Contractors’ Guide to Mass Concrete

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Pre- and post-bid considerations for meeting performance and cost demands

Concrete contractors must sometimes deal with specifications requiring them to control the heat generated in mass concrete members. To bid accurately, estimators need to know which structural components are considered mass concrete and the temperature limits that will apply to these components. They also need to be familiar with the options available for keeping concrete temperatures within the limits so they can determine cost-effective options. A well-prepared bid requires a careful look at the contract documents and includes documentation of the assumptions made during its preparation.

Is It Mass Concrete?

ACI 301-05, “Specifications for Structural Concrete,” requires the specifier to designate which portions of the structure are mass concrete. Some engineers believe that contractors should know which portions are mass concrete and believe they don’t need to identify mass concrete sections in the contract documents. This may be based on older specifications that designated mass concrete as any section with a least dimension greater than a stated value—say 3 ft or 1 m. As early as 1970, however, ACI Committee 207, Mass Concrete, defined mass concrete as:

“Any large volume of cast-in-place 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.”

Note that in this definition, no specific size is provided. Although the definition doesn’t explicitly identify the sources of the heat, the committee document provides extensive discussion of the effects of the cementitious material and ambient temperatures.

The Optional Requirements Checklist for Section 8.1.1.1 of ACI 301-05 instructs the specifier as follows:

“Designate portions of the structure to be treated as either plain mass concrete or reinforced mass concrete. Whether or not concrete should be designated as mass concrete depends on many factors such as weather conditions, the volume-surface ratio, rate of hydration, degree of restraint to volume change, temperature and mass of surrounding materials, and functional and aesthetic effect of cracking. In general, heat generation should be considered when the minimum cross-sectional dimension approaches or exceeds 2-1/2 ft [750 mm] or when cement contents above 600 lb/yd^3 [355 kg/m^3] are used. The requirements for each project, however, should be evaluated on their own merits.”

As stated in the Foreword to Checklists, “Checklists do not form a part of ACI Specification 301. Checklists assist the Specifier in selecting and specifying project requirements in the Project Specification.” Thus, the specifier, not the contractor, needs to determine whether
or not any concrete should be designated mass concrete based on the merits for each project. If portions of the structure are designated as mass concrete, the additional requirements in ACI 301-05, Section 8, “Mass Concrete,” apply. If no concrete is designated as mass concrete in the contract documents, Section 8 does not apply.

Engineers must understand that there is a cost associated with including mass concrete requirements in the specifications. Section 8 of ACI 301-05 includes some provisions, such as a 70°F (21°C) maximum limit on as-delivered concrete temperature and a maximum lift height of 18 in. (450 mm), which are not typical for other concrete members. For projects with high-strength requirements and a least dimension as large as 10 ft (3 m), considerably higher costs can be expected.

Contractors need to carefully read specifications, general notes on the drawings, and notes on the sections to determine if any concrete has been designated as mass concrete. If the contract documents are confusing, ambiguous, or conflicting with regard to mass concrete requirements, contractors should consider requesting clarification or qualifying their bid. The bid can be qualified by stating the mass concrete provisions that are included in the bid and, when necessary, even indicating which portions of the structure are considered mass concrete. Then they can have a discussion with the owner regarding the cost and with the design professional regarding options for satisfying the intent of the specifications. If the engineer or owner disagrees with the contractor’s interpretation, differences can be worked out before signing a contract.

REDUCING THE COST OF COPING WITH HEAT GENERATION

Measures for coping with heat generation are generally aimed at minimizing two measured values: maximum internal temperature and maximum temperature difference between the hottest portion and the surface. This is done to control thermal cracking and minimize durability problems. The measures needed to reduce maximum temperature and temperature differences, however, are sometimes made more costly by other specification and project requirements.

On some projects, for example, the contractor is required to control temperature but is also required to provide concrete with a specified strength at a certain age or with a specified maximum water-cementitious material ratio that increases cement content. In addition, some specifications prohibit or limit the use of supplementary cementitious materials that could reduce heat generation.

Some specifications require the contractor to limit maximum temperature to 160°F (71°C), set the required 28-day compressive strength at 6000 to 10,000 psi (40 to 70 MPa), and do not allow any supplementary cementitious material. These concretes can require 600 to 900 lb/yard³ (356 to 534 kg/m³) of portland cement and increase the maximum temperature by about 13°F (7.2°C) for each 100 lb/yard³ (59 kg/m³) of cement. In these cases, cement in the concrete generates heat leading to temperature increases of about 80 to 120°F (43 to 65°C), which requires the contractor to deliver the concrete at a maximum temperature of 40 to 80°F (6 to 28°C) to stay within the maximum limit of 160°F (71°C). The cost of achieving these delivered concrete temperatures will be substantial, especially if any of the mass concrete must be placed in the summer. When specifications set a maximum as-delivered concrete temperature as low as 70°F (21°C), meeting such a requirement for concrete placed in a hot-weather climate or in the summer presents a severe challenge.

