REMR Technical Note GT-SR-1.3

# DESIGN PROCEDURE FOR PLASTIC CONCRETE CUTOFF WALLS

PURPOSE: To provide information on a design procedure that can be used to select mixtures for plastic concrete walls that meet strength, stiffness, and permeability requirements for remedial cutoff wall construction.

BACKGROUND: Seepage control is critical to the safe operation of earth dams. While remedial seepage control can be achieved with a rigid concrete cutoff wall, deformation of the earth embankment can cause the concrete wall to rupture. Therefore, materials selected for construction of cutoff walls must be strong and watertight and have stiffness comparable to the surrounding embankment soil. Satisfying strain-compatibility between the wall and surrounding soil will lessen the likelihood of overstressing the wall and will allow the wall and soil to deform without separating. Plastic concrete shows great promise for satisfying the strength, stiffness, and permeability requirements for remedial cutoff wall construction. Plastic concrete consists of aggregate, cement, water, and bentonite clay mixed at a high water-cement ratio to produce a ductile material. However, current literature provides little guidance for proportioning constituents to arrive at the desired properties. This technical note describes a design procedure that can be used to select mixtures for plastic concrete walls.

TEST RESULTS: An unconfined compression test database was used to develop a batching procedure that will allow a designer to select a plastic concrete mixture that satisfies the strength and stiffness requirements for a cutoff wall. The mixture design can be related to short-term (3 days) and long-term (90 to 660 days) stress-strain behavior.

Some triaxial test results indicated that self-weight consolidation of the plastic concrete may increase the undrained strength ten-fold over unconfined samples. At the same time, the strain at failure can be as much as five times greater than that measured during unconfined compression. The coefficient of permeability measured on samples with 0-, 20-, and 40-percent bentonite content did not vary greatly and was typically between $10^{-8}$ and $10^{-9}$ cm/sec. Although the 40-percent bentonite sample was richer in bentonite, the permeability was not greatly lowered because more water was required in the mixture to maintain an 8-in. slump. The increased water tended to counterbalance the increased bentonite.

DESIGN PROCEDURE: Based on laboratory results, a design procedure for plastic concrete cutoff walls was developed. Particular emphasis was placed on quantifying the relationship between mixture composition and stress-strain-strength behavior to minimize or eliminate a trial and error approach to mixture design.

The guiding philosophy behind the analyses was to correlate complex and time-consuming (expensive) triaxial tests to simple and quick (less expensive) unconfined compression tests. This change will allow designers to estimate triaxial stress-strain-strength parameters from unconfined stress-strain-strength data. In addition, unconfined behavior was examined at ages up to 660 days, a much longer period than typical project test programs allow.

Figures 1 through 3 are companion plots for selecting a plastic concrete mixture proportion (bentonite content, cement factor, and water-cement ratio) that will produce a certain unconfined compressive strength and ultimate tensile strength at a particular age. In addition, Figure 2 can be used in conjunction with Figure 4 to specify unconfined (Young's) elastic modulus.

The unconfined compressive strength as a function of water-cement ratio, bentonite content, and age (Figure 2) are presented in detail in Figures 5 through 9. Data provided in Figure 3 (ultimate tensile strength as a function of water-cement ratio, bentonite content, and age) are incomplete because of the limited number of tensile strength batch designs and curing ages tested.

A designer who needs plastic concrete of a certain unconfined compressive strength or modulus at a certain age can enter Figures 2 through 9, obtain a corresponding water-cement ratio and bentonite content, and then enter Figure 1 to obtain the corresponding cement factor. For example, a designer has measured the unconfined elastic modulus of a proposed compacted embankment soil as 200 ksi (using a compressometer to measure deflection) and wants to specify a plastic concrete cutoff wall of matching long-term stiffness. Figure 4 yields a corresponding unconfined compressive strength of 210 psi. Figure 2 then shows a choice exists at 210 psi, between 10- and 20-percent bentonite content at curing ages of 3 days and a 40-percent bentonite content

