LAYERED SHELL

The official documentation for concrete shell design implementation in SAP2000 is still under development and should be available soon. Meanwhile, here is some interim information on concrete shell design to keep you going.

The design of reinforcement for concrete shells in accordance with a predetermined field of moments, as implemented in SAP2000, is based on the following two papers:

1. Optimum design of reinforced concrete shells and slabs" by Troels Brondum-Nielsen, Technical University of Denmark, Report NR.R 1974
2. Design of Concrete Slabs for Transverse Shear", Peter Marti, ACI Structural Journal, March-April 1990

Generally, the slab elements are subjected to eight stress resultants. In the SAP2000 terminology, these are: the three membrane force components F11, F22, and F12; the two flexural moment components M11, M22, and the twisting moment M12; the two transverse shear force components V13, and V23. For the purpose of design, the slab is conceived as comprising two outer layers centered on the mid-planes of the outer reinforcement layers and an uncracked core (this is sometimes called a "sandwich model"). The covers of the sandwich model (i.e. the outer layers) are assumed to carry moments and membrane forces while the transverse shear forces are assigned to the core. The design implementation in SAP2000 assumes that there are no diagonal cracks in the core. In such a case, a state of pure shear developes within the core, and hence the transverse shear force at a section has no effect on the in-plane forces in the sandwich covers. Thus, no transverse reinforcement needs to be provided, and the in-plane reinforcement is not enhanced to account for transverse shear.

Given below is a summary of the procedure as implemented in SAP2000:

1. As mentioned above, the slab is conceived as comprising two outer layers centered on the mid planes of the outer reinforcement layers

2. The thickness of each layer is taken as equal to the lesser of:

   - twice the cover measured to the center of the outer reinforcement
   - twice the distance from the center of the slab to the center of outer reinforcement

3. The six resultants F11, F22, F12, M11, M22, and M22 are resolved into pure membrane forces **N11**, **N22**, and **N12** calculated as acting respectively within the central plane of the top and bottom reinforcement layers. In transforming the moments into forces, the

   lever arm is taken as the distance between the outer reinforcement layers.

4. For each layer, the reinforcement **NDes1**, **NDes2**, concrete principal compressive forces **Fc1**, **Fc2**, and concrete principal compressive stresses **Sc1** and **Sc2**, are calculated according to the rules set out in Reference 1 above.

5. Reinforcement forces are converted to areas per unit width (i.e. reinforcement intensities) **Ast1**, and **Ast2** using appropriate steel stress and stress reduction factor.

You can use this feature to estimate the reinforcement requirements for a concrete shell element used in any model. As is evident from the above discussions, the design is solely based on element stress resultants obtained from a finite element analysis. No effect of the boundary conditions is directly used in the design routines.

I hope this helps.

Regards,

Faisal

From: Max Brunetta [mailto:max@brunetta2.it]
Sent: Wednesday, February 15, 2006 10:37 AM
To: Syed Hasanain
Cc: Support
Subject: New Shell Element

Syed,

Sorry to bother, but perhaps you could help. We are having a difficult time figuring out how the new SAP v10 shell element works, with reference to reinforced concrete design. Linear analysis. We tried hard to figure it out ourselves, but still have many doubts. Could you give us a hint? May be just some reference we could get from the Internet. Our customers are pestering us with questions on this subject.

With regards to the seminars in Italy, are you still into it? Would end of March be a suitable time? Please, let me know.

Kind regards,

Max

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