and coefficient of shrinkage may be taken as 450 x 10-6 for initial shrinkage and
200 x 10-6 for drying shrinkage.

STAAD.Pro- STAAD.Pro is a general purpose structural tool utilized for the purpose of scrutiny and construction of primary applications of the building industry such as commercial buildings, public welfare structures like water tanks, storage tanks, highways structures, petrochemical plants, business structures, dams, retaining walls, turbine foundations, channels and other embedded frameworks. It has the ability to use various forms of scrutiny's from the traditional 1st order static analysis, 2nd order p-delta analysis, geometric non-linear analysis, Pushover analysis(Static-Non Linear Analysis) or a buckling analysis.
It can also make use of various forms of dynamic analysis from modal eradication to time history and response spectrum study. STAAD.Pro was initially developed by Research Engineers International at Yorba Linda, CA in 1997. Recently in 2005 the Research Engineers International was procured by Bentley Systems [14]. From that point onwards, STAAD.Pro has become a vital part of Bentley Systems, who has been working towards continuous enhancements in its most its various releases.

LITERATURE REVIEW- A brief review of previous studies on the application of the different methods to the analysis of liquid storage tanks is presented is this section. This literature review focuses on recent contributions related to analysis of liquid storage tanks, past efforts most closely related to the needs of the present work.

Jindal Bharat Bhushan, March (2012) The conclusion of this paper is that the size of member remain same for working stress method by both IS 3370(1965) or 3370(2009)and Requirement of area of steel increased in IS:3370(2009) as the allowable stresses in steel were lower. And the size of member or requirement of steel decreases for LSM by 3370:2009 as compare WSM by IS 3370:2009 or 3370:1965

Neeta K. Meshram, Dr.P.S.Pajgade, August(2014) The steel quantity is more for a reservoir by WSM as compare to LSM. And if we want to design a water tank by LSM, the crack width calculation is necessary. The recent introduction of the LSM of design in IS:3370
Part 2:2009 and IS 456 : 2000 with crack width limit of 0.2 mm and in line with international codes of practice is found to results in more rational and economical design method

R.V.R.K.Prasad and Akshaya B.Kamdi (2012), Storage elevated water tanks are used to store water. BIS has brought out the revised version of IS 3370 (part-1& 2) after a long time from its 1965 version in year 2009. In this revision important is that limit state method is incorporated in the water tank design. Design of water tanks by LSM is most economical as the quantity of material required is less as compared to WSM. Water tank is the most important container to store water therefore, Crack width calculation of water tank is also necessary.

M. V. Waghmare and S.N.Madhekar (2013) studied behaviour of tank under sloshing effect. Different parameters have been considered such as height of container, depth of water in tank (30%, 50%, 70% and full) and height of staging etc. It is observed that Sloshing of water in tank depends not only on the volume of water in tank but also on staging height and aspect ratio (h/D).
B.V. Ramana Murthy, M Chiranjeevi [4] had done the "DESIGN OF RECTANGULAR WATER TANK BY USING STAAD PRO SOFTWARE". In this paper he said that this mini project is conducted for a period of 15 days from 21-05-2010 to 07-06-2010 to have complete practical knowledge of various techniques and problems faced in the field. A different topic
like Construction Aspects, Design Parameters, Details of Formwork, Details of reinforcement, Process of Water Treatment Plant and Execution have been dealt with in the course of our miniproject.

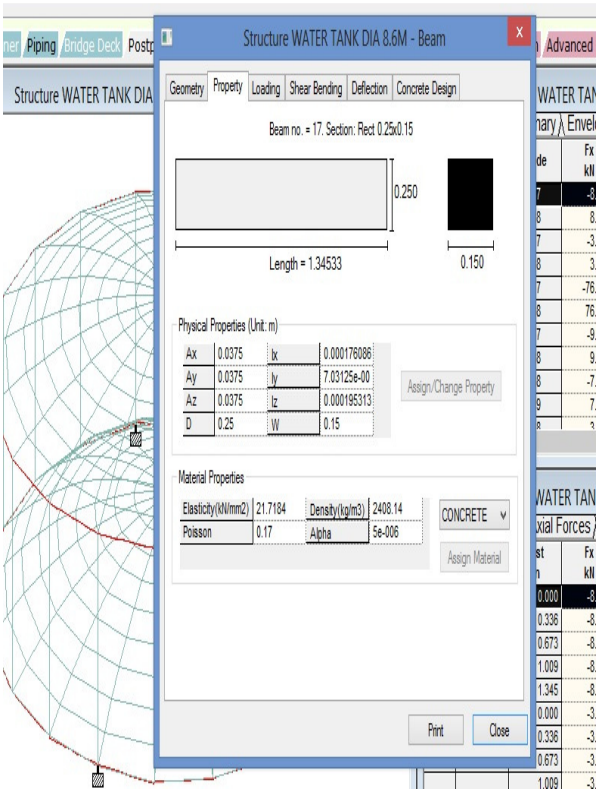
Nallanathel, M,Ramesh. B, Jagadeesh. (2018) , showed that corner stresses and maximum shear and bending stresses are less in case of circular tanks than remaining other designs and the shapes of water tanks plays vital role in the stress distribution and overall economy and by using Staad pro, the results obtained was very accurate than conventional results.