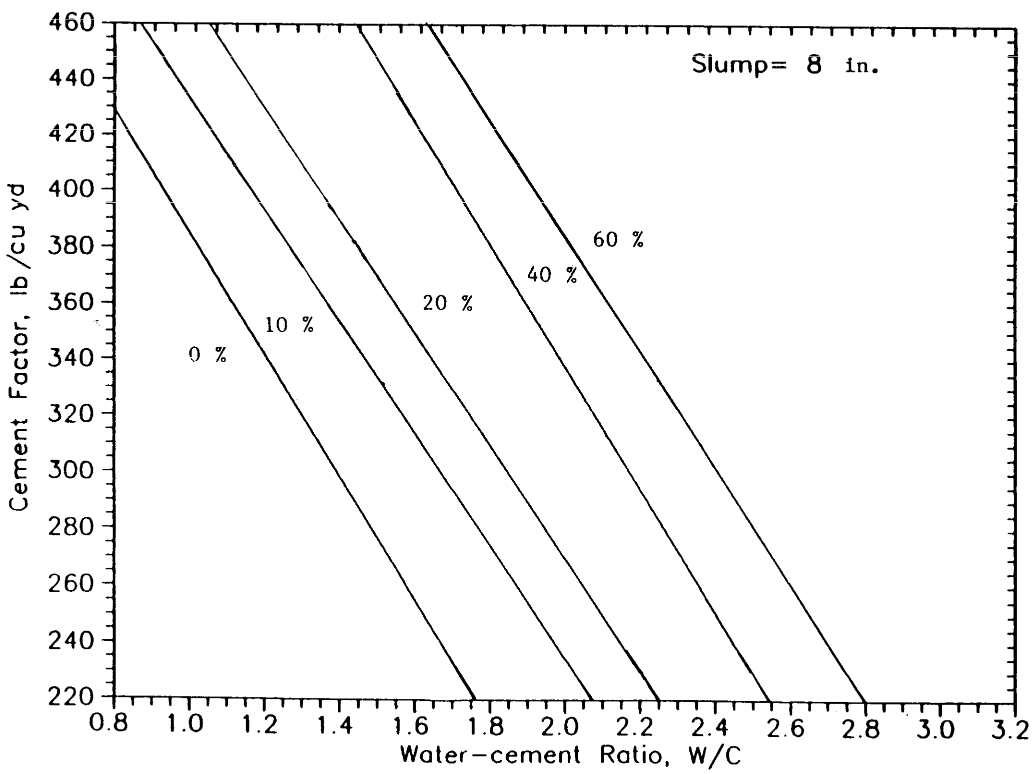


Figure 1. Cement factor versus water-cement ratio and bentonite content

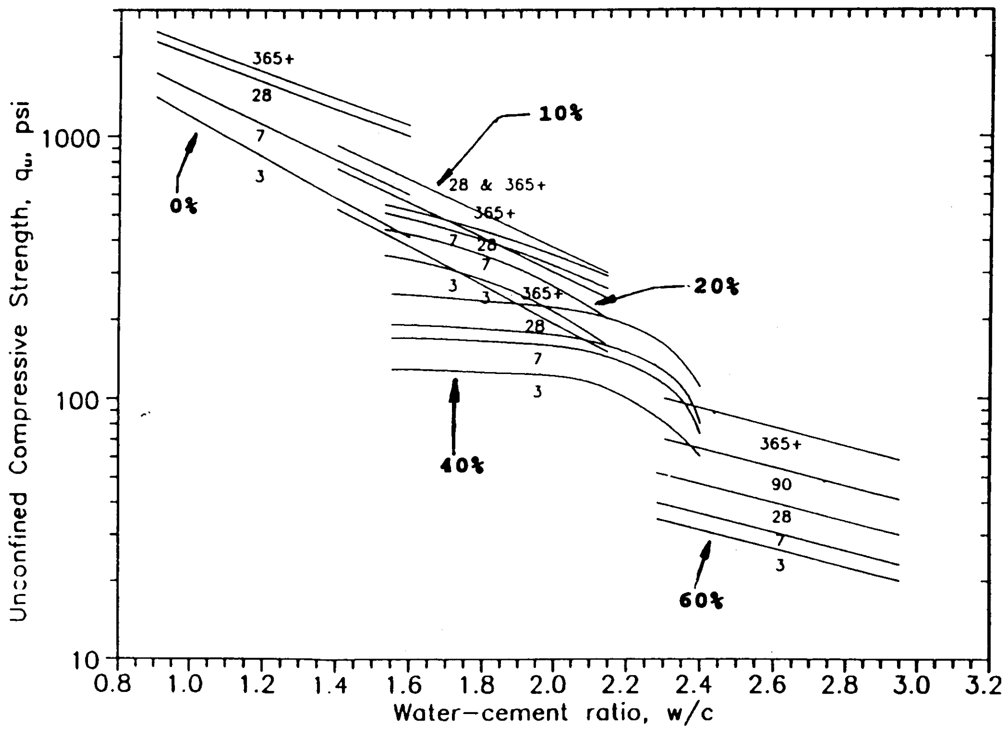


Figure 2. Unconfined compressive strength versus water-cement ratio for