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RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION OF ANTIWASHOUT UNDERWATER CONCRETE

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SYNOPSIS

The Committee on Concrete in the Japan Society of Civil Engineers (JSCE) organized the Antiwashout Underwater Concrete Research Subcommittee in 1989 when private companies entrusted the research to JSCE. The recommendations for design and construction of antiwashout underwater concrete was drawn up in 1991 by the research subcommittee on the basis of the results of research and actual applications in construction work.

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CHAPTER 1 GENERAL

1.1 Scope of Application

This Guideline provides general standards for the design and construction of antiwashout underwater concrete for use in concrete structures underwater.

Matters not provided for in this Guideline shall conform to the Standard Specifications for the Design and Construction of Concrete Structures.

[Comments]: Although underwater concreting has been in use for a long time, development of the technique has mainly proceeded in the areas of concrete placing method and improvements to the construction machinery. The prepacked concrete method, tremie method, concrete pump method, and others are now the representative underwater concreting methods. With all these concreting methods, the essential aim of technological development has been to improve how the concrete is placed and to minimize contact between the water and mortar so as to prevent the concrete from segregating under water.

On the other hand, antiwashout underwater concrete is quite different in concept from the methods mentioned above; the developmenta1aim in this case was improved performance of the fresh concrete. That is, the viscosity of the concrete was increased and its resistance to segregation under the washing action of water was enhanced by mixing an antiwashout admixture with the concrete. The effect of this is not only to greatly improve the reliability of Concrete placed underwater, but it also has remarkable effects on environmental preservation in the construction area. In addition, the earlier tremie and concrete pump placing methods can be adopted for construction.

The specific advantages of antiwashout underwater concrete include the following:

1 Compared with ordinary concrete, antiwashout underwater concrete is highly resistant to the washing action of water, and rarely separates even when dropped under water

2 Its yield value is small and viscosity high, so the concrete components never segregate and it displays high fluidity.

3 As a result of the high fluidity, filling property and self-leveling ability are improved.

4 Almost no bleeding occurs.

These qualities are taken full advantage of in work which would be difficult to handle using conventional underwater concrete. This includes work where high reliability is required, work in flowing water, work where water turbidity is restricted due to environmental considerations, and work where construction stretches over a considerable area and good flatness is necessary. On the other hand, however, handling is more difficult than with
ordinary concrete, and in order to produce concrete of the required quality and a structure of the required performance, careful consideration of mix proportion, mixing, transport, and placing, etc. is necessary when antiwashout underwater concrete is used. In particular, when producing the concrete it is necessary to mix it for longer than ordinary concrete in a mixer large enough to uniformly disperse the antiwashout admixture. Also, when using concrete pumps for placement, it is necessary to design a pumping plan with care as regards pumping equipment, pumping distance, etc., because the pumping resistance is increased by the higher viscosity.

Antiwashout underwater concrete may be considered for use in a diverse range of work underwater (both fresh water and sea water) where its excellent characteristics (resistance to washout, filling property, and self-leveling ability) are of great advantage. This Guideline assumes placement of several tens of cubic meters or more of antiwashout underwater concrete, and structures are taken to be medium-sized non-reinforced and reinforced concrete constructions. The following structures fall outside the scope of this Guideline.

1 Above-water structures.

2 Structures that may be exposed to air in the future.

3 Prestressed concrete.

4 Underground continuous walls (it was decided to place this outside the scope of this Guidelinebecausetherearepracdcal1ynorecordsofsuchwork).

As regards construction, placement conditions should in principle be still water (current below 5cm/s), drop height of less than 50 cm, and a flow distance of less than 5 m. The main differences in designing the mix proportion of antiwashout underwater concrete as compared with ordinary concrete are that the target strength is determined on the basis of test pieces prepared in water and that resistance to freezing damage is not considered.

This Guideline covers matters particular to the design and construction of underwater structures using the antiwashout underwater concrete, and anything not provided for in the Guideline should conform to the Standard Specifications for Concrete.

1.2 Definitions

The following terms are commonly used in this Guideline.

Antiwashout admixture for underwater concrete: An admixture that increases the viscosity of concrete and prevents its component materials separating even in water.

Antiwashout underwater concrete: An underwater concrete that has improved resistance to segregation as a result of adding an antiwashout admixture.

High-range water-reducing agent: An admixture with the main purpose of reducing the water content necessary to obtain the required slump flow.

Antiwashout property: A property which gives the concrete components resistance to segregation even when the concrete is subjected to washing action in water.

Self-leveling property: A property which ensures that the concrete disperses plane-wise due to its weight, thus forming a horizontal surface.

Filling property: A property which ensures the concrete flows into every nook and cranny due to its weight.

Slump flow: The spread of fresh concrete which results when a slump cone is withdrawn after filling with a specimen in conformity with JIS A 1101 “Testing Method for Concrete Slump.”

Underwater dropping height: The height concrete is dropped in water from the bottom of the placing tool to the placing location.

Specimen prepared underwater: Specimen prepared underwater by dropping antiwashout underwater concrete into a form work as provided for in JIS A 1132.

Specimen prepared in air: Specimen prepared by placing antiwashout underwater concrete into a formwork in air as provided for in JIS A 1132.

Air/underwater strength ratio: Ratio of compressive strength of a specimen prepared in air to that of a specimen prepared underwater at the same age.

[Comments]:

Antiwashout admixture and high-range water-reducing agent: The antiwashout admixture and high-range water-reducing agent are mainly used to give antiwashout properties and to reduce the unit water content, respectively. Antiwashout underwater concrete of the required quality can be produced by combining them as necessary. The antiwashout admixture and high-range water-reducing agent should conform respectively to “Quality Standards for Antiwashout Admixtures for Underwater Concrete “ and “Quality Standards for Superplasticizers for Concrete” of the Japan Society of Civil Engineers.

Slump flow: This is used as an index to represent the fluidity of concrete and its measurement Should conform to “Testing Method for Concrete Slump Flow” of the Japan Society of Civil Engineers. The slump is taken to be the spread of the sample measured five minutes after the Slump cone is withdrawn.

Specimen prepared under water: The concrete strength referred to when considering “mix proportion,” “quality control,” etc., in this Guideline is that obtained for a specimen fabricated under water. The preparation of underwater specimens should conform to “Method of Preparing Specimens Under Water for Testing of Compressive strength of Antiwashout Underwater Concrete” in the Standards of the Japan Society of Civil Engineers.

Air/underwater strength ratio: In this Guideline, this value is used as an index of the antiwashout properties of antiwashout underwater concrete.

CHAPTER 2 QUALITY CONTROL OF ANTIWASHOUT UNDERWATER CONCRETE

2.1 Requirements

Antiwashout underwater concrete shall have the required strength, durability, compactness, and ability to protect steel materials, and the scatter in quality shall be small. Also, the concrete shall have a workability suitable for the placing operation and shall not cause water pollution.

[Comments]: As in the case of ordinary concrete, antiwashout underwater concrete should have the desired strength and durability, as well as the capacity to protect steel materials from corrosion. However, when a large unit water content is needed to obtain the required fluidity, i.e. greater than 200 kg/m^3,the amount of cement as determined from the water-cement ratio sometimes exceeds $400kg/m^3$.It is therefore necessary to thoroughly examine not only the fluidity and strength needed for the structure, but also the temperature rise due to heat of hydration and whether it is proper to use various admixtures, etc. Furthermore, since the final quality of the concrete depends not only on fluctuations in the quality of the materials and measurement errors, but also on the effects of underwater drop height, underwater flow distance, and water currents in the area of construction, consideration should also be given to these points. That is, the final quality of antiwashout underwater concrete is greatly affected by the construction conditions as well as the materials used and the mix proportion, so it is important that these factors be comprehensively considered if a structure of the required performance is to be obtained.

There are a variety of types of antiwashout admixtures, such as those based on the cellulose system and the acrylic system. Also, the degree of antiwashout property and flow property differs depending on the brand of antiwashout admixture, even though the main Ingredient may be the same. It is thus important to comprehend the performance of the antiwashout admixture to be used using available reference materials, as well as to confirm that the required quality can be obtained by conducting tests in advance using the chosen materials.

2.2 Quality of Fresh Concrete

(1) The antiwashout underwater concrete shall have adequate fluidity and the required antiwashout properties underwater.

(2) The antiwashout property is expressed as the ratio of air to underwater strength.

(3) The fluidity is expressed as the slump flow.

(4) The antiwashout underwater concrete shall have the required filling and self-leveling properties as required.

[Comments]

Concerning(1): During the placing of concrete, segregation is liable to occur as the concrete is Dropped at such times as: when starting placement, when replacing the placing tool, when the Placing tool rises and falls with the motion of the flat barge or similar, when a current crosses the placing location, and when the concrete has to be dropped with out inserting the placing tool to the bottom. To obtain good quality concrete despite these conditions, the most important factors the antiwashout property of the concrete. The antiwashout underwater concrete should be able to withstand these washing actions of the water and suffer only minor reductions in quality.

