Self-Consolidating Concrete Construction for Modular Units

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ABSTRACT:

In construction of modern nuclear structures, self-consolidating concrete (SCC) offers important advantages, including improved concrete flow without segregation in congested sections; this results in savings in labor, cost, and time. As a result, SCC is increasingly used in placements between the steel plates in steel composite (SC) modules. However, one disadvantage with this construction practice is that SCC must be placed continuously to avoid "cold joints" (i.e., intersection between concrete placements due to concrete setting between placements) – a costly approach due to significant increases in reinforcement required to address hydrostatic loading due to the height of the SCC and logistical challenges with materials production and delivery.

Permitting cold joints would eliminate the need for careful scheduling of concrete delivery and would reduce the bursting construction loads on the plates; each reduction would simplify design and construction, reducing costs. Adequate strength across cold joints must be ensured, however. Strength derives from shear-friction developed across the cold joint, which then depends on the surface roughness, among other factors, of the concrete at the joint. Because of the self-leveling qualities of SCC, producing surface roughness in SCC is a challenge which must be overcome.

Therefore, the primary objective of this project is to develop SCC mixtures so that concrete placement can be made into steel plate composite (SC) modular structures without the need for continuous concrete placement. This will be achieved through the incorporation or "seeding" of a relatively small fraction of low-density coarse aggregate (LDA) which will, as demonstrated in a proof-of-concept test, rise and protrude at the hardened SCC surface. Prior efforts have demonstrated that a clean and rough, as-cast surface where aggregates protrude as little as ¼-in. (6 mm) provides an adequate surface for developing good composite action.

In this investigation, LDA-seeded SCC mixtures will be developed and their use validated to ensure sufficient shear capacity across cold-joints, while minimizing shrinkage and temperature increase during curing to enhance concrete bonding with the steel plates in SC modular construction. Mix development will be accelerated through the use of thermal and rheological modeling. Multi-scale experimental studies will be used to quantify the effects of surface roughening, achieved through LDA-seeded SCC, on shear friction and to appreciate mass concrete effects central to adequate long-term performance of SC modules. Linear finite element analyses will be compared with large-scale experimental results to calibrate models for future use in design. As final deliverables, we aim to provide SCC mixtures featuring a self-roughening capability to produce adequate shear friction between cold joints and to produce draft provisions addressing shear-friction, for consideration in the AISC N690-12 Appendix N9 code used for the design of SC modular structures.