PROBLEM IDENTIFICATION:

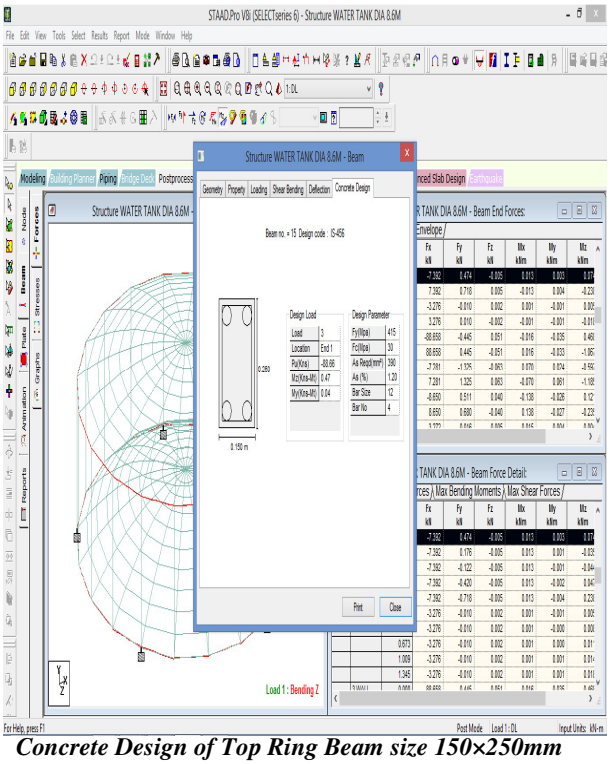
To design the circular water tank by study of provisions in IS 3370 (2009), Double dome type of water tank was taken. Then it was designed manually following Limit State Method. After that STAAD.Pro is used to match the design and make structure optimize and economical by trying different dimension for same capacity tank.
For quick cost prediction of tanks, this study therefore examines the cost effectiveness in terms of amount of materials

Dimensions of three different Circular Water Tank

Serial No.	Dimension's of Water Tank	Value	Units
1.	Circular Water Tank 1 Diameter of Tank Height of Cylindrical Portion of Tank	 7 4.5	 m m
2.	Circular Water Tank 2 Diameter of Tank Height of Cylindrical Portion of Tank	 8.6 3.2	 m m
3.	Circular Water Tank 3 Diameter of Tank Height of Cylindrical Portion of Tank	 10 2.8	 m m



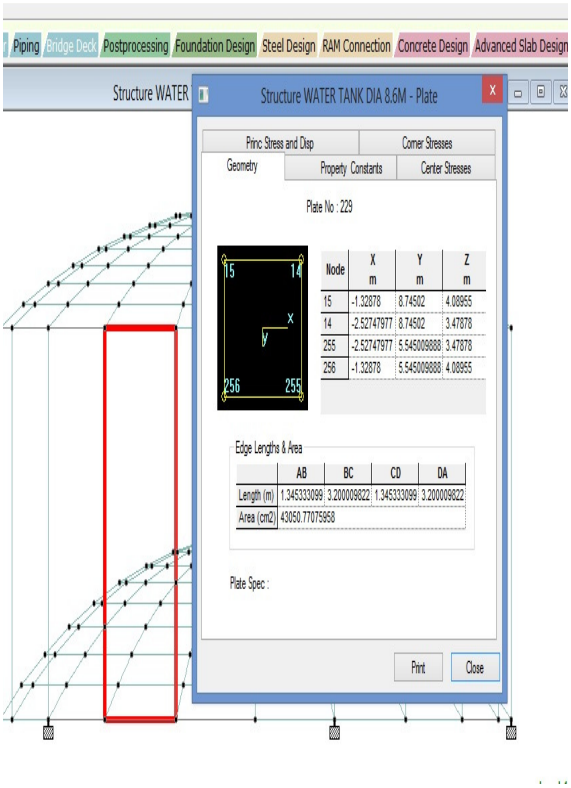
Property of Top Ring Beam size 150×250mm



