Spherical void formers in concrete slabs

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DISCUSSION

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COMMENT

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I read this excellent paper with great interest since I have been consulted in a couple of instances where flat plate slabs, containing spherical void formers, had experienced deflections far in excess of their designers' expectations. These slabs had been constructed in arid areas with very low average relative humidity. There may be several factors that contribute to greater than anticipated long-term deflections:

- These days, when such a high slump concrete (as recommended by the authors, i.e. 120 mm to 140 mm) is specified, it will generally be pumped for convenience and speed. To make a concrete mix pumpable, approximately 150 kg of stone is substituted with paste (extra sand, cement and water). The effect of this substitution is a concrete with reduced stiffness and increased drying shrinkage, since the stone is the stable part of the mix that resists deformation. Furthermore, if the second layer of this pumped mix is well compacted in a simply supported slab, the stone will tend to settle to the bottom, leaving the top surface lean of stone in the critical compression zone just where stiffness and resistance to drying shrinkage is needed most.
- Compaction of the first layer of high slump concrete is difficult, due to the fact that the contiguously placed spheres obstruct the operator's vision (he effectively works blind). I have witnessed some large air pockets and honeycombed concrete between soffits and spheres. Other reasons for such poor compaction might include the common misconception that it is easy to over-vibrate concrete, as well as the concern that vibrating the concrete will cause the spheres to become buoyant.
- The baskets of plastics spheres are anchored/tied to the bottom reinforcing with wire. When the first layer of high slump concrete is placed, there may be a tendency for this bottom steel to be lifted as the spheres become buoyant. This reduces the effective depth, which will have a marked effect on deflections. The designer may carefully calculate exactly how thick this bottom concrete layer needs to be before buoyancy becomes a problem, but in practice it is impossible to fill a form evenly and uniformly, even when using pumped concrete. Beneath the distal end of the conveying pipe, the spheres will be totally immersed in concrete and therefore buoyant.
- The climate in South Africa is different to other parts of the world, particularly Europe where spherical void formers originated. A creep factor (or creep coefficient) of between 2,5 and 4 may be too optimistic, particularly in our inland arid regions. Taylor and Heiman (1977) cite instances in Australia where long-term deflections can be as much as five to eight times higher than elastic deflections, depending on the degree of initial cracking, as well as exposure conditions. Fast-track structures which are gradually loaded when the concrete is immature and drying out will exhibit a much higher creep coefficient than a structure which is well cured and allowed to mature for a period (of say a month) before it is first loaded. This aspect is frequently overlooked.

Engineers must be very careful not to let themselves be browbeaten and coerced into using any new system just because it has been used elsewhere. Advertisements for such systems may exaggerate capabilities – for example, by showing graphically an example of the elimination of every second column in every alternate row of columns when spherical void formers are substituted for traditional alternatives. Clients are often unaware of the trade-off between slab thickness and deflection and do not understand that shaving off 10% of slab thickness will do more than increase deflections by 10%. Commercial pressure to make the cost of a spherical void former slab equal or less than a conventional alternative may be considerable and provide the designer with a compelling temptation to take undue risks. Furthermore, suppliers may predict optimistic elastic deflections using finite element models, which assume the plate structure to act as a continuous monolith when in fact it may actually behave more like a simply-supported slab, in cases where actual tensile stresses exceed the elastic capacity of the steel above supports.

The above factors need to at least be considered.

Reference

Taylor, P J & Heiman, J L 1977. Long-term deflection of reinforced concrete flat slabs and plates. *Proceedings of the American Concrete Institute*, 74: 556–561.

RESPONSE FROM AUTHORS

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I find Dr Roderick Rankine's comments very interesting, and also agree on every point of his discussion. I might add to it that, since I've been working in Australia, it is very evident to me how poor workmanship discipline is on South African construction sites, when comparing the two countries.

As Dr Rankine also comments, the proper curing of a concrete slab is of extreme importance – without the necessary knowledge of this, and without integrity and discipline during construction, the curing of concrete is often neglected, unlike in Europe for example.

Another point that may be raised is that in Europe, Australia and just about any developed country, the strength of concrete used is significantly higher than in South Africa. In Europe the flat slabs are constructed with 35 MPa cylinder strength concrete, which is equal to 43,75 MPa cube strength concrete in South Africa. Compare this to the poor 25 MPa concrete that is often used in South Africa for slab construction.

This I mention, for the elasticity of higher strength concrete is also a few percent higher than weaker concrete, leading to smaller deflections in high-strength concrete.

In general, construction of flat slabs with spherical void formers in South Africa is still not cost-effective, due to relatively unskilled labour and high product cost, worsened by the increased safety factors in design required to counter the anticipated poor construction discipline on site and utilisation of an inferior grade of aggregate in certain parts of South Africa, which is seldom investigated thoroughly.