Antiwashout underwater concrete is widely used in revetments, slope coverings, the fabrication of horizontal members, and filling into narrow gaps. Since the concrete needs a dry consistency to prevent it from flowing when used to cover a slope and the ability to permeate thoroughly between reinforcing bars and structural steel when used in small space sand in the fabrication of horizontal members, it should have a fluidity suitable for each of these uses. However, if the underwater flow distance is increased in anticipation of greater fluidity, there is
a danger of coarse aggregate settling at the tip of the flow and increasing the mortar ratio. Therefore, it is necessary to carefully examine the underwater flow distance in advance to prevent loss of quality.

Concerning(2): The antiwashout property is actually the ability of constituent materials to withstand the washing action of water (obtained by giving the concrete sufficient viscosity) but for practical purposes it is expressed as the air/underwater strength ratio. Also, depending on the application, the amount of suspended solids, pH, and other factors may be taken into consideration.

When a concrete is mixed with the proper proportion of antiwashout admixture, thus giving it adequate antiwashout properties under water, quality requirements can be met perfectly satisfactorily even if it is placed with some drop under water Judging from past experience, the air/ underwater strength ratio of concrete with adequate antiwashout properties is generally greater than 0.70. Where concrete of greater quality is called for, as in the case of reinforced concrete, then it is desirable to use an antiwashout underwater concrete with a higher strength ratio.

Where antiwashout underwater concrete is used to control water pollution, the quantity of suspended solids and pH, etc. should be taken into account in addition to the strength ratio. In this case, thorough attention should be paid to the dilution ratio in the area of construction to ensure that water quality standards in the surrounding environment, as provided for in the related laws, are not exceeded. The laws in question include the Water Pollution Prevention Act, the Environmental Pollution Prevention Act, and the Sewerage Law.

Concerning(3): Although concrete consistency is expressed in terms of slump in conformity with JIS A 1101 “Testing Method for Concrete Slump” for concretes in general, it is not proper to express it in this way in the case of antiwashout underwater concrete, because of its peculiar flow properties. Therefore, the fluidity of antiwashout underwater concrete should be expressed as a slump flow, in conformity with ”Testing Method for Concrete Slump Flow” of the Standards of the Japan Society of Civil Engineers.

Concerning(4): Since the fluidity of the antiwashout underwater concrete can be varied without leading to segregation, good filling and self-leveling properties can be obtained. The filling property is useful when placing into the corners of structures and in portions with complex slopes, etc., while the self-leveling property is advantageous when the surface of the concrete is required to be of good flatness over a wide area. Although good filling may be displayed with a slump flow above 45-50 cm, it is necessary to examine the effects of the maximum size of coarse aggregate and shape of portions where the concrete is being placed. Where the antiwashout underwater concrete is expected to display superior self-leveling properties, as in the case where an installation is to be loaded after the concrete hardens, the slump flow should be about 55-60 cm. However, since concrete never has perfect self-leveling properties, it is necessary to examine fluidity in terms of its relationship with allowable unevenness.

2.3 Strength of Hardened Concrete

The strength standard for antiwashout concrete shall be the test value of a specimen prepared underwater at the age of 28 days, as a rule.

[Comments]: The strength of the antiwashout underwater concrete is affected by the type and quantity of antiwashout admixture used and the method of preparation; however, the relationship between compressive strength of a specimen prepared underwater and the cement/water ratio for generally recommended ratios of antiwashout admixture is a straight line in the range of practical strengths. Past records show that the strength of cores taken from actual structures made with antiwashout underwater concrete when the underwater drop height was less than 50 cm and underwater flow distance less than 5 m, was the same or greater than that of 28-day strength of specimen prepared under water and when curing was done under water. In consideration of this, the standard of strength for antiwashout underwater concrete is taken as the test value at the age of 28 days for specimens prepared underwater. However, where the strength is needed relatively earlier the standard shall be the strength of specimen at the age earlier than 28 days.

On the other hand, if cement that achieves higher long-term strength is used from the viewpoint of heat of hydration, as in the case of mass concrete, or if a longer period elapses before the structure is loaded, the standard of strength may be taken at an age older than 28 days.

Compressive strength tests should be conducted in conformity with JIS A 1108 “Testing Method for Concrete Compressive strength.” The specimens for compressive strength tests shall be prepared in conformity with ”Method for Preparing Specimens Under Water for Compressive strength Tests of Antiwashout Underwater Concrete” of the Japan Society of Civil Engineers.

CHAPTER 3 MATERIALS

3.1 General

The materials used shall be of verified quality.

[Comments]: To produce antiwashout underwater concrete of the required quality, the materials used should have the prescribed quality. Whether the underwater admixture is good or bad greatly influences the antiwashout underwater properties of the concrete, so it is particularly important that the admixture used be of the prescribed quality.

3.2 Cement

(1) Ordinary Portland cement, high early-strength Portland cement, and moderate-heat Portland cement shall conform to JIS R 5210; blast-furnace slag cement to JIS R 5211; and fly-ash cement to JIS R 5213.

(2) Cement other than (1) above shall be checked for quality as an antiwashout underwater concrete, and its method of use thoroughly examined.

[Comments]

Concerning (1): Since the records of antiwashout underwater concrete use are few, cement is limited to those types which have a proven record.

Concerning (2): Cements other than (1) should be checked for mixing effectiveness with the antiwashout admixture, a suitable method should be selected for the type of cement.

3.3 Fine Aggregate

(1) Fine aggregate shall conform to the Standard Specifications for Concrete.

(2) The allowable limit of chloride ion content where sea-sand is used in reinforced concrete structures shall be 0.02% of absolute dry weight of fine aggregate.

(3) The fine aggregate used shall be a type judged to be non-harmful according to an alkali-silica reaction test.

[Comments]

Concerning (1): Where granulated blast-furnace slag is used, it should conform to JIS A 5012 “Granulated Blast-furnace Slag Aggregate for Concrete.“ Where crushed sand is used, it should conform to JIS A 5004 “Crushed Sand for Concrete” Where crushed sand is used, it should be borne in mind that the required unit water content will be larger for a given fluidity.

Concerning (2): The allowable limit for chloride in the concrete should be determined through a comprehensive consideration of the structure's required durability, the environmental conditions, etc. Where the antiwashout underwater concrete is being used for reinforced concrete, the quantity of chloride ions should be less than 0.30 kg/m^3 from the view point of quality control. Where sea-sand is used as the fine aggregate, chloride ions in the sea-sand should account for less than 0.02% (0.03% by conversion to NaCl) of absolute dry weight of fine aggregate.

Concerning (3): Where the antiwashout underwater concrete is to be placed in sea water, the alkali contained in the concrete is supplemented by alkali metals from the seawater. Also, since the structure is permanently immersed in water, maintenance and repair can be difficult. For these reasons, the aggregate should be one judged harmless according to alkali-silica reaction tests, thus falling on the safe side as far as the alkali-aggregate reaction is concerned.

The alkali-silica reaction tests should be conducted in conformity with JIS A 5308 “Ready Mixed Concrete,” Attachments 7 and 8.

3.4 Coarse Aggregate

(1) The coarse aggregate used shall conform to the Standard Specifications for Concrete.
(2) The coarse aggregate shall be one judged non-harmful according to alkali-silica reaction tests.

[Comments]

Concerning (1): Restrictions on the physical properties of the coarse aggregate used in antiwashout underwater concrete are basically the same as those for ordinary concrete. However, it should be remembered that where coarse aggregate is used, the antiwashout Properties when the concrete is dropped underwater would tend to be lower.
Concerning (2): Refer to 3.3 Comments (3) in this Guideline.

3.5 Antiwashout Admixture for Under water Concrete

The antiwashout admixture for underwater concrete shall conform to “Quality Specifications for Antiwashout Admixtures for Underwater Concrete” of the Standards of the Japan Society of Civil Engineers.

[Comments]: The document “Quality Specifications for Antiwashout Admixtures for Underwater Concrete” of the Standards of the Japan Society of Civil Engineers provides quality standards of antiwashout admixtures according to the final quality of the concrete. In other words, the antiwashout admixture should be chosen such that the concrete, when produced under the prescribed conditions and admixture usage methods, falls within the allowable range in all tests provided for in the Standards. This includes demonstrating antiwashout properties under water of more than the fixed depth and having the required compressive strength.

There are standard and delayed types of antiwashout admixture. They differ only in their setting and hardening rate, and there is no essential difference in mixing effects. Where fluidity needs to be retained for many hours, the delayed type is more suitable; combined use of standard-type and delayed-type AE water-reducing agents has a similar effect.

In addition to classification by setting and hardening time, antiwashout admixtures can be classified into those whose main constituents are of the cellulose system and of the acrylic system. These main constituents are various types of water-soluble high polymers, and it is thought that they display their effects by dissolving into the concrete mix water.

Antiwashout admixtures come in powder form. When the concrete is being produced they are thrown into the mixer, where, when water is added and mixed, they dissolve.

Of the under water concrete admixtures on the market that increase viscosity, there are some which do not meet “Quality Specifications for Antiwashout Admixtures for Underwater Concrete” of the Standards of the Japan Society of Civil Engineers. However, there are also some whose test values indicate the capability to satisfy all requirements when tested in conformity with the method provided for in the Quality Standards using sea water except in mixing. Although they do not meet the Japan

Society of Civil Engineers standards, these admixtures can be treated proportionately with ordinary antiwashout admixtures, provided they are used for construction in sea water.