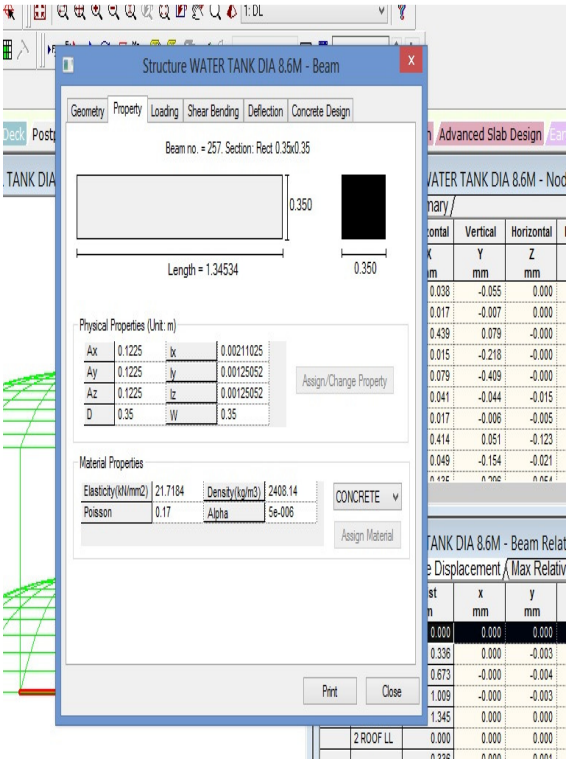
Concrete Design of Top Ring Beam size 150×250mm


```
      M30                Fe415 (Main)            Fe415 (Sec.)

 LENGTH:  1345.3 mm   CROSS SECTION:  150.0 mm X  250.0 mm  COVER: 40.0 mm

 ** GUIDING LOAD CASE:    3 END JOINT:    11  TENSION COLUMN

-------------------------------< PAGE 46 Ends Here >--------------------------
  STAAD SPACE                                              -- PAGE NO.   47


 REQD. STEEL AREA   :      390.00 Sq.mm.
 REQD. CONCRETE AREA:    37110.00 Sq.mm.
 MAIN REINFORCEMENT : Provide   4 - 12 dia. (1.21%,    452.39 Sq.mm.)
                      (Equally distributed)
 TIE REINFORCEMENT  : Provide  8 mm dia. rectangular ties @ 150 mm c/c

 SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)
 ----------------------------------------------------------
 Puz :    622.37   Muz1 :      5.70   Muy1 :      3.49

 INTERACTION RATIO: 0.82 (as per Cl. 39.6, IS456:2000)

 SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)
 ----------------------------------------------------------
 WORST LOAD CASE:     3
```

