REMR Technical Note CS-MR-7.2

ANTIWASHOUT ADMIXTURES FOR UNDERWATER CONCRETE

(Supersedes previously issued CS-MR-7.2)

PURPOSE: To describe the purpose, types, and functions of antiwashout admixtures for concrete used in underwater repairs.

BACKGROUND: Over a period of time, concrete can begin to deteriorate due to various factors. This deterioration may or may not be related to the original quality of the concrete. In a hydraulic structure, many times this deterioration is underwater. It has been necessary to dewater the damaged area before concrete repairs could be executed. Recently, however, new chemical admixtures have made it possible to increase the viscosity of concrete. This added viscosity now makes it possible to place concrete underwater without maintaining a tremie seal. As a result, many concrete repairs can be carried out without dewatering the structure. The U.S. Army Engineer Waterways Experiment Station has conducted research on underwater repair materials and techniques. The results can be found in two published reports (Ref a & b). Three additional reports are now in preparation (Ref c, d, & e). A video report is also available (Ref f).

The Japanese have been leaders in this new concrete technology. This Technical Note summarizes an article by Toru Kawai entitled "Special Underwater Concrete Admixtures" in the Japanese Concrete Journal (Ref g). It is an excellent compilation of research on antiwashout admixtures and their effects upon both fresh and hardened concrete. Although there is emphasis on research conducted in Japan, results from both Europe and the U.S. are included.

INTRODUCTION: Underwater concrete that does not disperse significantly when placed in water was developed about 10 years ago in West Germany. Subsequently, the technology was introduced in Japan, where various types of this underwater concrete were developed. This sort of underwater concrete is called both "nondispersible concrete" and "colloidal underwater concrete." The admixture that provides the properties of this special concrete is known as "nondispersible underwater concrete admixture" and "antiwashout admixture." The actual amount of such concrete in use at the present time is more than 150,000 m^3.

THE ANTIWASHOUT ADMIXTURE: The main objective of the admixture is to prevent wash-out of cement and dispersion of aggregate during underwater placement of concrete. The admixture serves to increase the viscosity and the water retention of the concrete matrix. In short, it plays the role of "a viscosity enhancement agent." The antiwashout admixtures currently marketed in Japan have cellulose or acrylic as the principal ingredient. The acrylic admixture takes a polyacrylamide polymer as its main ingredient. The cellulose admixture is a non-ionic water-soluble cellulose ether, which has an OH [hydroxide ion] base and is almost like water. HEC (hydroxyethylcellulose), HEMC (hydroxyethylmethylcellulose), and HPMC (hydroxypropylmethylcellulose) are among the admixtures being used. It is known that their viscosity, when dissolved, differs considerably according to polymerization, molecular weight, and type of substituent. These water-soluble, cellulose ethers dissolve rapidly in a mixture high in pH like concrete. They also are not prone to such chemical changes within concrete as reaction, gelation, or decomposition.

In Japan, quality standards of the antiwashout admixtures have been listed in Special Underwater Concrete Manual (Design and Execution), which was published in November 1986 by the Special Underwater Concrete Investigative Committee.

CHARACTERISTICS OF ANTIWASHOUT UNDERWATER CONCRETE: Antiwashout underwater concrete has different properties from those of ordinary concrete because of the effect of the antiwashout admixture.

a. Properties of Fresh Concrete:

(1) Flowability. Due to the increased viscosity of antiwashout underwater concrete, the slump transformation takes place over several minutes. The slump is ultimately 22 to 27 cm. To more keenly appreciate the flowability of this type of concrete, a slump flow value or a spread value of DIN 1048 is more suitable than a slump value. The relationship of these is demonstrated in Figure 1.