3.6 Admixtures

(1) Water-reducing agents and AE water-reducing agents used as admixture shall conform to JIS A 6204 and shall have no ill effects on the concrete when used in conjunction with the antiwashout admixture.

(2) High-range water-]reducing agents used as admixtures shall conform to ”Quality Standards for Superplasticizers for Concrete” of the Standards of the Japan Society of Civil Engineers, and should have no ill effects on concrete when used in conjunction with the
Antiwashout admixture.

(3) Admixtures other than (1) and (2) above shall be thoroughly checked for quality and method of use beforehand.

[Comments]

Concerning (1) and (2): Since the number of water-reducing agents and AE water-reducing agents with proven records of use in antiwashout underwater concrete is limited, it is not clear whether all of them are free of harmful effects in mixing, and certain mixing effects can be expected. It is necessary to check through past records, tests, etc., prior to use of such agents.

Where an antiwashout admixture of the cellulose system is used, no AE water-reducing agent will normally be used as air entrainment is determined by the antiwashout admixture and no improvements in fluidity due to air entraining will be recognized. Generally, AE water reducing agents are used for their water-reducing effects and to delay or accelerate setting. Where an antiwashout admixture of the acrylic system is used, the air content is adjusted with an AE water-reducing agent.

To control the tendency for the unit cement quantity to rise as the amount of water is increased to obtain the required fluidity, a high-performance water-reducing agent is used. It is known that there are some problems between high-range water-reducing agents and antiwashout admixtures, and there have been cases where unfavorable symptoms appear, such as an increase in air content, a resulting loss of strength, and reduction in fluidity, depending on the combination. Consequently, it is essential to confirm that the high-range water-reducing agent used in combination with the antiwashout admixture is not harmful to the concrete through checking reference materials or performing tests.

Concerning (3): Where admixtures other than (1) and (2) are used, it is important to thoroughly examine the method of use in advance as well as to confirm the quality of the resulting concrete through tests, because there may be cases where the properties of the antiwashout underwater concrete are impaired.

3.7 Mineral Admixtures

(1) Fly ash used as a mineral admixture shall conform to JIS A 6201.

(2) Granulated blast-furnace slag used as a mineral admixture shall conform to “Specifications for Granulated Blast-furnace Slag for Concrete” of the Standards of the Japan Society of Civil Engineers.

(3) Mineral admixtures other than (1) and (2) above shall be thoroughly checked for quality and method of use in advance.

[Comments]

Concerning (1): Since there are almost no records of the use of mineral admixtures other than fly-ash and granulated blast-furnace slag, the quality of antiwashout underwater concrete using other mineral admixtures should be thoroughly checked prior to their use.

3.8 Reinforcing Bars

(1) Reinforcing bars shall, in principle, conform to JIS G 3112.
(2) Reinforcing bars that conform to JIS G 3117 shall also be tested to check that they are suitable.
(3) Epoxy resin coated reinforcing bars shall conform to "Quality Standards for Epoxy Resin Coated Reinforcing Bars" of the Standards of the Japan Society of Civil Engineers.

[comments]: Refer to the "Part of Construction"3.7.1 Notes of the Standard Specification for Concrete.

3.9 Storage of Materials

(1) The antiwashout admixture for underwater concrete shall be stored such that it does not to absorb moisture and is not exposed to direct sunshine.
(2) The antiwashout admixture for underwater concrete shall, when stored for a long period of time or when found to show irregularities, be tested before use. If in the test the required performance cannot be obtained, the admixture shall not be used.
(3) Materials other than antiwashout admixture for underwater concrete shall be stored in conformity with the Standard Specifications for Concrete.

[Comments]
Concerning (1): Since antiwashout admixtures are moisture absorptive, there is a danger of coagulation and loss of ratio of effective ingredients. The admixtures may also deteriorate when directly exposed to sunshine or high temperatures. Therefore, when storing admixtures, care should be taken to avoid direct exposure to sunshine and to keep them in a sealed, moisture proof container at normal temperatures (below 30^{o}C is desirable). The standard storage limit is six months under the prescribed conditions.
Concerning (2): Irregularities that can arise when an antiwashout admixture is stored for a long period of time include those which can be visually observed, such as coagulation of grains, and discoloring., and those which can be judged only by mixing with concrete, such as antiwashout properties underwater and flow irregularities. The indices for the latter include an increase in slump flow, reduction in strength and air/underwater strength ratio, and an increase in suspended solids when it is dropped underwater. When it has been stored for a long period of time, an admixture should be tested before use to confirm that it still conforms to "Quality Standards for Antiwashout Admixtures for Underwater Concrete" of the Standards of the Japan Society of Civil Engineers.

CHAPTER 4 MIX PROPORTION

4.1 General

The mix proportion of antiwashout underwater concrete shall be determined by tests such that the concrete has the required antiwashout properties, strength, fluidity, and durability.

[Comments]: As a basic rule, the mix proportion of ordinary concrete is determined such that the unit water content is minimized within the range of appropriate workability. On the other hand, the procedure for antiwashout underwater concrete is to firstly select the quantity of antiwashout admixture and high-range water-reducing agent according to the required antiwashout properties and fluidity. Then the unit water content is made as small as possible. In other words, since these quantities have an effect on each other, the basic rule for designing Mix proportions for antiwashout underwater concrete is to properly determine the quantities of antiwashout admixture, high-range water-reducing agent, and the unit water content corresponding to the required concrete qualities. Accordingly, the mix of antiwashout underwater concrete should, as a rule, be determined through tests.

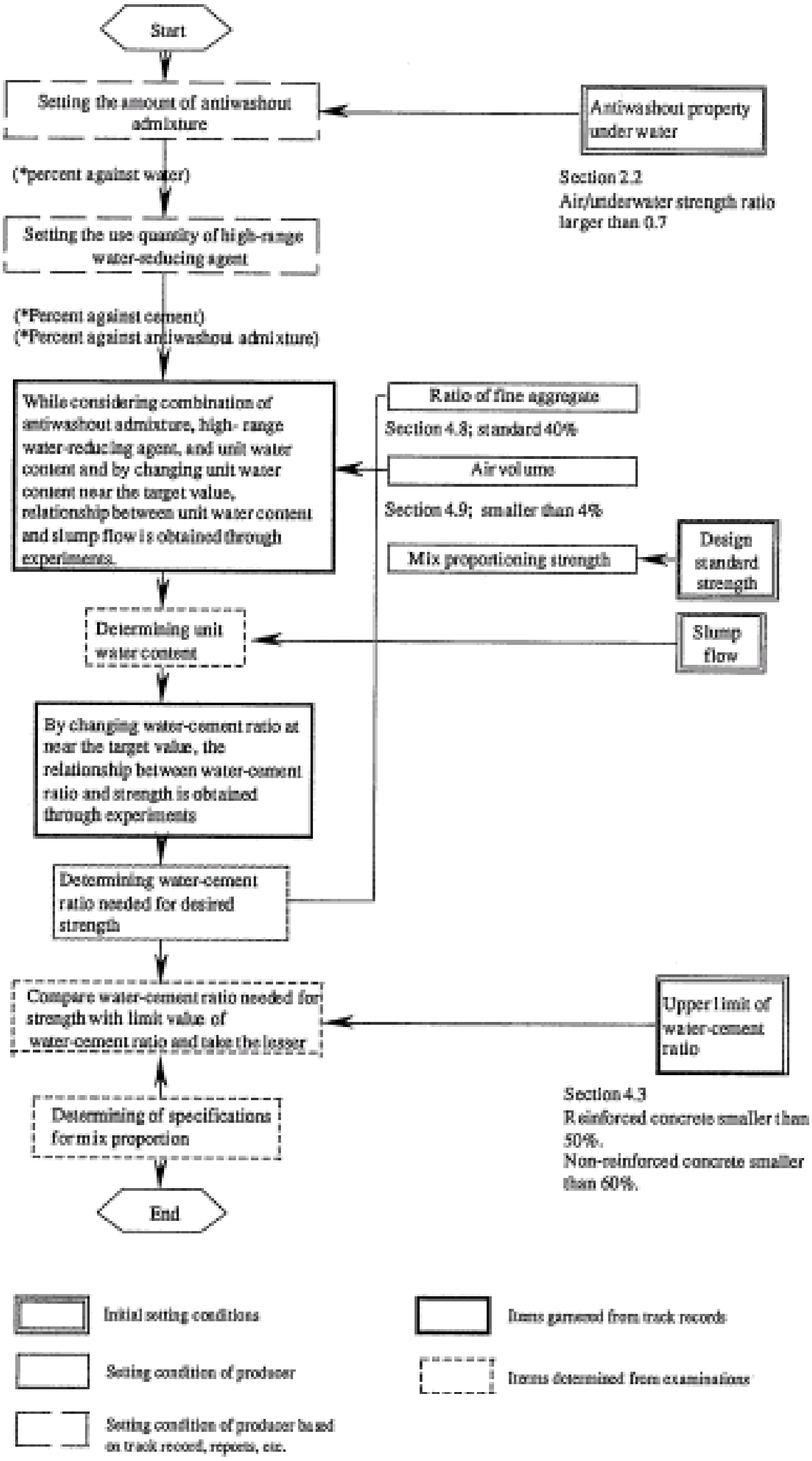
[Comments]: Figure4.1.1 gives a general outline of how the mix proportion for antiwashout underwater concrete should be determined. The thick lines on the left of the figure indicate the main process of mix proportion design, while the thin horizontal lines linking some items are the conditions set with reference to particular work specifications, this Guideline, experience records, and reports.

