Guide to Mass Concrete

Reported by ACI Committee 207

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Mass concrete is any volume of concrete with dimensions large enough to require that measures be taken to cope with the generation of heat from hydration of the cement and attendant volume change to minimize cracking. The design of mass concrete structures is generally based on durability, economy, and thermal action, with strength often being a secondary concern. This document contains a history of the development of mass concrete practice and discussion of materials and concrete mixture proportioning, properties, construction methods, and equipment. It covers traditionally placed and consolidated mass concrete and does not cover roller-compacted concrete.

Keywords: admixture; aggregate; air entrainment; batch; cement; compressive strength; cracking; creep; curing; durability; fly ash; formwork; grading; heat of hydration; mass concrete; mixing; mixture proportion; modulus of elasticity; placing; Poisson's ratio; pozzolan; shrinkage; strain; stress; temperature rise; thermal expansion; vibration; volume change.

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CHAPTER 1—INTRODUCTION AND HISTORICAL DEVELOPMENTS

1.1—Scope

Mass concrete is defined in ACI 116R as "any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change to minimize cracking." The design of mass concrete structures is generally based on durability, economy, and thermal action, with strength often being a secondary, rather than a primary, concern. The one characteristic that distinguishes mass concrete from other concrete work is thermal behavior. Because the cement-water reaction is exothermic by nature, the temperature rise within a large concrete mass, where the heat is not quickly dissipated, can be quite high. Significant tensile stresses and strains may result from the restrained volume change associated with a decline in temperature as heat of hydration is dissipated. Measures should be taken where cracking due to thermal behavior may cause a loss of structural integrity and monolithic action, excessive seepage and shortening of the service life of the structure, or be aesthetically objectionable. Many of the principles in mass concrete practice can also be applied to general concrete work, whereby economic and other benefits may be realized.

This document contains a history of the development of mass concrete practice and a discussion of materials and concrete mixture proportioning, properties, construction methods, and equipment. This document covers traditionally placed and consolidated mass concrete, and does not cover roller-compacted concrete. Roller-compacted concrete is described in detail in ACI 207.5R.

Mass concreting practices were developed largely from concrete dam construction, where temperature-related cracking was first identified. Temperature-related cracking has also been experienced in other thick-section concrete structures, including mat foundations, pile caps, bridge piers, thick walls, and tunnel linings.

High compressive strengths are usually not required in mass concrete structures; however, thin arch dams are exceptions. Massive structures, such as gravity dams, resist loads primarily by their shape and mass, and only secondarily by their strength. Of more importance are durability and properties connected with temperature behavior and the tendency for cracking.

The effects of heat generation, restraint, and volume changes on the design and behavior of massive reinforced elements and structures are discussed in ACI 207.2R. Cooling and insulating systems for mass concrete are addressed in ACI 207.4R. Mixture proportioning for mass concrete is discussed in ACI 211.1.

1.2—History

When concrete was first used in dams, the dams were relatively small and the concrete was mixed by hand. The portland cement usually had to be aged to comply with a boiling soundness test, the aggregate was bank-run sand and gravel, and proportioning was by the shovelful (Davis 1963). Tremendous progress has been made since the early 1900s, and the art and science of dam building practiced today has reached a highly advanced state. Presently, the selection and proportioning of concrete materials to produce suitable strength, durability, and impermeability of the finished product can now be predicted and controlled with accuracy.

Covered herein are the principal steps from those very small beginnings to the present. In large dam construction, there is now exact and automatic proportioning and mixing of materials. Concrete in 12 yd^3 (9 m^3) buckets can be placed by conventional methods at the rate of 10,000 yd^3/day (7650 m^3/day) at a temperature of less than 50 °F (10 °C) as placed, even during extremely hot weather. Grand Coulee Dam still holds the all-time record monthly placing rate of 536,250 yd^3 (410,020 m^3), followed by the more recent achievement at Itaipu Dam on the Brazil-Paraguay border of 440,550 yd^3 (336,840 m^3) (Itaipu Binacional 1981). The record monthly placing rate of 328,500 yd^3 (250,200 m^3) for roller-compacted concrete was achieved at Tarbela Dam in Pakistan. Lean mixtures are now made workable by means of air entrainment and other chemical admixtures and the use of finely divided pozzolanic materials. Water-reducing, strength-enhancing, and set-controlling chemical admixtures are effective in reducing the required cement content to a minimum and in controlling the time of setting. Placing rates for no-slump concrete, by using large earth-moving equipment for transportation and large vibrating rollers for consolidation, appear to be limited only by the size of the project and its plant's ability to produce concrete.

1.2.1 *Before 1900*—Before to the beginning of the twentieth century, much of the portland cement used in the United States was imported from Europe. All cements were very coarse by present standards, and quite commonly they were underburned and had a high free lime content. For dams of that period, bank-run sand and gravel were used without the benefit of washing to remove objectionable dirt and fines. Concrete mixtures varied widely in cement content and in sand-coarse aggregate ratio. Mixing was usually done by hand and proportioning by shovel, wheelbarrow, box, or cart. The effect of the water-cement ratio (w/c) was unknown, and generally no attempt was made to control the volume of mixing water. There was no measure of consistency except by visual observation of the newly mixed concrete.

Some of the dams were of cyclopean masonry in which "plums" (large stones) were partially embedded in a very wet concrete. The spaces between plums were then filled with concrete, also very wet. Some of the early dams were built without contraction joints and without regular lifts. There were, however, notable exceptions where concrete was cast in blocks; the height of lift was regulated, and concrete of very dry consistency was placed in thin layers and consolidated by rigorous hand tamping.

Generally, mixed concrete was transported to the forms by wheelbarrow. Where plums were employed in cyclopean masonry, stiff-leg derricks operating inside the work area moved the wet concrete and plums. The rate of placement