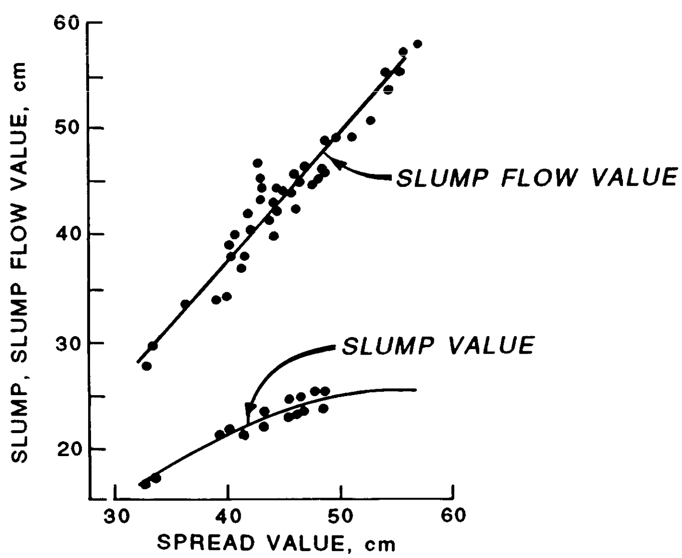

Figure 1. Relationship of Slump, Slump Flow Value, and Spread Value

Table 1
Criteria of Relationship between Flowability and Conditions of Execution

Slump Flow Value (cm)	Softness	Conditions for Application and Conditions for Execution
	Hard consistency	When it is desired to keep the flow small, such as the execution of a slanted path Concrete pump pressure transmission boundary
40		
	Medium consistency	General case Less than 50m concrete pump pressure transmission distance
45		
	Medium soft consistency	When excellent filling capability is needed Concrete pump pressure transmission distance is 50–200 m
50		
	Soft consistency [plastic concrete]	When excellent flowability is especially needed, such as RC [reinforced concrete] members of dense fiber and filler for narrow and deep holes
55		
	Supersoft consistency	

(2) Air Content. Mortar and concrete mixed with cellulose ether have greatly increased air content. For that reason, an air-detraining admixture has been added to the antiwashout admixture to reduce the air content of the concrete to between 3 to 5 percent. In this case, the bubble spacing factor of concrete with the antiwashout admixture is the same as concrete without the admixture, but the frost resistance tends to be somewhat low.

(3) Bleeding. The antiwashout admixture causes concrete to retain more water. Because the ordinary amount of admixture is more than double the amount needed to prevent bleeding, virtually no bleeding occurs in antiwashout underwater concrete. This fact is responsible for the partial reduction in the quality of the concrete and increases the need for reinforcing.

(4) Setting Time. The setting time of concrete is affected by cellulose admixtures. When a simple cellulose is used, setting time is

greatly retarded. Consequently, an accelerator is included in the antiwashout admixture. The most common admixture amounts are adjusted to result in a setting time of from 5 to 12 hours. Acrylic admixtures have virtually no effect on the setting time.

When an air-entraining, water-reducing admixture is added to the antiwashout admixture, the setting time is somewhat retarded, but the retardation time for the usual admixture amounts is less than five hours. Also, there is a retarding admixture that makes the initial setting time about 30 hours that can be used to prevent cold joints during construction.

(5) Underwater Dispersion Resistance. The dispersion resistance of concrete during underwater placement is evaluated by such things as the cement outflow rate, the change of water permeation rate, the turbidity of the water, the change of the pH value, and the change of composition. The rate of dispersion is decreased as the antiwashout admixture is increased.

b. <u>Characteristics of Hardened Concrete:</u>

(1) Compressive Strength. Figure 2 shows the relationship between the admixture amount of the cellulose admixture and concrete compressive strength. Compressive strength of a test specimen made in air is generally lowered by an increase of the amount of admixture added, but there are cases in which compressive strength has also increased, albeit slightly, because of the amount of admixture. Test specimens made underwater are produced by placing concrete into water 30-50 cm deep. Compressive strength increases with an increase of the admixture. As a result, the compressive strength ratio of test specimen made underwater to those made in air increases as the amount of admixture increases.

The amount of admixture to be added is determined by the flowability needed, distance placed underwater, horizontal flow distance, and such proportional conditions as water-cement ratio and unit cement content. In general, the compressive strength ratio is fixed to be from 0.8 to 0.9.

(2) Miscellaneous Strength and Other Characteristics

The ratio of tensile strength and flexural strength to compressive strength of an underwater-made test specimen is virtually identical with that of an air-manufactured test specimen of ordinary concrete. The modulus of elasticity is the same or slightly less than that for ordinary concrete.

The unit volume of water for antiwashout underwater concrete is much greater than that for ordinary concrete. Because water retention is high, drying shrinkage is great at 20-35 percent. Moreover, air creep appears to be somewhat greater than for ordinary concrete.