4.2 Mix Proportioning Strength

The mix proportioning strength of antiwashout underwater concrete shall be determined in consideration of the design standard strength and the fluctuations in concrete quality.

[Comments]: To ensure that the compressive strength of concrete throughout the structure does not fall below the design standard compressive strength, the mix strength of antiwashout underwater concrete should be made higher than the design standard strength in consideration of fluctuations in concrete quality at the site.

The quality of antiwashout underwater concrete at the site suffers scatter as a result of fluctuations at the time of production (fluctuations in material quality, errors in weighing, fluctuations due to mixing, etc.) and fluctuations at the time of placement under the water (fluctuations due to dropping of the concrete underwater, fluctuations due to placing, etc.). Of these, the latter can generally be excluded from consideration because the mix proportioning strength is determined according to test values from specimens prepared underwater. In this Guideline, placing is specified as taking place under conditions with an underwater drop height of less than 50 cm and a flow distance of less than 5 m in still water. Methods of preparing specimens under water on the basis of construction principles are provided for in the Standards of the Japan Society of Civil Engineers, etc. Accordingly, strength increment adopted when determining mix proportioning strength should be about the same as that used for ordinary concrete. However, since placing tools cannot be maneuvered where narrow gaps have to be filled, fluctuations at the time of placing should be considered if special conditions apply to the construction, such as when the underwater drop height is greater than 50 cm.



Comments Fig. 4.1.1 General Ideas of Mix Proportion Design of Antiwashout Underwater Concrete

4.3 Water-cement Ratio

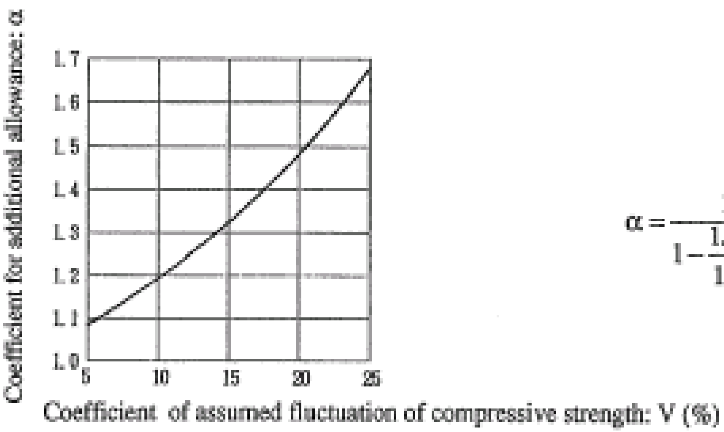
The water-cement ratio shall be determined in consideration of the required concrete Strength and durability.

(1) When the water-cement ratio is determined based on the compressive strength using specimens prepared under water.

(a) The relationship between compressive strength and water-cement ratio shall as a rule be determined by tests using specimens prepared underwater. The standard of age of the specimen shall be 28 days.

(b) The water-cement ratio shall be the reciprocal of cement-water ratio corresponding to mix proportioning strength (f'_{cr}) in the relational equation between cement-water ratio(c/w) at the standard age and compressive strength (f'_{cw}) of specimen prepared underwater. The mix proportioning strength (f'_{cr}) shall be the result obtained by multiplying design standard strength (f'_{ck}) with the proper coefficient.

This coefficient shall be determined according to assumed compressive strength at the site so that the probability of any test measurement of compressive strength for a specimen prepared under water being below the design standard strength is smaller than 5%; generally it is the value obtained from the curve in Fig.4.3.1.



$$\alpha = \frac{1}{1 - \frac{1.64}{100} V}$$

Fig. 4.3.1 Additional allowance & coefficient of antiwashout underwater concrete

Table4.3.1Maximum Water-Cement Ratio of Concrete Determined from Durability(%)

Type of structure / Environment	Non-reinforced concrete	Reinforced concrete
In fresh water	65	55
In sea water	60	50

(2) Where the water-cement ratio is determined in consideration of corrosive action on the reinforcing

bars, chemical action on the concrete etc., the maximum value shall be that given by Table4.3.1 as standard.

[Comments]

Concerning (1)(a): In the case of antiwashout underwater concrete, a rule for the water-cement ratio can be expressed and there is a straight-line relationship between compressive strength of specimens prepared underwater and the water-cement ratio, as in the case of ordinary concrete. This relationship can be effectively used in the design of mix proportion, so the relationship between compressive strength of specimens prepared under water and the water-cement ratio is fixed by tests, as a rule.

The relationship between the cement-water ratio(C/W) and compressive strength of specimens prepared underwater (f'_{cw}) can be obtained as follows: Tests are conducted, using specimens prepared in conformity with “Method of Preparing Specimens Under Water for Compressive strength Tests of Antiwashout Underwater Concrete” of the Standards of the Japan Society of Civil Engineers, on antiwashout underwater concrete with three different C/Ws within a range deemed to be proper and the C/W-f'_{cw} curve is drawn. It is desirable to use a value of f'_{cw} for each C/W which is the average of specimens prepared from more than two batches of concrete, so as to reduce the occurrence of errors in mix proportion. The relationship between C/W and f'_{cw} can be expressed approximately as a linear equation where the air content is fixed, though it differs depending on air content.

In cases where the design standard strength is specified at other than 28 days, tests will be conducted at the specified age, and the mix proportion may be determined from the relationship between strength at that age and cement-water ratio.

Concerning (2): Underwater structures are often subjected to erosive action due to various salts in the water that comes into contact with them and to abrasive action where the water flows. When placing in sea water, salts from the sea water are absorbed during placing.

Also, antiwashout underwater concrete tends to make it easier for chlorides to enter the structure compared with ordinary concrete of the same water-cement ratio. However, there are reports which claim that the physical and chemical characteristics of antiwashout underwater concrete, such as reinforcing steel corrosion, compressive strength, and unit weight, are approximately the same as for ordinary concrete after exposure to sea water for 5-6 years, and there are no serious concerns regarding practical use and durability. Therefore, The limit value of water-cement ratio was made the same limit value as provided for in the Standard Specifications for Concrete.

4.4 Unit Water Content

The unit water content shall be determined through tests in consideration of the amount of antiwashout admixture and high-range water-reducing agent used. It shall be as low as possible within the range that yields the required fluidity.

[Comments]: Antiwashout underwater concrete rises in viscosity in proportion to the quantity of antiwashout admixture used, so the unit water content necessary to obtain the required fluidity also increases. A high-range water-reducing agent is also added to counter act this effect. Although the amount of high-range water-reducing agent used is correctly determined according to the quantity of antiwashout admixture, it is preferable to add as much as is possible without producing any ill-effects such as loss of antiwashout properties and delayed setting.

The unit water content should be determined by tests, and should be as low as possible with in the range giving the required fluidity. Tests are implemented with a suitable combination of antiwashout admixture, AE water-reducing agent, high-range water-reducing agent, and mixing water. Normally, the unit water content in antiwashout underwater concrete with a slump flow of about 50 cm is 210-230 kg/m^3. For details of unit water content, refer to Table 4.4.1.

Table 4.4.1 Approximate Values of Unit Water Content in Antiwashout Underwater Concrete

Maximum size of coarse aggregate (mm)	Unit water content (kg/m^3)
20	220
40	215

(1) Values given in this table are for antiwashout underwater concrete with a slump flow of 50 cm made with sand aggregate ratio and crushed stone of standard aggregate grade.

(2) Conditions in this case include use of W x 1.15% antiwashout admixture, about 10 L/m^3 high-range water-reducing agent (solid content, 2.5kg/m^3), about 40% fine aggregate, and 4% air. W is the unit water content.

(3) Where material qualities and the concrete differ from conditions (1) and (2), corrections should be made using the values in the table below.

Difference	Correction to unit water content (kg/m^3)
For each increase/decrease of 1 cm in slump flow	Increase/decrease 3
For each increase/decrease of W x 0.10% in amount of antiwashout admixture	Increase/decrease 5

Note: This correction table is applicable to slump flows in the range 45-55 cm.

4.5 Unit Cement Content

The unit cement content shall be determined from the unit water content and the water cement ratio.

[Comments]: Refer to Comments 4.5 of "Part of Construction" of the Standard Specifications for Concrete.

4.6 Maximum Size of Coarse Aggregate

The maximum size of coarse aggregate shall be smaller than 40 mm, as standard, and shall not exceed 1/5 of the minimum size of a member nor 1/2 the minimum gap of reinforcing steel.

[Comments]: From the view point of producing concrete economically, it is advantageous to use larger coarse aggregate when ever possible. However, as flowing the concrete in a horizontal direction is inevitable, leading to a tendency for segregation of the coarse aggregate to readily occur with coarser aggregate, the maximum coarse aggregate size is limited to 40 mm as standard. In the case of a mix where increased fluidity is called for, it may be desirable to keep the coarse aggregate below 25 mm.