all bentonite contents with lines being isobars of curing age

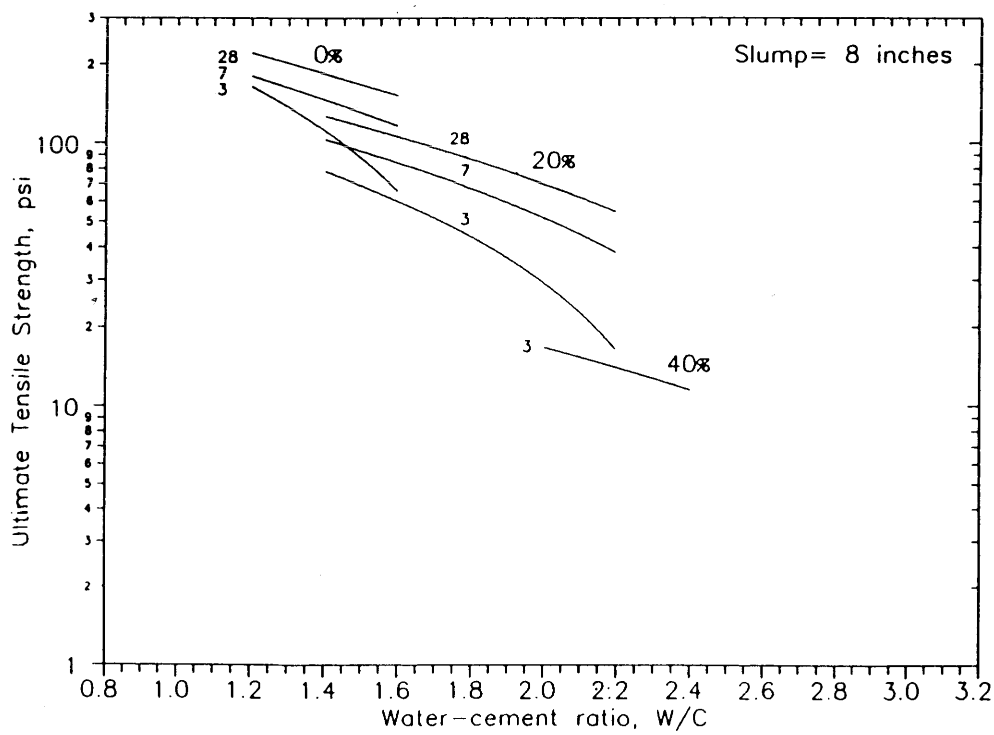


Figure 3. Ultimate tensile strength versus water-cement ratio and bentonite content with lines being isobars of curing age