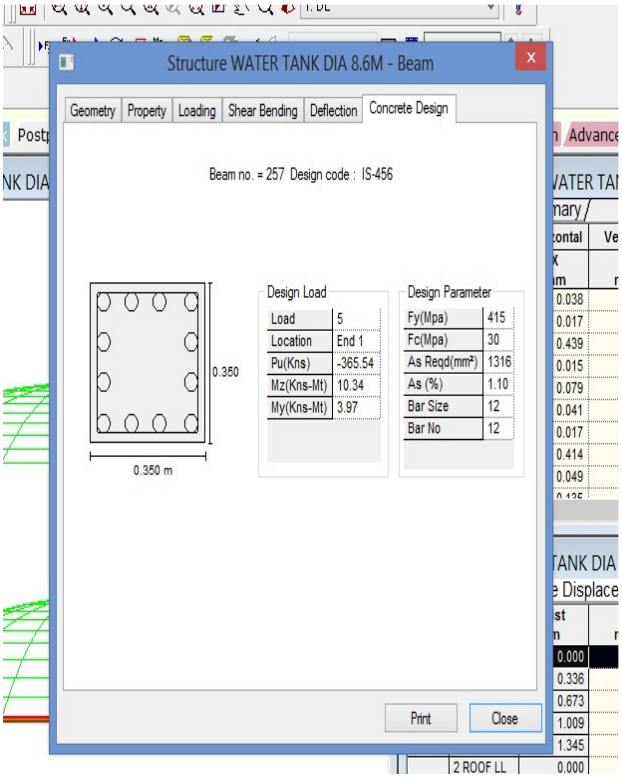
Report of Top Ring Beam size 150×250mm



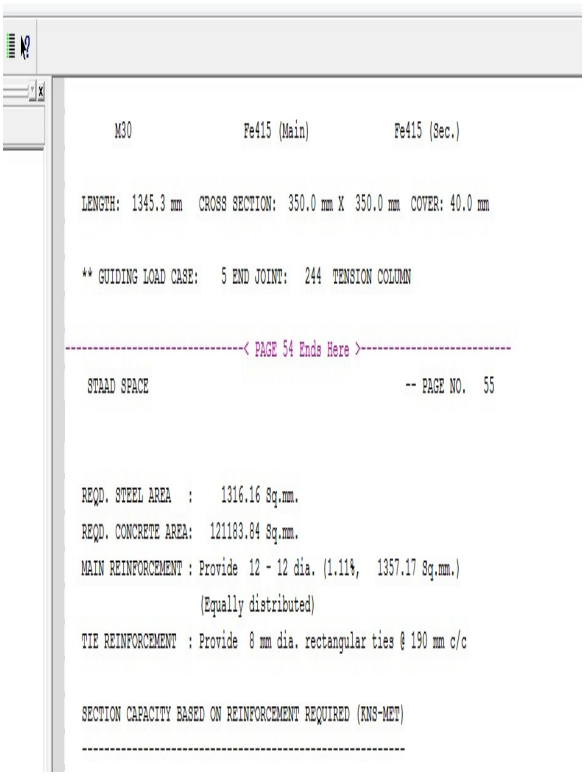
Geometry of Cylindrical wall of thickness 100mm



Property of Bottom Ring Beam size 350×350mm



Concrete Design of Bottom Ring Beam size 350×350mm



M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 1345.3 mm CROSS SECTION: 350.0 mm X 350.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 5 END JOINT: 244 TENSION COLUMN

----------< PAGE 54 Ends Here >----------

STAAD SPACE -- PAGE NO. 55

REQD. STEEL AREA : 1316.16 Sq.mm.
REQD. CONCRETE AREA: 121183.84 Sq.mm.
MAIN REINFORCEMENT : Provide 12 - 12 dia. (1.11%, 1357.17 Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)

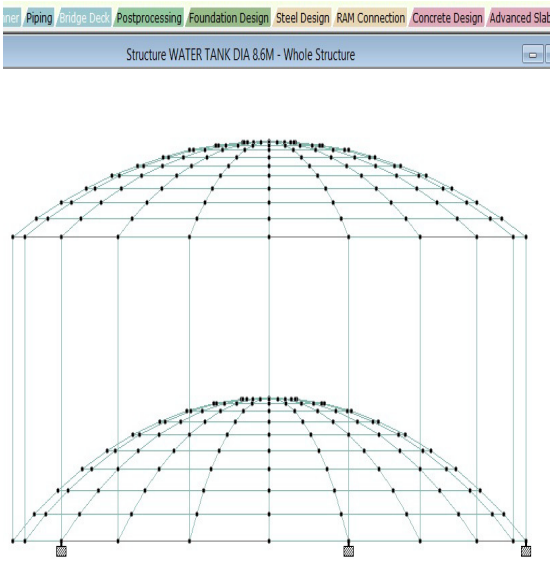
Report of Bottom Ring Beam size 350×350mm