4.7 Slump Flow

The slump flow shall be determined in full consideration of antiwashout properties, filling properties, self-leveling properties, etc., and shall be within the range suitable for operations such as transportation, and placing.

[Comments]: The slump flow suitable for the operation may differ according to the construction site, the construction conditions, the reinforcing bar arrangement, the placing method, etc. Although work is easy using soft concrete with larger slump flow, such concrete tends to contaminate the water and result in sinking of the coarse aggregate during placing. On the other hand, harder concrete with a smaller slump flow does not flow well in water even though its antiwashout properties underwater are improved. This may result in structural defects, such as insufficiently filled portions, depending on the shape and reinforcing bar arrangement. For these reasons, the slump flow should be carefully chosen within the range suitable for the work with reference also to the required antiwashout properties, filling properties, and self-leveling properties of the concrete.

[Comments]: Table 4.7.1 shows the standard range of slump flow. In the case of antiwashout underwater concrete, the loss in slump flow with time is less than with general concrete, but if the transport time is long and the temperature high, the mix should be selected to give a slump flow that takes into consideration any reduction.

Table 4.7.1 Standard Range of Slump Flow for Antiwashout Underwater Concrete

Construction Condition	Range of slump flow (cm)
In cases where fluidity is required to be less, such as for consolidation of stone resting on a steep slope (1:1.5 to 1:2) or construction of a thin slab on a slope (up to about 1:8)	35-40
In cases where concrete is placed into simply shaped forms	40-50
In cases where concrete is placed into standardized RC structures	45-50
In cases w here concrete is placed into complex shape. In cases w here especially high fluidity is required	55-60

4.8 Sand Aggregate Ratio

The sand-aggregate ratio shall be 40% as standard.

[Comments]: Chapter 23 of the “Construction Edition” of the Standard Specifications for Concrete recommends that the sand-aggregate ratio in concrete be increased in order to reduce the segregation of materials, and proposes 40-45% sand as standard. However, in the case of antiwashout underwater concrete, the concrete resists washout even with less sand due to the effects of the antiwashout admixture, and the effects of sand-aggregate ratio on unit water content and fluidity are smaller than with ordinary concrete. For this reason, the sand-aggregate ratio is fixed at 40% as standard.

In the case of lean-mix concrete, the unit water content and fluidity change with the amount of sand, so the sand-aggregate ratio should be properly determined by tests.

4.9 Air Content

The air content shall be less than 4% as standard.

[Comment]: In the case of antiwashout underwater concrete, the high viscosity resulting from addition of the antiwashout admixture leads to more air being entrapped in the concrete during the mixing operation. Since these air bubbles are larger than those in ordinary AE concrete, no improvement in fluidity as in the case of ordinary air entrained concrete can be expected.

Generally, the greater the amount of air, the lower the concrete strength. The scatter in concrete quality also tends to be larger as the air content increases. This is also true in the case of antiwashout underwater concrete, and it was decided that the air content should generally be less than 4% as standard.

As excess air is introduced into the concrete, particles of cement will accompany the air as it escapes from the concrete under water, and this leads to contamination of water nearby. For this reason it is desirable that the air content be kept be as small as possible.

4.10 Unit Content of Antiwashout Admixture for Underwater Concrete

The unit content of antiwashout admixture for underwater concrete shall be correctly determined according to the required characteristics of the antiwashout underwater concrete.

[Comments]: The unit content of antiwashout admixture is determined so as to secure the desired antiwashout properties underwater. These properties depend on the combination of construction conditions, such as the method of placing, the underwater drop height, currents around the placing, location, and the allowable turbidity during placing. In cases where there are special restrictions on environmental conditions, the appropriate unit content of antiwashout admixture must be determined through tests. As well as the restrictions, the strength of specimens prepared underwater using actual construction conditions, the air/underwater strength ratio, pH, suspended solid density, etc., must be considered. Generally, the unit content of antiwashout admixture is approximately 1.0-1.5% of the unit water content.

It must be remembered that some of the antiwashout admixture in fresh concrete is adsorbed on to cement particles, thereby increasing the cement paste’s viscosity by creating a cohesive force between particles, most of it dissolves in the water and increases its viscosity. All the ingredients in the water are then secured as a result of the increased viscosity, leading to manifestation of antiwashout properties underwater. Because of this relationship, it is recommended that the unit quantity of the antiwashout admixture be determined as a ratio of the unit water content.

4.11 Unit Content of Admixture

(1) The unit content of high-range water reducing agent shall be determined so as to minimize the unit

water content with in the range of required fluidity.

(2) The unit quantity of admixture other than (1) shall, as a rule, be determined by tests to give suitable characteristics for the application.

[Comments]

Concerning(1): Since the amount of water needed in antiwashout underwater concrete tends to be large in order to obtain the required fluidity, a high-range water-reducing agent is generally used to reduce it. The effects of high-range water-reducing agent is differ according to the brand and quantity of the antiwashout admixture. There are some cases where a high-range water-reducing agent will have ill-effects, such as reducing the antiwashout properties and delaying settling, if too much is added and mixing is not perfect. This problem has to be taken into account when using a high-range water-reducing agent, and the amount used should preferably be determined through tests. Generally, the amount of high-range water-reducing agent used is about 2% for the unit cement content, or about 5-10 L/m^3.

Concerning(2): Since the effects of admixtures other than (1) differ depending not only on their respective characteristics, but also on the type of antiwashout admixture employed, the mix proportion of the concrete, and other factors, the quantity used should be determined through tests to suit the application, and any effects they have on the concrete should be confirmed as a rule.

4.12 Trial Mixing

(1) The trial mixing of antiwashout underwater concrete shall be done with the actual materials to be used in the work, and it shall be implemented before starting the work.

(2)Trial mixing shall include tests of the following items:

(a) Mixing conditions
(b) Slump flow
(c) Air content
(d) Concrete temperature
(e) Compressive strength and ratio of air/underwater strength.

[Comments]

Concerning(1): Trial mixing is performed to find a mix of concrete that satisfies the quality requirements, and trial mixing should be timed such that there is sufficient time available before work commences to allow the results to be reflected in the work.

Since the unit water content needed to obtain the required slump flow and the water cement ratio needed to obtain the required strength may differ depending on the materials used, trial mixing should be done with the actual materials to be used in the work.

Concerning(2): The test items indicated are only the main ones. Where environmental pollution and effects on aquatic life require special controls, tests of pH, suspended solids, etc., should be conducted as occasion demands. Where tests other than those shown are needed to verify the quality of the concrete to be placed, they should be added.

(a) Mixing conditions: Visually check the condition of the concrete as it leaves the mixer and its condition when conducting slump test. At the same time, pick up some mixed concrete in a hand shovel and drop it into a water-filled container to observe how turbid the water becomes and how much the concrete segregates, thus confirming whether concrete of the required quality has been obtained.

(b) Compressive strength and ratio of air/underwater strength: Confirm whether antiwashout underwater concrete of the required quality has been obtained by measuring the compressive strength and the ratio of air/underwater strength. To confirm that the required strength characteristics have been manifested, tests should be implemented using two types of specimen; specimens prepared under water and specimens prepared in air. This conforms with testing methods as provided for in the Standards of the Japan Society of Civil Engineers. However, it is necessary that specimens are prepared according to the site conditions where special conditions are involved, such as the drop height being raised.

Standard curing applies to the specimens. Since the design standard strength for concrete structures is measured at 28 days, it is proper to judge the compressive strength at the age of 28 days. However, where special circumstances are involved, such as early loading of the actual structure, it is preferable to cure specimens under the same condition as to be used on the site wherever possible and to implement compressive strength tests at a nearly age.

Method of Expressing Mix Proportion

4.13 Form for Expression Mix Proportion

(1) The mix proportion shall, as a rule, be expressed as shown in Table

4.13.1.

(2) The specified mix is for fine aggregate which completely passes a 5 mm sieve and coarse aggregate which is completely retained on a 5 mm sieve; both of these shall be indicated in the surface-dry condition.

(3) To convert the specified mix to a job mix, the moisture content of the aggregate, the weight of fine aggregate remaining on the 5 mm sieve, the weight of coarse aggregate passing the 5 mm sieve, the aqueous dilution ratio of admixtures, etc., shall all be taken into consideration.

Table4.13.1 Method of Expressing Mix Proportion Unit Content

Maximum size of coarse aggregate (mm)	Range of slump flow (cm)	Range of air content (%)	Water-cement ratio* W/C (%)	Sand-aggregate ratio s/a (%)

Unit Content (kgf/m^3)								
Water	Cement	Additive	Fine Aggregate	Coarse aggregate G		Admixture		
W	C	F	S	mm mm	mm mm	Antiwashout admixture	High-range Water-reducing Agent**	Other Admixture***

*Where an admixture is used, the water-cement ratio becomes the water-binder ratio.
**Quantity of high-range water-reducing agent shall be expressed in terms of solid ingredients. However, where it is difficult to express it in this way, the unit volume of undiluted solution of high-range water- reducing agent may be expressed as a weight or volume. In this case, all the unit volume is considered part of the mixing water.
***Quantity of admixture shall be expressed in cc/m^3or, g/m3, and not in diluted or dissolved terms.

