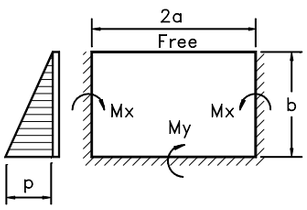
The Design of Concrete Tanks

Robin Atkinson of CCP Consulting Engineers compares traditional methods of designing reinforced concrete rectangular tanks with modern computer based methods and discusses how existing software can be developed to make the whole design process more efficient.

TANKS have traditionally been designed by reference to published tables derived from elastic thin plate theory.

These tables cover isolated rectangular panels with various proportions, and edge conditions and loading as shown below. Interpolation is required and the values cannot represent the real interaction between adjacent walls and the base. The base rarely provides the assumed fixity and it is not easy to calculate these affects accurately.



Moment = (Coefficient)(pb^2)
Reaction = (Coefficient)(pb)

Engineers now have access to powerful computers and suitable software which should enable them to design tanks more accurately as complete structures and show worthwhile savings. This has not become a routine method however because the time spent generating the structure and loadings and dealing with the output can be such that many tanks can still be designed economically and quicker by hand.

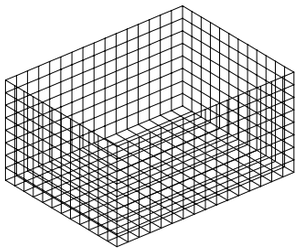
It is pointless to aim for the extreme accuracy of a “Perfect Analysis” for a concrete structure when the variability of factors such as ground conditions and panel thickness can affect the results by as much as 20% in some cases. The aim, therefore, is to develop a practical and quick theoretical analysis procedure that can give results to between 5% and 10% of a “Perfect Analysis”.

The following methods can meet these criteria and show that a balance can be struck between accuracy and practicality.

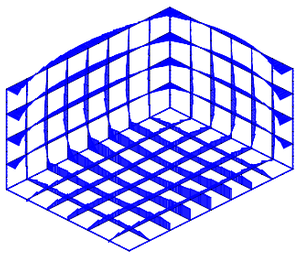
Grillage Method

This method subdivides each wall and slab panel of the tank into a grillage of rectangular beams which are connected at the panel junctions.

The beams are given properties relating to their orientation, spacing and the panel thickness. The support conditions are applied at the base panel nodes as springs which can be specified to suit piles or the stiffness of the ground. The loads are applied onto the beams.



The above model produces acceptably smooth moment diagrams and the results have an error of less than 4%. They can be plotted as shown in the cut-away view below or against sections through the structure. The values must be divided by the beam width to produce values per metre width.

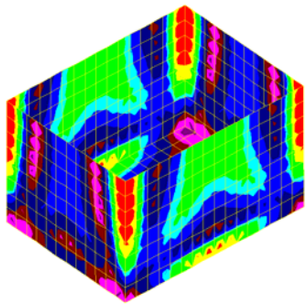


The grillage pattern can be made coarser to reduce the input time and model size but at the expense of some loss of accuracy and smoothness of the results plot. This can be more practical for large multiple tank structures.

Finite Element Method

This method subdivides each panel into a mesh of small elements. The element thickness is specified and the supports or springs can be added at nodes in the same way as for the grillage. The pressure loads on the panels can be applied by specifying the intensity on the panel as a whole

Finite Element Analysis (FEA) programs can produce a coloured results value contour plot as shown in the following diagram.



The results from FEA can improve on the accuracy and smoothness of the grillage method and can be presented with values per metre width.

In some FEA programs the results plots are based on the average or centre of element value so it is important in these cases to use small elements at panel joints. The coarse mesh option therefore is not always appropriate with FEA but the speed of mesh generation and loading input outweighs this.

The FEA method can show very high local force values at point loads such as at pile supports so these need to be modelled carefully to reflect their real width and load spread.

Comparisons

The grillage method uses general purpose 3-D Space Frame analysis software which is used regularly by Engineers in many design offices, whereas the FEA programs are more specialised and are not used as generally. So this can limit its use to the larger organizations.

The preparation of the grillage model is not as fast as FEA mesh generation because the beams must be defined for each beam spacing and panel thickness condition.

The application of uniform loading is equally fast by both methods but hydrostatic loading is much faster by FEA by virtue of its full panel loading facility.

A Pentium computer can now analyse the above FEA model in less than 5 minutes so run times are no longer a real issue.

The output from the grillage model is more familiar to Structural Engineers but it does need to be converted manually to show the results per metre width. This requires a degree of vigilance by the Engineer.

Developments

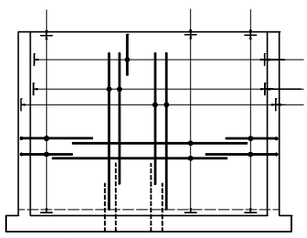
The grillage method needs to be automated further so that the designer can specify the panel width and beam spacing and let the computer calculate the beam properties and output the results in a per metre width format. The loading input method also needs to be enhanced to allow globally varying loads to be applied to the panel as a whole.

FEA programs which are to be used for tank analysis should be able to access and plot the results at the element boundaries and plot moment diagrams.

Both analysis methods would benefit from a library of tank models which could be modified or multiplied by simple input from the Engineer.

The most valuable benefit however, would be the automation of the reinforcement detailing process. The results could easily be fed through a post processor to calculate the requirements to BS 8007.

The Engineer could specify the main parameters and preferred spacing and the computer could then produce reinforcement proposal diagrams for review. The information could then be passed to the detailing program to produce drawings to a standard format similar to the wall elevation below.



The details would then be checked and edited where necessary for holes and items not covered by the main tank analysis.

It is quite possible therefore, to automate the design process for many tanks and bring cost benefits to the water industry.

One final note: Engineers; don’t throw out your tables because with all this computer sophistication, someone has still got to check the result!

Grillage used QSE SPACE
FEA used STAAD III