Propose 56- or 90-day strengths

Strength requirements for foundations are likely to be set at 28 days. The foundation, however, is unlikely to receive the full loading for 6 to 12 months. Thus, in
most cases, contractors can recommend meeting the strength requirement at a later age without affecting the construction schedule or structural integrity of the foundation.

Contractors can indicate in their bids that the required compressive strength be based on a 56-day or even a 90-day test. The strength gain from 28 to 56 or 90 days varies from about 10 to 20%, but this may reduce the required cement content by about 50 lb/yd$^3$ (30 kg/m$^3$). This would reduce the temperature increase resulting from cement hydration by about 7 °F (4 °C).

They can also indicate if Type F fly ash, slag cement, or other supplementary cementitious materials are being used as a means for producing the needed strength. Replacing 100 lb/yd$^3$ (59 kg/m$^3$) of Type I cement with 100 lb/yd$^3$ (59 kg/m$^3$) of fly ash halves the temperature rise resulting from heat of hydration from about 13 °F (7.2 °C) to 6.5 °F (3.6 °C).

Reducing the cement content by about 50 lb/yd$^3$ (30 kg/m$^3$) and replacing 100 lb/yd$^3$ (59 kg/m$^3$) of cement with 100 lb/yd$^3$ (59 kg/m$^3$) of fly ash can reduce the heat generated by about 10 to 15 °F (5 to 8 °C). This may not seem like much, but it’s a great cost advantage to the owner compared to the cost of decreasing the delivered concrete temperature in the summer by the same 10 to 15 °F (5 to 8 °C).

**Consider different temperature maximums**

Some design professionals recommend a maximum temperature of 135 °F (57 °C) and a maximum temperature difference of 35 °F (19 °C). On some projects, however, these temperature requirements may be too conservative. Recent projects, including 8 ft (2.4 m) thick mass foundations built by the Tennessee Valley Authority, have successfully required a maximum temperature of 160 °F (71 °C) and a maximum temperature difference of 50° F (28 °C). With these increased temperature requirements, engineers may be able to get the necessary performance while owners benefit from reduced costs.

If considering different temperature maximums without getting prior approval of the owner and engineer, make sure the bid clearly qualifies the temperature choices on which the pricing is based.

**Use reinforcing steel to control crack width**

Reinforcement does not guarantee that the concrete will not crack and certainly will not prevent the concrete from generating heat. Reinforcement can, however, hold the crack faces tightly together. Placing additional reinforcement near the surface may not cost as much as using active methods for cooling the concrete. When using this method, the expectation should not be a crack-free component but, instead, one with cracks that don’t open too wide.

Note that Section 1.2 of ACI 301-05 defines reinforced mass concrete as “mass concrete containing adequate prestressed or nonprestressed reinforcement to act together with the concrete in resisting forces including those induced by temperature and shrinkage.”

This is often the most economical method for coping with cracking in mass foundations; however, it’s difficult for contractors to propose the necessary amount of additional reinforcement. Contractors have two options when submitting a bid: (a) state this as their method for limiting crack width in mass concrete members and also state that the cost will be estimated when the engineer determines the appropriate amount of reinforcing steel; or (b) include an allowance for additional reinforcing steel needed to control crack width.

**Recommend a higher maximum delivery temperature**

Although many specifications set the maximum as-delivered concrete temperature at 70 °F (21 °C), the local ready mixed concrete supplier may not have the equipment to cool the concrete to this temperature, especially during hot weather. Costs for using large amounts of ice or adding liquid nitrogen to cool the concrete can be very high. Any steps taken to reduce the cementitious material content and increase the specified maximum temperature will increase the maximum delivery temperature and reduce the cost of the concrete.

**Handling crack repair provisions**

Specifications often require the contractor to epoxy inject any cracks that occur. This requires the contractor
to estimate the amount of cracking that will take place when the specification requirements in the contract documents are met. Overestimating cracks results in a higher bid that will not be beneficial to the owner. Under these circumstances, contractors may want to exclude crack repair costs in their bid but include a price per unit length for epoxy injection where required. The engineer can then determine which cracks need to be repaired and how best to spend the owner’s money to achieve the desired performance.

**SUMMING UP**

Accurately bidding any structural concrete project that includes mass concrete can best be achieved by:

- Determining if the plans and specifications clearly designate all portions of the structure that are to be treated as mass concrete;
- Evaluating the options available for increasing the specified maximum temperatures and temperature differences;
- Evaluating the options available for reducing the as-built maximum temperatures and temperature differences;
- Considering alternatives to temperature control, such as reinforcement that will control crack width; and
- Including crack repair provisions as a separate item to remove one source of uncertainty from the bid.

The contractor’s goal when bidding projects that include mass concrete placements should be to bid as accurately as possible so the engineer’s expectations for crack control are met at minimum cost to the owner.

**References**

1. ACI Committee 301, “Specifications for Structural Concrete,” American Concrete Institute, Farmington Hills, MI, 2005, 49 pp.

Selected for reader interest by the editors.