[Comments]

Concerning (1): The mix proportion is, as a rule, to be expressed in conformity with the "Construction Edition" of the Standard Specifications for Concrete and fluidity is taken as the value of the slump flow. Unit content of the antiwashout admixture and of high-range water reducing agent have been added in the table.

It is desirable that the design standard strength, mix proportioning strength, type of cement, type of fine and coarse aggregates, absolute proportion of coarse aggregate, type of admixtures, transport time, time of construction, method of placing, underwater drop height,
etc., be noted.

Since the quantity of antiwashout admixture used is normally small, i.e. 2-4 kg/m^3, it May be disregarded in calculations of the overall content of mixed concrete.

Although it is recommended that the amount of high-range water-reducing agent be expressed in terms of quantity of solid ingredient, measurements should be in conformity with "Testing Method for Solid Fluidizing Agent" in Attachment 1of "Quality Standards for Antiwashout Admixtures for Underwater Concrete" of the Standards of the Japan Society of Civil Engineers.

CHAPTER 5 PRODUCTION OF CONCRETE

5.1 General

To produce antiwashout underwater concrete of the required quality, each component of the concrete shall be properly weighed and thoroughly mixed.

[Comments]: In order to obtain antiwashout underwater concrete of uniform quality, materials weighed to the required accuracy should be mixed in the proper sequence and for adequate time using a mixer of sufficient capacity. Since errors in weighing each component become the source of fluctuations in concrete quality, the weighing of each material should be carried out carefully to the required accuracy.

5.2 Batching

5.2.1 Batching Equipment

(1) The method of batching and the batching equipment used for each component shall be capable of batching each material within the required tolerance.
(2) The batching equipment shall be inspected and adjusted periodically before starting work and during the work.

[Comments]: Refer to 5.1.2 Notes in the "Construction Edition" of the Standard Specifications for Concrete.

5.2.2 Batching of Materials

(1) Each material shall be weighed batch by batch. However, water and admixture solutions may be measured by volume.
(2) The batching error shall be less than the value shown in Table5.2.1 for each material.

Table5.2.1 Permissible Error in Batching

Type of material	Permissible Error (%)
Water	1
Cement	1
Aggregate	3
Additive	2
Antiwashout admixture	3
Admixture	3

[Comments]
Concerning (1): Where a bagged antiwashout admixture is used, it may be added directly to the mixer from the bag, provided the entire bag has been properly weighed in advance and is all used in one batch. However, amounts that are less than the weight of a full bag should be properly weighed to the specified batching accuracy.

Concerning (2): Each material batching is subject to some degree of error. Antiwashout under water concrete of stable quality can be obtained as long as the batching error is within 3% for the antiwashout admixture and other admixtures.

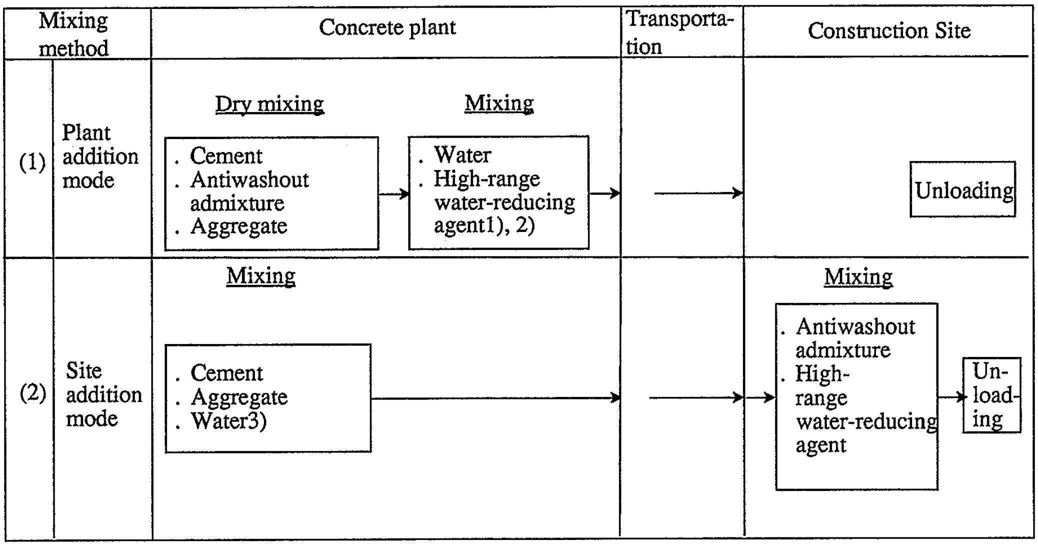
5.3 Mixing

5.3.1 General

The entire process of mixing shall, as a rule, be carried out in a well-equipped concrete production facility.

[Comments]: The mixing of antiwashout underwater concrete should, as a rule, be done in a plant with a well-equipped concrete production facility, and all materials should be finally mixed after a dry mixing process (plant addition mode). This is because the antiwashout admixture will be lumpy if it is mixed with water first, resulting in difficulties in combining it with other materials. Special care should be exercised at the time of mixing if antiwashout underwater concrete of the required qualities is to be produced.

The process of mixing, as shown in Notes Fig.5.3.1 (1) begins with the dry mixing of cement, aggregate, and antiwashout admixture in the mixer, followed by addition of water and high-range water-reducing agent. It is then mixed for the necessary time. The standard time for dry mixing is usually 20-30 seconds.



1) There may be cases where high-range water-reducing agent is added at the site.
2) There may be cases where addition of high-range water-reducing agent is delayed when mixing.
3) The quantity of water required if the antiwashout admixture is added in slurry form should be deducted in advance.

Fig.5.3.1 Method of Mixing Antiwashout Underwater Concrete

When mixing in the plant addition mode, it is sometimes necessary to add the high-range water-reducing agent at the site— as in the case of a fluidizing agent. Since there is then a danger that the high-range water-reducing agent will not be uniformly mixed with the highly viscous antiwashout underwater concrete, this method should not be used as a general method. However, where it is essential for the high-range water-reducing agent to be added after transport to the site, precautions such as reducing the volume of concrete transported at one time should be taken, and the method of addition should be determined properly and checked by tests.

For various reasons related to the concrete production facility or the particular construction work, there are sometimes cases where the method given in Notes Fig. 5.3.1 (2) may be unavoidable. Here, the antiwashout admixture is added at the site. (Site addition mode: method in which concrete is mixed in the plant without the antiwashout admixture and high-range water-reducing agent, is transported to the site, and the antiwashout admixture and high-range water-reducing agent are added later and mixed or stirred using a mixer or truck agitator at the site.) In such a case, the mixer used should have the capacity to thoroughly mix the concrete in conformity with 5.3.2 in this chapter, and the method of addition, timing, etc., of the antiwashout admixture, high-range water-reducing agent, etc., should be determined properly. In addition it should be confirmed through tests in advance that concrete of the required quality can be produced using such a method. Since a truck agitator is basically a stirring device, it is not really suitable for mixing concrete. However, incases where it has to be used for such a purpose, it should be confirmed in advance that concrete of the required quality can be produced, as in the case of adding the admixtures and agents later at the site in a mixer.

In a case where the site addition mode is used, special consideration should be given to the following points:

1 The mix of concrete prior to addition, and the quantity of admixture added later, the timing of addition, etc., should be determined in advance.
2 The time between mixing the concrete and addition of admixture at the site should be as constant as possible between batches.
3 In cases where the antiwashout admixture is added as a suspended slurry as part of the mixing water, a time limit for the period between production of the slurry and its addition should be fixed in advance.
4 If the concrete is ordered from a ready-mixed concrete plant, the mix proportion and the pre-addition slump should be specified in advance. Also, when a truck agitator is used, care should be exercised as regards the following points:
    1 The load per truck should be reduced.
    2 Mixing should be for longer duration than with a mixer.

5.3.2 Mixer

A forced mixing type batch mixer shall be used.

[Comments]: Since antiwashout underwater concrete is highly viscous, a forced batch mixer with good mixing characteristics should be used so as to produce antiwashout underwater concrete of uniform quality. The forced mixer should conform to JIS A 8603 ”Forced Mixing Type Mixers.” A forced mixer with a nominal capacity in excess of 3 m^3 should have a performance in conformity with JIS A 1119 “Method of Test for Variability of Constituents in Freshly Mixed Concrete. “ It is preferable to produce test batches of antiwashout underwater concrete of the planned mix using the chosen mixer in advance, and to confirm that the concrete meets the required quality specifications.

If for unavoidable reasons a mixer of another type has to be used, make test batches of concrete with the planned mix and confirm that the required quality can be obtained. In cases where a gravity-type mixer is used, it should conform to JIS A 1119 and JIS A 8602 “Tilting Mixers.” If using a gravity-type mixer, the concrete may adhere to the inner wall of the drum due to its viscosity, depending on mix proportion, thus causing mixing to be in sufficient. In such a case, it is necessary to take appropriate measures, such as hitting the drum or changing the rotation speed.