METHODOLOGY

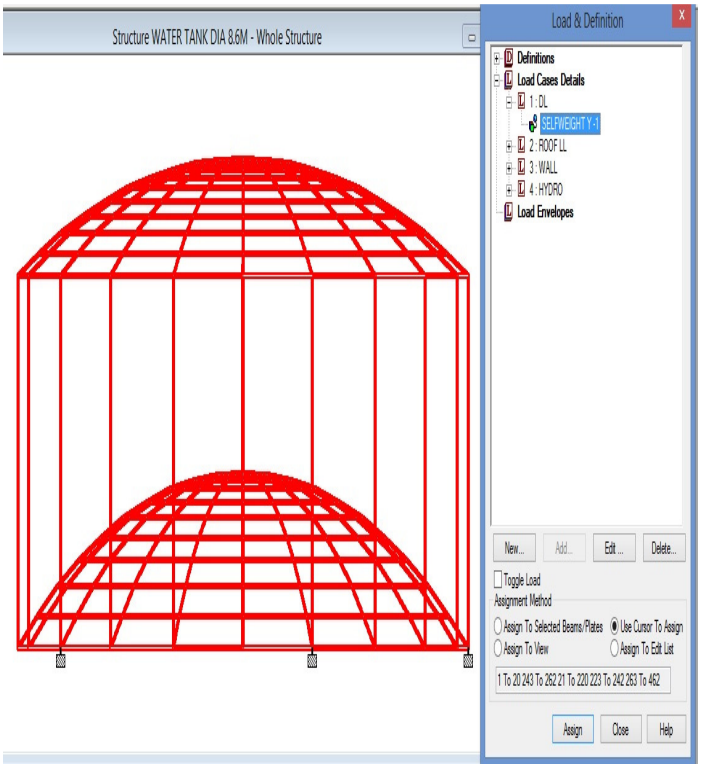
Limit state design methods enable the possible modes of failure of a structure to be identified and investigated so that a particular premature form of failure may be prevented. Limit state may be ultimate' or 'serviceability'. In UK, limit state design has been used successfully for over 20 years for the design of liquid retaining structures. Elastic design is a simpler process, but with the widespread use of computer facilities, there is no difficulty in preparing limit state designs. There are two important factors to be noted in the design of an R.C.C. tank to have necessary strength as well as imperviousness. It is necessary to prevent shrinkage cracks in the tank walls. The WSM gives more area of reinforcement steel hence in WSM there is no need to check the crack width. But the LSM gives less area of reinforcement of steel and hence the check for crack width has to be done and the maximum limit as per IS:456-2000 is 0.2mm..

Under no circumstances shall the use of porous aggregates, such as slag. crushed over burnt brick or tile, bloated clay aggregates and sintered f1yash aggregates, be allowed for parts of structure either in contact with the liquids on any face or enclosing the space above the liquid.

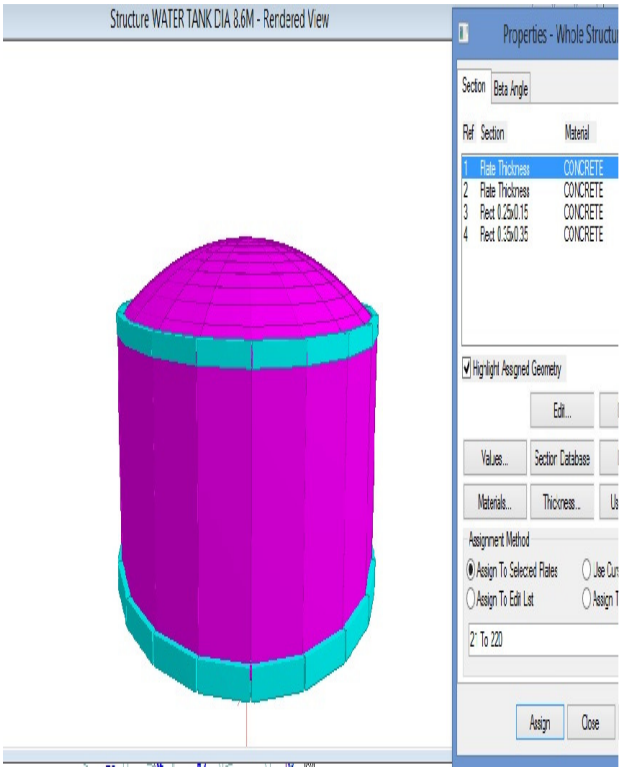
Joint tillers, joint sealing compounds, and water bars shall conform to the requirements of relevant Indian Standards. Other jointing materials such as polyurethane and silicone based sealants may also be used provided there are satisfactory data on their suitability. The jointing materials used shall not have any adverse effect on the quality ofliquid to be stored.