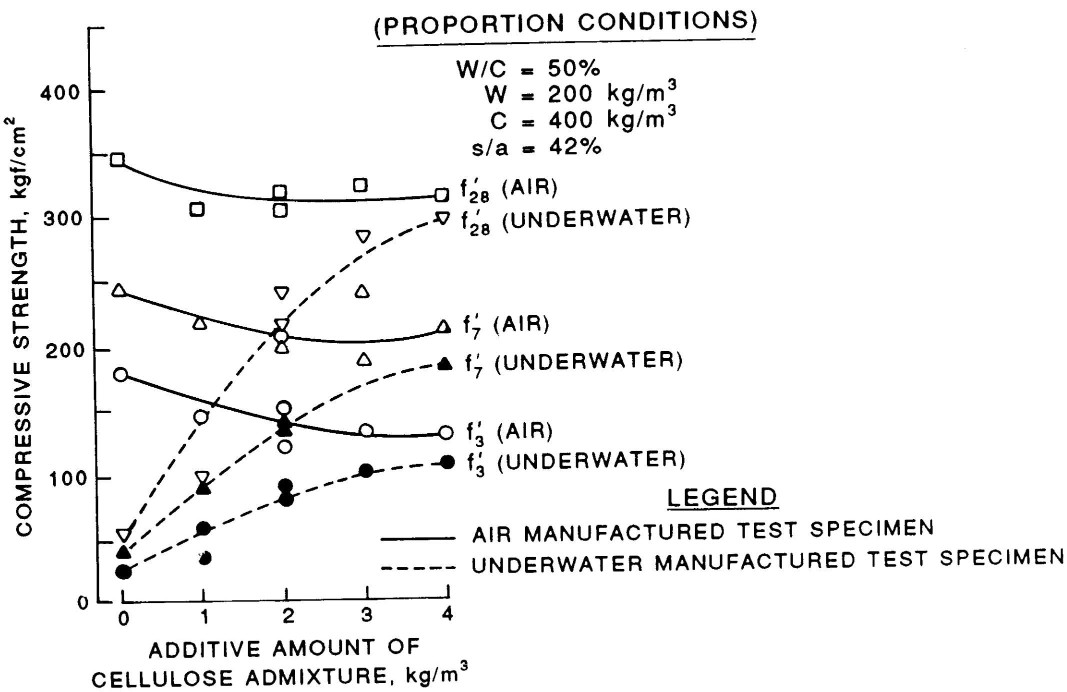

Figure 2. Relationship Between the Additive Amount of Cellulose Admixture and Concrete Compressive Strength

c. Characteristics of Horizontal Flow Time of Non-Dispersible Underwater Concrete: There are reports of qualitative changes in antiwashout underwater concrete that is provided with greater slump flow value by the addition of a water-reducing admixture and made to flow a long distance. An example of the test results for flowing concrete is shown in Figures 3 and 4. The underwater concrete with water-reducing admixtures had a slump flow value of 50 to 60 cm, a unit cement content of C = 364 to 430 kg/m^3, and a W/C = 48–60. In all of the test results, the final flow gradient was 1/125 to 1/500. Even though the concrete surface was virtually horizontal, qualitative changes were recognizable when the flow distance exceeded 10 m. In short, the area near the tip of the concrete is apt to suffer a drop in its unit weight and modulus of elasticity as well as its compressive strength because the proportion of aggregate declines. Consequently, the largest flow distance is best determined by fully considering proportions and placement.

CHIEF CONSIDERATIONS FROM AN EXECUTION STANDPOINT:

a. Concrete Mixing: There are reports that antiwashout underwater concrete, because of its high viscosity, increases the mixer load