A continuous mixer is seldom used in making antiwashout underwater concrete. In cases where it is necessary to use a continuous mixer, it should be confirmed that the mixer has the required mixing characteristics as per ”Method of Test for Mixing Efficiency of Continuous Mixers” of the Standards of the Japan Society of Civil Engineers. It is also necessary to confirm that the antiwashout underwater concrete thus produced meets the required quality specifications.

5.3.3 Mixing

(1) The mixing time shall, as a rule, be determined through tests.
(2) When beginning mixing, the mortar shall, as a rule, be added to the mixer in advance.
(3) Each batch shall, as a rule, be no larger than 80% of the nominal capacity of the mixer.
(4) Until all the concrete in the mixer has been discharged, no new materials shall be thrown into the mixer.

[Comments]

<u>Concerning (1)</u>: The time required to produce concrete of uniform quality differs depending on the capacity of the mixer, the mix of the concrete, the type of admixtures, and other factors. The mixing time should therefore be determined, as a rule, after conducting mixing tests using the planned mix proportion. At this time, it should be confirmed that the variation in unit volume weight of mortar in the concrete is smaller than 0.8% and the variation in unit coarse aggregate quantity smaller than 5%. It should also be confirmed that the concrete meets the required quality specifications using method conforming with JIS A 1119 ”Method of Test for Variability of Constituents in Freshly Mixed Concrete”

The mixing time also depends on the type and quantity of antiwashout admixture being used, but is generally 90-180 seconds in the case of a forced mixer.

<u>Concerning (2)</u>: Concrete of required mix proportion cannot be discharged in the first batch because the mortar will adhere to the inner drum of the mixer. Therefore, it is proper to mix a suitable quantity of mortar of the same mix and discharge it followed by throwing in of required materials and mixing.

<u>Concerning (3)</u>: Since antiwashout underwater concrete is highly viscous, increasing the load on the mixer, it is preferable to mix batches which are less than 80% of the nominal capacity of the mixer in order to obtain concrete of required quality.

5.4 Cleaning of Mixer, Conveyance Equipment, and Disposal of Cleaning Water

(1) The mixer and conveyance equipment shall be thoroughly cleaned before and after use.
(2) The means of disposing of cleaning water shall be determined in advance.

[Comments]

<u>Concerning (1)</u>: If the mixer used for antiwashout underwater concrete and the equipment used to convey it are then used for ordinary concrete without cleaning, there may be harmful effects on slump, air content, etc. Therefore, it is necessary that any antiwashout underwater concrete adhering to the mixer and conveyance equipment be thoroughly rinsed off. Cleaning techniques include throwing in

aggregate and water followed by stirring, mixing concrete of a lean mix and then dumping it, and cleaning with high-pressure water or detergent, or a combination of these.
Concerning (2): The method of disposal for cleaning water should be determined after consultation in advance.

5.5 Ready-mixed Concrete

5.5.1 General

When ready-mixed concrete is used, it shall conform to JIS A 5308 in addition to this Guideline.

[Comments]: To produce the antiwashout underwater concrete of stable quality, it is desirable to entrust production to a ready-mixed concrete plant. If the antiwashout underwater concrete is produce data ready-mixed concrete plant in this way, JIS A 5308 should be complied with and serious considerations given as regards matters not provided for in this Guideline.

5.5.2 Designation of quality

When placing an order for antiwashout underwater concrete with a ready-mixed concrete plant, consultations shall be held with the manufacturer regarding the following points, and a proper designation made:

1) Slump flow
2) Compressive strength of specimens prepared underwater and the age at which it is guaranteed
3) Air/underwater strength ratio
4) Air content
5) Type and amount of antiwashout admixture
6) Type and quantity of high-range water-reducing agent
7) Type of cement
8) Type of coarse aggregate
9) Maximum size of aggregate
10) Limit of chloride content
11) Upper limit of water-cement ratio
12) Lower or upper limit of unit cement quantity And, as occasion demands,
13) Quantity of suspended solids and pH
14) Setting time
15) Reduction in slump flow with time
16) Maximum or minimum temperature of concrete

[Comments]: Concrete varies depending on the conditions and type of structure and on the construction conditions, etc. Therefore, when placing an order for concrete, it is important to consult fully with the manufacturer and designate the necessary specifications properly to ensure that concrete of the required quality can be obtained.

5.5.3 Acceptance Test

Acceptance tests shall be conducted in conformity with JIS A 5308 and also according to the following points:

(1) The tests shall cover slump flow, air content, compressive strength of specimens prepared underwater, and other characteristics designated through consultations with the manufacturer.

(2) Tests shall be conducted, as a rule, once every $100m^3$.

[Comments]

Concerning (1): The preparation and measurement of specimens prepared underwater should be carried out in conformity with “Method of Preparing Underwater Specimens for Compression Tests of Antiwashout Underwater Concrete” and ”Testing Methods for Slump Flow of Concrete” of the Standards of the Japan Society of Civil Engineers, respectively. The slump flow is to be the value taken five minutes after the slump cone has been removed.

Depending on the use of the antiwashout underwater concrete, characteristics other than slump now, air content, and compressive strength of specimens prepared underwater may be tested. Test items are to be selected through consultations with the manufacturer from among designated quality characteristics as provided for in 5.5.2 of this chapter, and the tests should be conducted in conformity with the methods given in the JIS or “Quality Standards for Antiwashout Admixtures for Underwater Concrete” of the Standards of the Japan Society of Civil Engineers. With respect to acceptance inspections of chloride content, it is difficult to take filtrate specimens from the antiwashout underwater concrete, so each ingredient is checked at the plant and the final chloride content of the concrete is obtained by calculation using this data.

Concerning (2): Refer to 9.3.1 (3) Notes of this Guideline.

CHAPTER 6 TRANSPORTATION AND PLACING

6.1General

(1) The methods of transportation and placing the concrete shall be suitable for the viscosity of the fresh concrete.
(2) The layout of placing tools and the height of each lift shall be chosen to give placed concrete of uniform quality.

[Comments]
Concerning (1): It is necessary to plan the conveyance equipment with particular attention to the following points, because the fresh concrete is highly viscous:
1 In cases where the concrete is force-fed using a pump, the pumping resistance is high.
2 The concrete adheres to wet hoppers, the drum walls in transporting trucks, and so on, making it necessary to give special consideration to cleaning.
Concerning (2): When the antiwashout underwater concrete has to now for a long distance underwater, there is a danger that the concrete quality may suffer. For this reason, a construction plan should be established which stipulates the height of each lift and the spacing of placing tools, etc., in consideration of the antiwashout underwater concrete's quality, the underwater flow distance, and the amount of reinforcing, so as to give uniform quality throughout the structure.

6.2 Transportation

Concrete shall be conveyed by a method which does not cause settling of the aggregate and which allows easy unloading.

[Comments]
If the antiwashout underwater concrete is conveyed in trucks, either an agitator truck or a truck equipped with a bucket and hopper should be used as a rule. The former may be the most suitable means of conveyance. In cases where the wet concrete has a slump flow exceeding 55 cm, using the latter type of truck may mean that the coarse aggregate settles and discharge may become difficult.
If marine transport is necessary, the truck agitator may be loaded onto a barge or the bucket and hopper may be loaded onto the barge.

6.3 Placement

6.3.1General

(1) Concrete shall, as a rule, be placed with an underwater drop height of less than 50 cm in still water.
(2) Concrete shall, as a rule, be placed using a concrete pump or tremie.
(3) The underwater flow distance shall, as a rule, be with in 5m.

[Comments]
Concerning (1): Although antiwashout underwater concrete may be placed with a certain drop distance in water where there is a current, it was determined that, as a rule, the placing drop should be less than 50 cm in still water. However, when a drop is allowed, the quality of the concrete tends to be reduced even

if the water is still. Therefore, it is essential that concrete be placed without a drop when ever possible. In a case where there is no choice but to place concrete in flowing water, it should be performed in conformity with 11.6 of this Guideline, “Construction in Flowing Water.”

In this Guideline, still water means conditions where the flow velocity is less than about 5 cm/s.

Concerning (2): As methods of moving the antiwashout underwater concrete to the placing position without allowing contact with the water, the concrete pump or tremie may be used. These methods also allow the underwater drop height to be properly controlled while supplying concrete continuously. Accordingly, one or other of these methods should be used, as a rule, so as not to impair the concrete quality. Even when placing concrete using a concrete pump or tremie, it is desirable that the discharge opening be adjacent to the upper surface of the placed concrete or below the surface to some degree.

If the antiwashout underwater concrete is to be placed using a bucket, chute, flexible hose, etc., consideration should be given to guiding it without turbulence to the placement position to prevent loss of quality and to prevent water pollution in the construction area. Since placing using this type of equipment tends to lead to reduced quality, it is necessary to reflect this in the mix proportion by increasing the amount of antiwashout admixture and choosing a proper slump flow, etc.

Concerning (3): Although antiwashout underwater concrete has excellent fluidity, if the underwater flow distance is large, mortar ratio increases at the tip because the coarse aggregate settles on the bottom, resulting in quality variations. This tendency is particularly severe if the placing position contains many reinforcing bars. Accordingly, when placing the concrete, it is important to plan pipe movements and the tremie layout such that the flow distance is less than 5 m. If it is necessary to use an underwater flow distance longer than 5 m, it has to be confirmed in advance through tests or past experience that concrete of the required quality can be obtained.