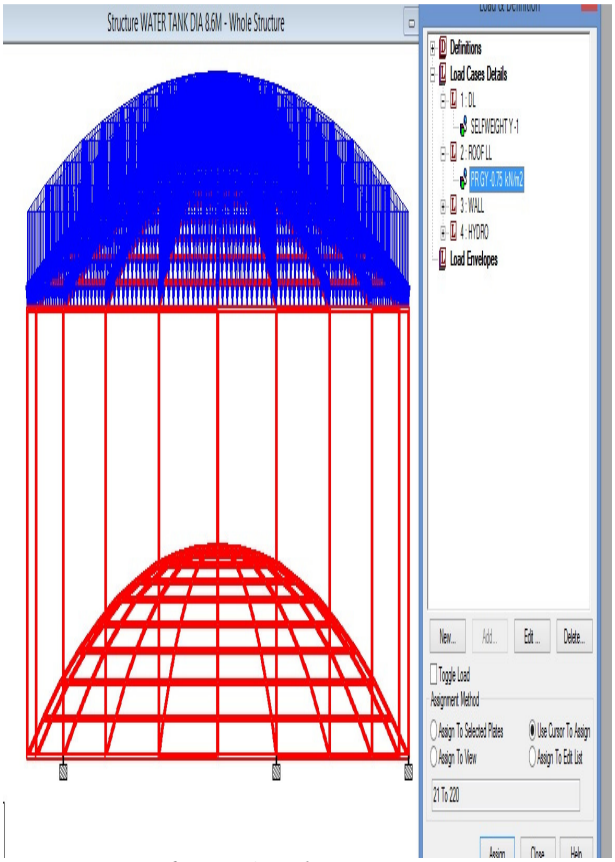
Geometry of Circular Water Tank



DL assigned to Circular Water Tank Structure

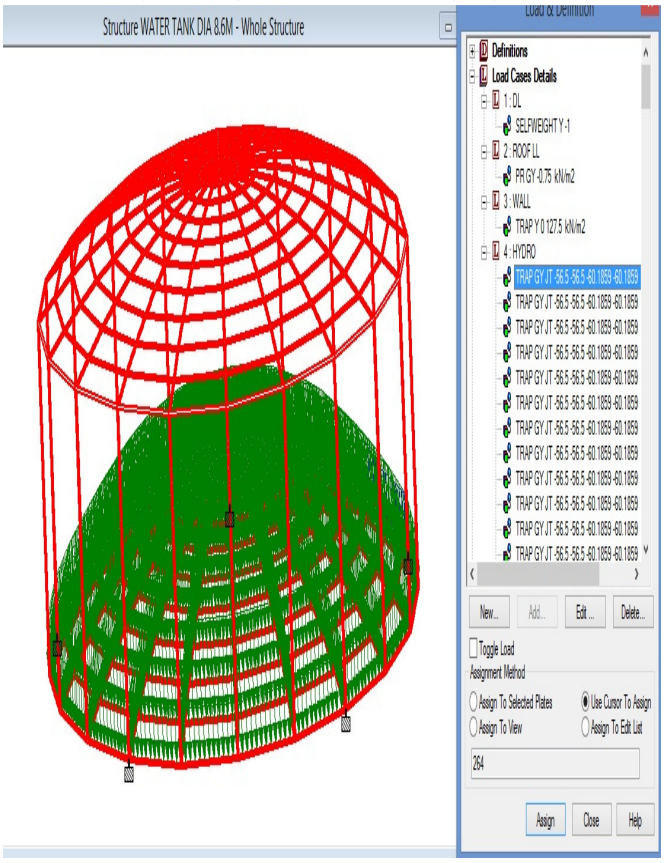


Property assigned to Beams and Plates

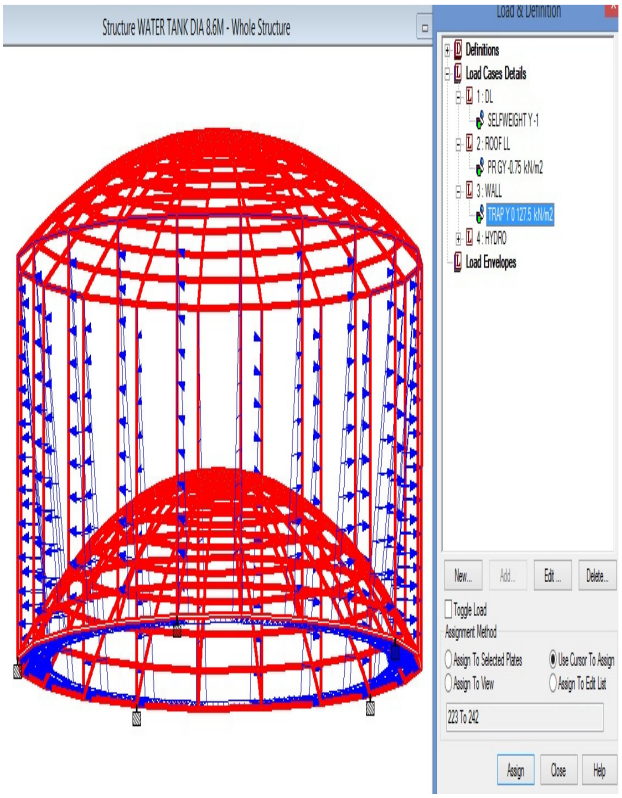


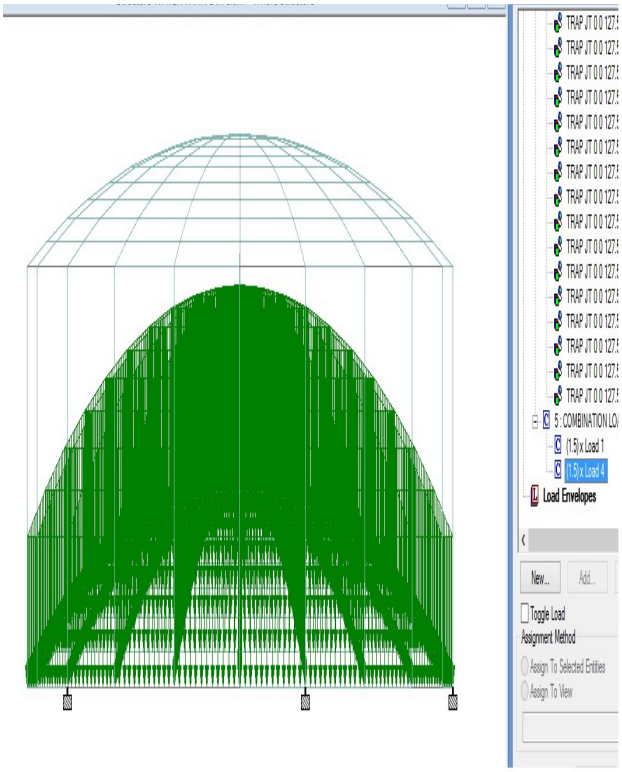
Roof LL assigned to Top Dome

Load assigned to Cylindrical Wall acting region

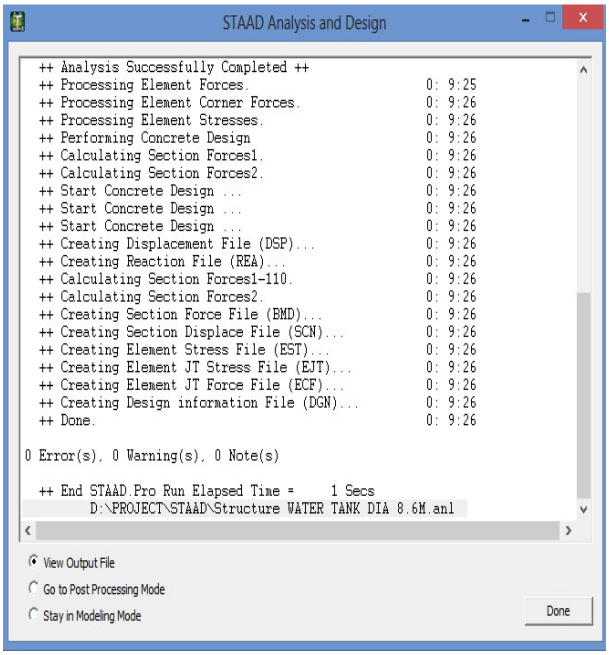


HydroStatic Pressure assigned to Bottom Dome region





Combined load case assigned to Bottom Dome region



STAAD Analysis and Design of Circular Water Tank Structure.

Estimation of Volume of materials by the software:
After applying all the loads on the structure, the STAAD.Pro software gives us the result as the selected code of design. In this design we select IS 456:2000 for the purpose of designing. As we know that STAAD.Pro gives the quantity of concrete and steel reinforcement in beams, columns and plates in detailed report.

```
************** CONCRETE TAKE OFF **************

      (FOR BEAMS, COLUMNS AND PLATES DESIGNED ABOVE)

NOTE: CONCRETE QUANTITY REPRESENTS VOLUME OF CONCRETE IN BEAMS, COLUMNS, AND PLATES DESIGNED ABOVE.
      REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND COLUMNS DESIGNED ABOVE.


TOTAL VOLUME OF CONCRETE =       4.0 CU.METER

                BAR DIA       WEIGHT
                (in mm)       (in New)
                --------      --------
                   8             1356
                  10             1589
                                ------------
                *** TOTAL=        2945

71. FINISH
```

STAAD.Pro Report of the Structure of Water Tank of dia 7m


```
************** CONCRETE TAKE OFF **************

(FOR BEAMS, COLUMNS AND PLATES DESIGNED ABOVE)

NOTE: CONCRETE QUANTITY REPRESENTS VOLUME OF CONCRETE IN BEAMS, COLUMNS, AND PLATES DESIGNED

REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND COLUMNS DESIGNED

TOTAL VOLUME OF CONCRETE =        8.6 CU.METER

    BAR DIA          WEIGHT
    (in mm)          (in New)
    --------         --------
       8               2374
      10               1634
      12                937
      20               2603
                   ------------
    *** TOTAL=         7548
```