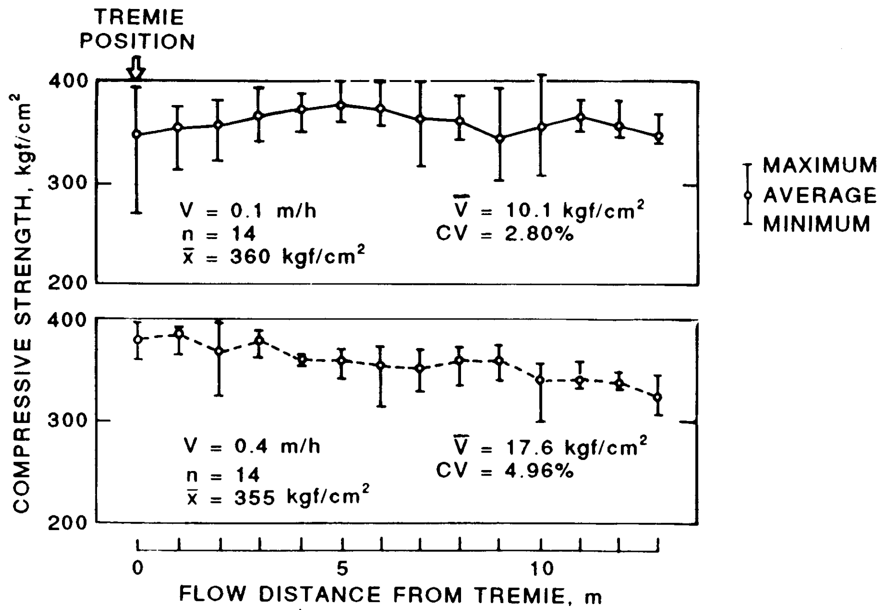

Figure 3. Relationship Between Flow Distance and the Core Compressive Strength

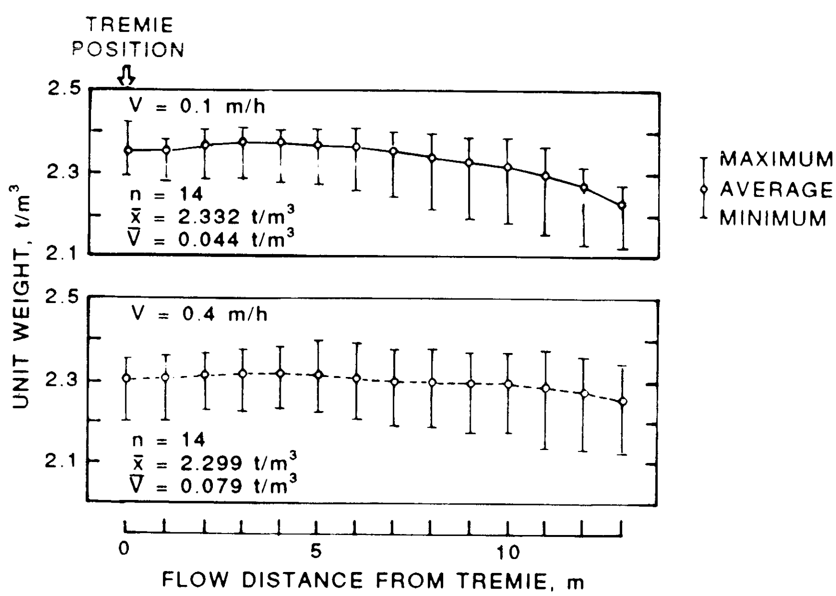

Figure 4. Relationship Between the Flow Distance and the Core Unit Weight

by 25 to 50 percent. Therefore, the capability of the mixer and the amount mixed need to be considered.

b. Water-reducing Admixture: Use of a water-reducing admixture causes a decline in dispersion resistance and some retardation of setting.

Moreover, there are instances wherein a specific flowability cannot be obtained by combining the water-reducing admixture and the anti-washout admixture. Therefore, the types of water-reducing admixtures and their appropriate additive amounts need to be taken into full consideration.

Table 2 illustrates the combination of types of antiwashout admixtures and fluidizing agents ordinarily used.

Table 2

Combination of the Various Kinds of Antiwashout Admixtures and Water-reducing Admixtures

Antiwashout Admixtures	Water-reducing Admixtures
Cellulose	Melamine sulfonate (triazin)
Acrylic	Naphthalene sulfonate
	Melamine sulfonate (triazin)
	Acrylic
	Polycarbonic acid

c. Pumping Pressure Transmission: Because dispersion resistance is high, blockage will occur only if there is difficulty within the pressure transmission tube during the pumping pressure period. Moreover, there will be hardly any qualitative changes to the concrete before or after the pressure is transmitted. However, because of high viscosity, pressure transmission resistance is 2 to 4 times that of ordinary concrete. In particular, a report that the pressure transmission capacity of the squeeze type is inferior to that of the piston type must be considered.

CONCLUSION: Today, antiwashout underwater concrete is being considered for use for many underwater structures and other large- scale projects. Under current conditions, several problems remain; for example, (1) differences in performance of the more than 10 kinds of antiwashout admixtures presently being marketed, (2) differences in mixing methods and placement methods used by operators, and (3) the antiwashout concrete's inappropriateness for use above water structures because of its drying-shrinkage and frost-resistance properties. Therefore, prior to actual use, there is a need to fully understand the quality of the antiwashout underwater concrete and the execution methods involved in its placement.

ENVIRONMENTAL CONSIDERATIONS: The antiwashout admixtures are not known to be hazardous materials. Since concrete with these admixtures is more cohesive and less susceptible to washing out of cement fines during an underwater concrete placement, the water quality should be affected to a lesser degree than if the admixtures were not used. If a significant amount of cement washes out of the concrete in a small body of water, the pH of the water can be increased slightly. Whether this increase, if it should occur, will result in unacceptable water quality or other undesirable environmental consequences should be evaluated on a project specific basis. Personnel familiar with evaluation of water quality impacts of construction operations should be consulted during the early stages of project planning to ensure that appropriate water quality criteria and other environmental regulations will be met.

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