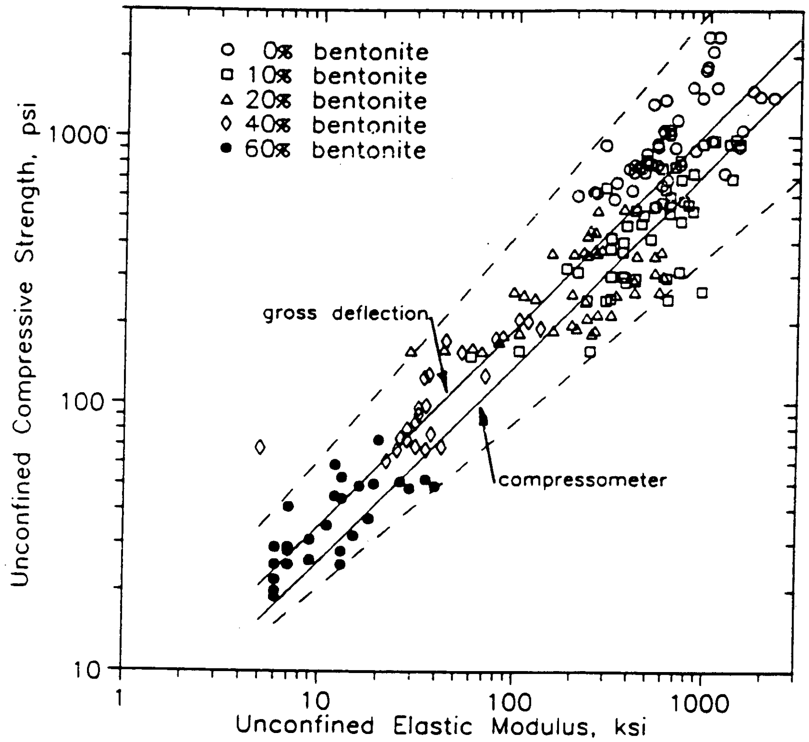


Figure 4. Unconfined compressive strength versus unconfined elastic modulus for all ages and bentonite contents

