SCA
SLAG CEMENT ASSOCIATION

Information Sheets

# 9: Reducing Thermal Stress in Mass Concrete

According to ACI 2071, "mass concrete is any large volume of concrete with dimensions large enough to require that measures be taken to cope with the generation of heat and attendant volume change to minimize cracking." Cement hydration generates heat. Heat dissipates from concrete slowly; the thicker the section, the longer it will take the interior to cool. This can result in large temperature differentials between the concrete surface and its interior. The concrete is then subject to high thermal stresses, which can result in cracking and loss of structural integrity.

## Reducing Thermal Stress

There are three generally accepted strategies for reducing thermal stress in concrete:

- Reduce the total cementitious content.
- Reduce the portland cement content.
- Slow down the hydration process using various admixtures or cooling the concrete.

## How Does Slag Cement Help?

When slag cement is incorporated in a concrete mixture, less heat is generated and thermal stress is reduced:

- Portland cement content is reduced by the percentage of slag cement used.
- Due to increased strength with slag cement, the total cementitious content can be reduced.
- Hydration characteristics of slag cement are such that the early rate of heat generation and peak temperature of the concrete are reduced.

## Slag Replacement Levels

Generally, 65 to 80% is considered an optimum replacement range for mass concrete applications. These levels typically provide significant heat reduction while achieving desired strengths. Levels from 50 to 65% have been used successfully in smaller mass concrete placements. Mixtures should be tested with job materials to ensure required thermal and strength characteristics.

Figure 1: The I-70 Stan Musial Veterans Memorial Bridge (opened 2014) pylons used 70% slag cement in the mass concrete mix, which also was used in other concrete classes of the structures

Figure 2 shows the specific heat of hydration of an ordinary portland cement and combinations from 25 to 75 percent slag cement substitution. Note that each increasing level of slag cement reduces peak heat of hydration of the binder. More importantly, the area under each curve represents total heat generated. This area reduces dramatically when the substitution rate increases from 50 to 75 percent, indicating that significantly less total heat is generated for 75 percent slag cement, even though the peak heat of hydration is not much reduced from 50 percent substitution. Figure 3 shows the effect of slag cement on temperature rise in mass concrete. Note that peak temperature dropped by 19 degrees F with 65 percent slag cement substitution, and by 42 degrees F for 80% substitution.

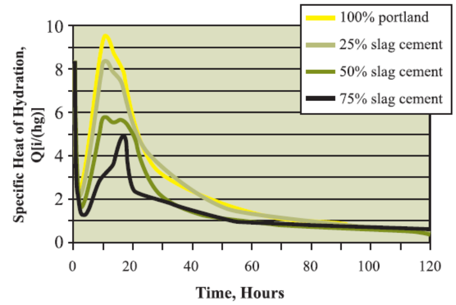


Figure 2: Effect of Slag Cement on Heat of Hydration

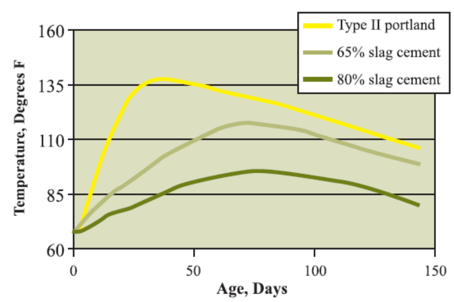


Figure 3: Effect of Slag Cement on Temperature Rise in Mass Concrete

## References

1. ACI 207.1R-05, "Mass Concrete," American Concrete Institute, Farmington Hills, MI, 2012.
2. Photo (Stan Musial Bridge) By Mitchell Schultheis - Own work, CC BY-SA 4.0,
3. Soutsos, M.; Hatzitheodorou, A.; Kwasny, J.; and Kanavaris, F., 2016, "Effect of In Situ Temperature on the Early Age Strength Development of Concretes with Supplementary Cementitious Materials," *Construction & Building Materials*, V. 103, pp. 105-116.