STAAD.Pro Report of the Structure of Water Tank of dia 8.6m

```
************** CONCRETE TAKE OFF **************

(FOR BEAMS, COLUMNS AND PLATES DESIGNED ABOVE)

NOTE: CONCRETE QUANTITY REPRESENTS VOLUME OF CONCRETE IN BEAMS, COLUMNS, AND PLATES DESIGNED

REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND COLUMNS DESIGNED

TOTAL VOLUME OF CONCRETE =        5.7 CU.METER

    BAR DIA          WEIGHT
    (in mm)          (in New)
    --------         --------
       8               1968
      10               1932
      12                409
                   ------------
    *** TOTAL=         4309
```

STAAD.Pro Report of the Structure of Water Tank of dia 10m

Summary of Quantity of Structure

S. No.	Work description	Quantity	Unit
1.	**Dia Water Tank 7m Height Of Cylindrical Portion 4.5m** (A) Volume of concrete in beams, columns, and plates of the structure. (B) Reinforcing steel in beams and columns designed above, reinforcing steel in plates	4 300	Cubic meter Kg
2.	**Water Tank of dia 8.6m Height Of Cylindrical Portion 3.2m** (A) Volume of concrete in beams, columns, and plates of the structure. (B) Reinforcing steel in beams and columns designed above, reinforcing steel in plates	8.6 769	Cubic meter Kg
3.	**Water Tank of dia 10m Height Of Cylindrical Portion 2.8m** (A) Volume of concrete in beams, columns, and plates of the structure. (B) Reinforcing steel in beams and columns designed above, reinforcing steel in plates	5.7 440	Cubic meter Kg

RESULTS:

- In the methodology we have taken three different structures of circular water tanks, for this we initially designed the water tank manually following IS 3370-2009. Using this we then proceed to design and analyse the structure through STAAD.Pro
  Using certain dimension for same capacity, circular water tank structure were designed.
- As we know that in structure, beams and columns contributes to almost the entire load of the building by transferring dead load and live load of the

structure. As a result we then proceeded to design the structure in STAAD.Pro.

- As the capacities increase, the amounts of materials for the structure also increases. But, a rather non-perfect proportionality result was seen, i.e. a proportional increase in the capacity would not, necessarily lead to a proportional increase in any of the materials required.
- After this detailed analysis a report was generated for all kinds of water tanks:
  - We observed that all members of the structure are safe. STAAD.Pro gives cumulative volume of quantity of concrete for beams and plates.
  - Also, in case of steel STAAD.Pro gives cumulative weight of reinforcement steel for beams and plates only.
  - Taking the Table given above into consideration we have observed that volume of concrete for water tank of dia 8.6m is 8.6 cubic meter, water tank of dia 10m is 5.7cubic meter and for water tank of dia 7m is 4cubic meter.
  - Taking the Table given above into consideration we have observed that weight of steel for water tank of dia 8.6m is 769kg, water tank of dia 10m is 440kg and for water tank of dia 7m is 300kg.

As we know that steel is the most costly material in the building industry, further concrete is also said to be a major costly material of the building and so by using three different circular water tank of different dimension for same capacity we can optimize the structure cost.

REFERENCES

- B.V. Ramana Murthy, M Chiranjeevi."Design of Rectangular Water Tank by Using Staad Pro Software". – International Journal of Computer Science information and Engg., Technologies, issue 6-volume 1, series 3, ISSN 2277-4408.
- M.V Waghmare and S.N Madhekar, " Behavior of elevated water tank under sloshing effect", *International Journal of Advanced Technology in Civil Engineering,*(2013), Vol.2 (1), (51-54)
- Nallanathel. M,Ramesh. B, Jagadeesh. L(2018). "Design and Analysis of Water Tanks using Staad Pro". International Journal of Pure and Applied Mathematics,Vol.119,No.17,3021-3029 pp, ISSN: 1314-3395 (on-line version). url: http://www.acadpubl.eu/hub/ Special Issue.
- **Sagar Mhamunkar,** Design and Analysis of Overhead Water Tank at Phule Nagar, Ambernath International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 06 Issue: 04
- Krishna Raju N. (2009), Structural Design & Drawing Reinforced Concrete and Steel, 3rd edition, *Universities Press, India.p.95.*
- IS : 3370:2009, Concrete Structures for the Storage of Liquids – Code of Practice