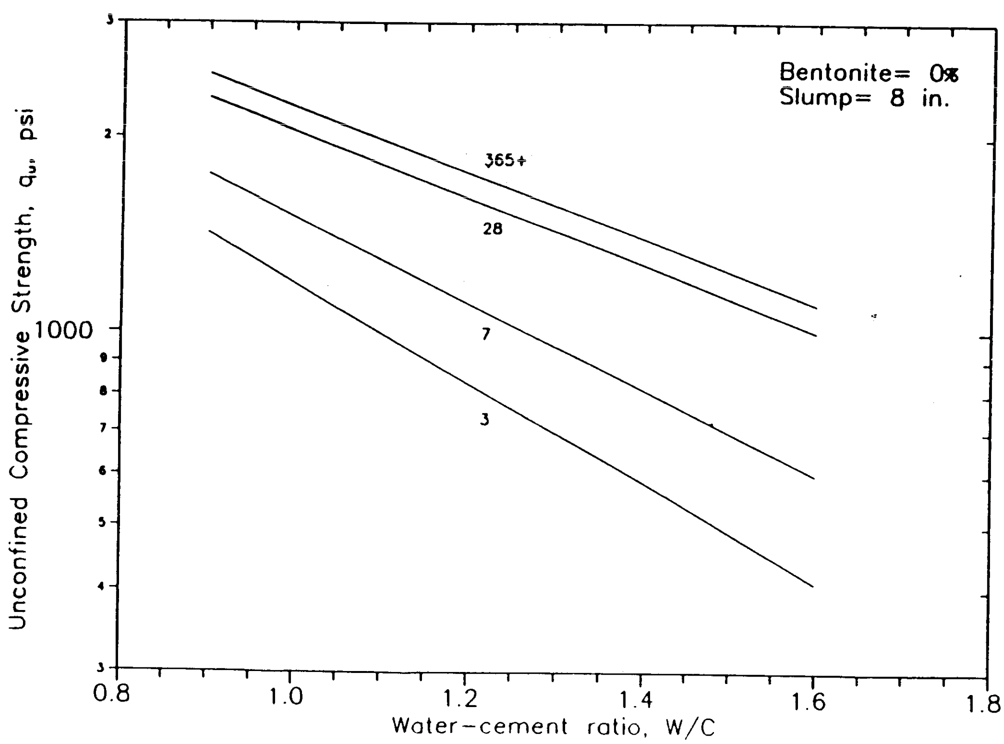


Figure 5. Unconfined compressive strength versus water-cement ratio for 0 percent bentonite content with lines being isobars of curing age

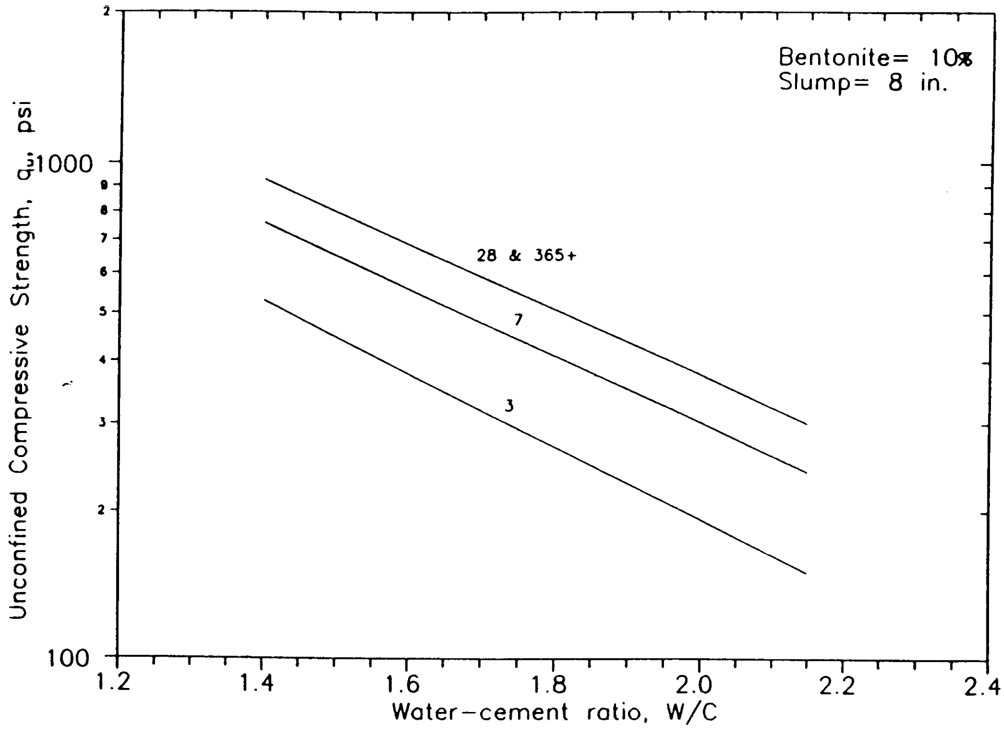


Figure 6. Unconfined compressive strength versus water-cement ratio for 10-percent bentonite content with lines being isobars of curing age

