Discussion Forum

Particle packing theories and their application in concrete mixture proportioning: A review

This has reference to the paper by Senthil Kumar V. and Manu Santhanam titled 'Particle packing theories and their application in concrete mixture proportioning: A review', published in *The Indian Concrete Journal*, September 2003, Vol 77, No. 9, pp. 1324-1331.

The authors are to be congratulated on producing an interesting and stimulating review of a number of major theories but appear to be unaware of *MixSim*, developed in the UK in the early 1980s initially from particle packing principles advanced by Dr Treval C. Powers in the USA.

MixSim is a computerised method and has been in use worldwide since the mid-1980s. It was developed principally for large-scale economic production of ready mixed concrete, does not rely on "ideal" gradings and enables the accurate design of concrete with any available materials. It involves the use of a comprehensive theory of particle packing that has been exhaustively validated through tests of cements, additions, admixtures, aggregates and concretes described in detail in the book referred to below.

Information on *MixSim*, including references, is given by SP Computing on www.mixsim.net and the details of a comprehensive book by J.D. Dewar titled 'Computer Modelling of Concrete Mixtures', and published by E and FN Spon 1999, referred to on this website can be seen on www.sponpress.com and on www.tandf.co.uk/books.

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(*Note:* Additional information on *MixSim* is presented on page 1523. — *Editor*)

Analysis and design of piles in a group

I have gone through, with great interest, the discussion generated on the paper titled 'Analysis and design of piles in a group', published in *The Indian Concrete Journal*, October 2003, Vol 77, No 10, pp. 1366-1370, 1398, and would like to make the following observations on laterally loaded piles.

(i) Most of the methods for design piles subjected to lateral loads are closely linked to the solution of a beam on an elastic foundation. The piles are considered as infinite beams embedded in soil as an elastic medium, for which modulus of subgrade reaction must be well established by tests for varying strata where the piles are embedded. The method given in IS 2911 Part 1 is also on the same basis, but put it in a simple form for the convenience of the designers.

(ii) The basic assumption usually made in the analysis of piles subjected to lateral loads is that the intensity of subgrade reaction is proportional to horizontal deflection of the pile at any point. In the analysis, the subgrade reactions are considered as elastic supports at discrete points along the depth of the pile. For more accurate results, spacing of these elastic supports must be closer. The depth of pile depends on the permissible subgrade reactions and the acceptable limit of horizontal deflection. The analysis can be made by the best use of a standard computer program which would give values of deflection, shear and moment at various support points of pile. The pile section is suitably reinforced to suit the forces and moments acting on it.

(iii) The results from this analysis are quite reliable. The top of the pile where the lateral load is applied, is normally at a considerable distance above the ground surface. Besides, the subgrade

modulus of soil near the ground surface is usually very low. In view of these conditions, it is seen that large horizontal movement of the pile takes place indicating the soil failure near the ground surface. However, this movement will reduce at lower depths of the pile due to higher subgrade modulus of the soil available there. The maximum bending moment in pile usually occurs in the upper portion of the embedded pile as indicated in *Fig* 1 of the paper, where the pile is considered as 'fixed'. This consideration of 'fixity' is only for the structural design of the pile, and it does not mean that the pile can be cut-off very close to this location in practice. The pile has to be embedded to its full depth as originally considered in the analysis in order to meet the structural compatibility requirements of applied lateral load and moment at any section being equal to those due to the subgrade reactions, and most importantly satisfying the limiting deflection permitted for the pile. If the pile is cut off at about three times the pile diameter below the 'fixity' location only, except where the pile is socketed in a rocky strata, then there would be large horizontal movement and rotation of the pile due to development of high subgrade reactions which the soil may not be able to resist, leading to imminent failure of the pile. While designing the pile foundation, it is not just providing structural strength to the pile to cater for the maximum bending moment, but one has to consider also the effect of reactions on the soil and the limiting horizontal deflection of the pile. This aspect has been completely ignored in the paper.

(iv) Regarding the failure mode of piles group, the generalised statements made in the paper are not as simple as they have been put forward, but are more complicated with several parameters involved. I agree with the views of Messrs. Focht and Fries on this subject. It is difficult to comprehend by any theory or practice that pile groups will have higher efficiency under lateral loading due to geometry of the group.

(v) The effect of over-reinforced piles in seismic zones is a different subject matter which should be dealt separately. If the percentage of longitudinal reinforcement in a pile section is more than that is permitted in IS 13920:1993, the pile diameter has to be increased. In any case, the piles have to be provided with closely spaced transverse reinforcement to meet the requirement of ductile detailing as required for high seismic zones.

I trust the readers will find my above observations, as a structural engineer, useful on a topic as important as pile design.

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