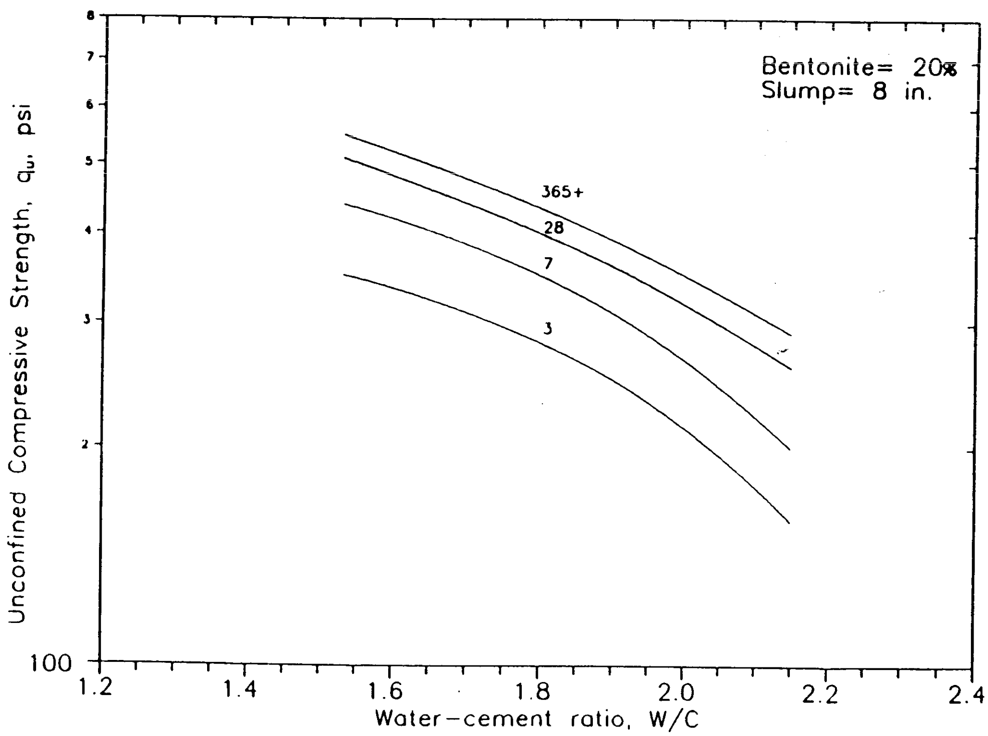


Figure 7. Unconfined compressive strength versus water-cement ratio for 20-percent bentonite content with lines being isobars of curing age

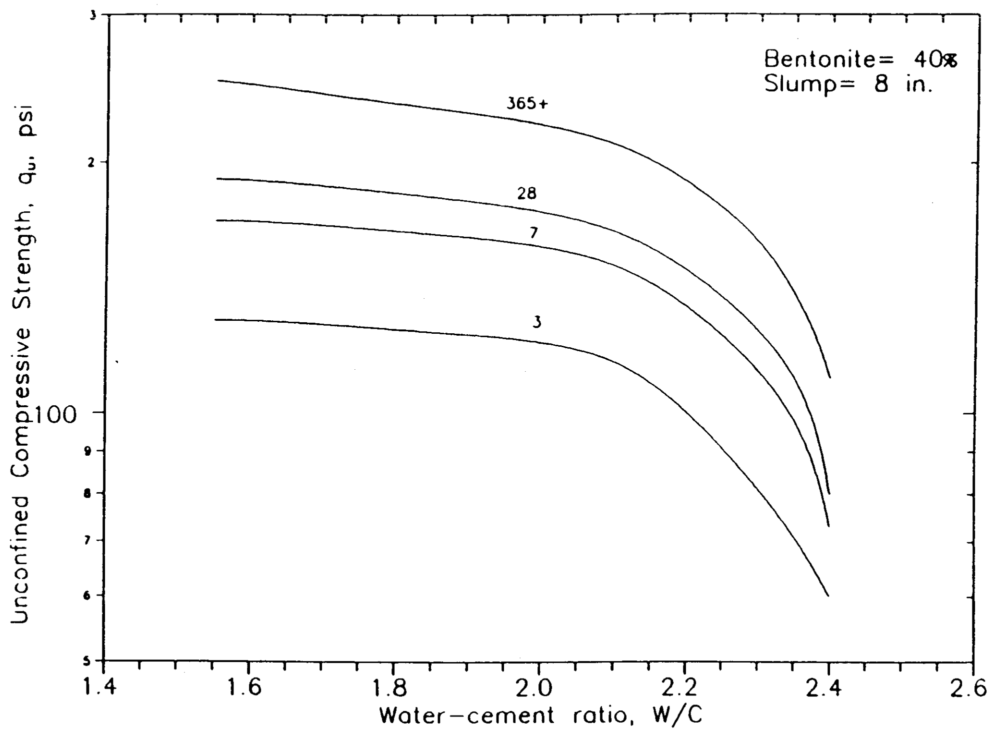


Figure 8. Unconfined compressive strength versus water-cement ratio for 40-percent bentonite content with lines being isobars of curing age

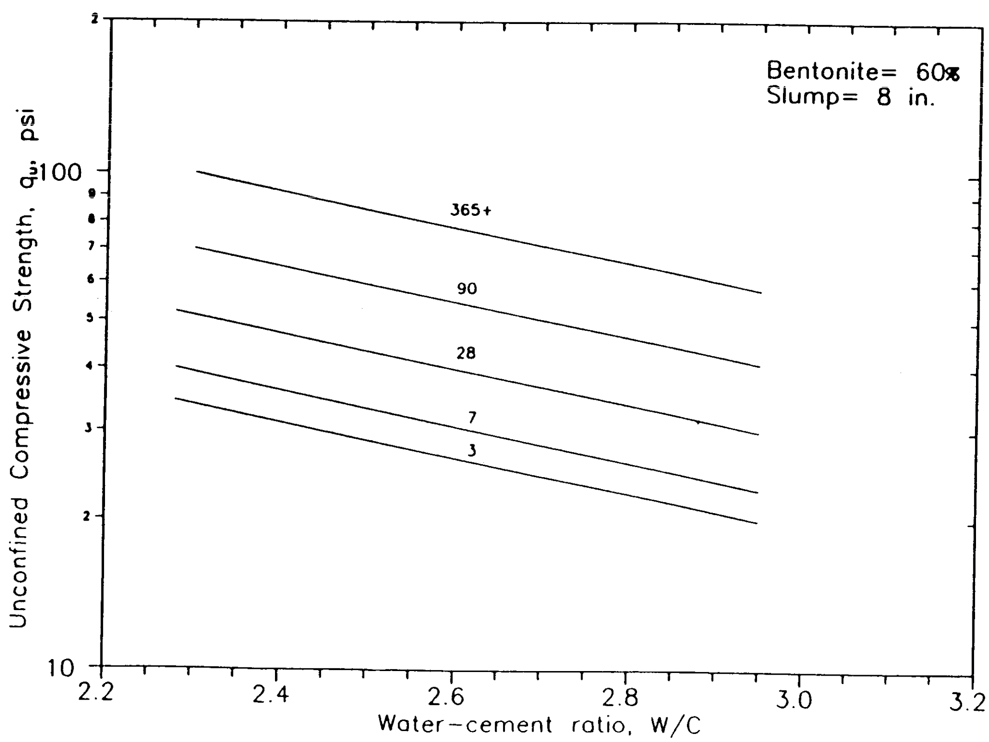


Figure 9. Unconfined compressive strength versus water-cement ratio for 60-percent bentonite content with lines being isobars of curing age

at a curing age of 365+ days. Since the criterion is long-term stiffness, the designer chooses the 40-percent bentonite mixture. The designer then refers to Figure 8 (a blow-up of the 40-percent bentonite content relation) to more precisely estimate the corresponding water-cement ratio 2.05. The designer then moves to Figure 1 and reads a cement factor of 325 $lb/yd^3$, corresponding to 40-percent bentonite content and 2.05 water-cement ratio. The designer thus has all the information necessary to proportion a batch. An identical procedure can be used to specify mixture proportions based on ultimate tensile strength by using Figure 3.

REFERENCE:

Kahl, Thomas W., Kauschinger, Joseph L., and Perry, Edward B. 1991. "Plastic Concrete Cutoff Walls for Earth Dams," US Army Engineer Waterways Experiment Station, Vicksburg, MS.