6.3.2 Preparation for placement

(1) Prior to placement, it shall be confirmed that the reinforcing bars, form works, placing tools, etc., are laid out as planned.

(2) In locations where placement is affected by waves, it shall be confirmed prior to starting work that meteorological conditions and marine conditions will not have a negative effect on construction and concrete quality.

[Comments]

Concerning (1): It should be confirmed in advance that the formwork is secure, and that the reinforcing bars and formwork will not move under the lateral pressure from the flowing concrete. Also, it is necessary to ensure that the concrete will not leak from angles in the form and at joints with the bedrock, etc.

The placing location should be inspected in advance for the presence of foreign matter (old concrete, mortar, algae, seaweed, shells, etc.) which could get mixed in with the antiwashout underwater concrete. Also, the sequence of placement and the amount of concrete to be placed should be reconfirmed.

Concerning (2): In locations where placing might be affected by wave motion, the meteorological conditions and marine conditions (significant waves, wave period, currents, tidal ebb and flow, etc.) should be assessed prior to the work according to forecasts and observations on the day of placing so as to confirm that placing will not be affected and that the placed concrete will suffer no ill effects. For example, if wave heights are excessive, the underwater drop height would fluctuate leading to a danger of reduced quality and pollution due to washing action if the current is strong.

6.3.3 Force feeding and placing using concrete pump

(1) The concrete pump shall be selected through consideration of the concrete quality, piping conditions, placing location, placing content, and placing speed, etc.

(2) The concrete pump shall be used such that it does not cause a reduction in the quality of the concrete.

[Comments]

Concerning (1): Using a concrete pump to force feed and place the concrete is the most frequently used construction method for antiwashout underwater concrete. Since the performance of concrete pumps differs according to the model, it is necessary to select one which suits the quality of the concrete, piping conditions (length, diameter, height difference), placing location, placing volume, and placing speed.

Antiwashout underwater concrete is highly viscous, so the pumping resistance is high during force-feeding. As a result, piston-type pumps of high capacity are often used. As a rule, the pumping resistance is 2-3 times and the placing speed about 1/2-1/3 (10-50m^3/h) that of ordinary concrete. It is recommended that a concrete pump be selected based on reference materials (experience records, test data, etc.) and experiments related to conveying and placing conditions, with reference to "Recommended Practice for Pumping Concrete" of the Japan Society of Civil Engineers.

In cases where concrete is force fed over a long distance or where the concrete has a dry consistency, it is necessary to establish piping plan in which:

1 The pipe diameter is larger

2 The use of bends and flexible hoses is minimized

3 A relaying pump is used

In this case, it is not desirable to increase the slump flow in an effort to improve the efficiency of force feeding.

When selecting a concrete pump with a suitable capacity for the slump flow and horizontal force-feeding distance, Table 6.3.1 may be used as a standard.

Table 6.3.1 Standard of Horizontal Force Feeding Distance

Slump flow (cm)	Horizontal force-Feeding distance (m)
35-40	30
40-45	40
45-50	50
50-55	100
55-60	200

Note: This is for a case where piping of about 5 cm in diameter is used.

Concerning (2): When beginning placing, first send a sponge ball and antiwashout underwater mortar through the piping to prevent loss of concrete quality due to direct contact with water in the piping. The piping should be as new as possible, and care should be exercised to connect pipes securely so that concrete leak sand permeation of water into the piping do not occur.

Care should be taken to leave the piping filled with antiwashout underwater concrete during placing and to embed the tip of the discharge pipe into the already-placed concrete if placing is interrupted. When replacing the discharge pipe during the work, special measures should be taken, such as attaching a valve at the tip to prevent a reverse flow of water into the piping and to prevent the concrete dropping into the water. The placing sequence and pipe movements, etc., should be worked out so as not to disturb the already-placed concrete. Care should be exercised to prevent the tip swinging if the pumping pressure is high.

Placing when using a concrete pump may be by one of the following methods:

1. Using a flexible hose and controlling the placing location and underwater drop height from the tip using a diver.
2 Putting a vertical steel pipe in the designated position and connecting the pump piping directly to it, as in the case of the tremie method.
3 In stalling a tremie (or steel casing) and placing the concrete by inserting the concrete pump piping directly into it.

6.3.4 Placing of concrete using tremie

(1) The tremie shall have a cross section which allows the concrete to flow smoothly downward. Its joints shall be watertight.

(2) The concrete shall be placed continuously so as to prevent loss of concrete quality.

[Comments]

Concerning (1): A tremie is generally used to place conventional underwater concrete. When a tremie is used to place antiwashout underwater concrete, a situation might arise where the placing speed cannot be secured or concrete will overflow from the hopper unless the proper balance is maintained between tremie pipe diameter, distance (underwater and in air), depth of tremie tip in the concrete, slump flow, and the rate of concrete supply to the hopper, etc., because the resistance of the piping is larger than with ordinary concrete. Also, the joints should be watertight because the concrete loses quality if water permeates into it. As a rule, the inside diameter of the tremie needs to be about eight times the maximum size of the coarse aggregate, which means 20-30 cm in a typical case.

Concerning (2): In laying out the tremie, a plan should be established in consideration of the various work conditions and the concrete characteristics. Particularly when reinforcing bars are in position, the tremie should be located in consideration of the bar arrangement. It is necessary to prevent loss of concrete quality due to direct contact with water in the tremie when starting placing. For this reason, it is recommended that a plunger or a tremie equipped with a bottom cover be used.

During placing, the tremie should be completely filled with antiwashout underwater concrete. If placing has to be interrupted, care should be taken to embed the tip of the tremie into the already-placed concrete so as to prevent a counter flow of water.

6.4 Joints Between Successive Pours

The joints between successive pours shall be made in away that fully considers the characteristics of the antiwashout underwater concrete, the position of the joints, the structural conditions, and the construction conditions, so as to avoid harmful effects on the structure.

[Comments]: Construction joints should, as a rule, be located where the shear force is a minimum, and the old and new concrete should adhere thoroughly. For this purpose, it is preferable to determine a method of jointing after carrying out bonding strength tests, etc. which simulate the actual method and conditions of jointing. Methods of treating the surface to be jointed include cleaning using a high-pressure water jet, underwater pumps, or underwater cleaning equipment, and joints may be reinforced with reinforcing bars as the occasion demands.

6.5 Protection of Concrete Surface

The antiwashout underwater concrete shall be protected to prevent the cement being washed out from the surface and to prevent scouring due water motion, waves, etc.

[Comments]: It is not necessary to protect surface of the concrete unless it is subjected to flowing of water or wave motion, etc., because antiwashout underwater concrete has good antiwashout properties underwater. However, where flowing water or waves might affect it, the surface should be protected by covering it with a sheet, etc. Since setting is delayed compared with ordinary concrete, the period for which this protection is maintained should be extended accordingly.

CHAPTER 7 REINFORCEMENT

7.1 General

The reinforcing bars shall, as a rule, be assembled in the air.

[Comments]: Since it is impractical to assemble reinforcing bars underwater from the view points of workability and accuracy, it is best to plan the assembly on the basis that they will be assembled on shore, on a bar, or other wise above the water and later sunk into position. It is considered proper to limit the underwater operations carried out by divers to laying out reinforcing bars for concrete joints, etc.

7.2 Assembly of Reinforcing Bars

(1) The size of reinforcing bar units shall be determined in consideration of lifting, ease of sinking, and the need for an assembly rack, etc.
(2) Reinforcing bars shall be assembled rigidly so that they will not move during transport, sinking, or placing concrete.

[Comments]
Concerning (1): It is recommended that reinforcing bars be arranged on the surface so as to minimize underwater operations, and they should be lifted into the designated position and sunk when mostly assembled. It may be considered preferable to divide the assembly into smaller units in consideration of the lifting and sinking operations, with the separate units being integrated underwater. There are cases where it is advantageous to use larger reinforcing bar units to rationalize construction. In such cases, a rack should be used for the assembly operation. Since the steel used in the rack is generally embedded into the concrete, consideration should be given to preventing corrosion after the work has been completed.
Concerning (2): It is essential that the reinforcing bars are assembled rigidly to prevent movement during transport, sinking, and placing. They should also be laid out properly as shown in the design drawings. The allowable error in the assembly of reinforcing bars differs depending on the size of the member and the direction of the error. For example, when covering of bed bottom is sufficiently deep in consideration of accuracy of ground leveling on the seabed, or when finish work can be performed on upper surface after drainage, errors of a certain degree may be allowed. To hold there in forcing bars infixed relative positions, intersections may be bound with wires, clamped with clips, or welded. If arc welding is used, arc fillet welding should be implemented. In this case, the work has to be carried out with care so as to avoid reducing the cross-sectional area of the reinforcing bars.

7.3 Joint of Reinforcing Bars

(1) Reinforcing bars shall be lapped for a designated length and bound using a suitable method.
(2) If joints other than lap joints are used, their performance shall be confirmed in advance through tests, etc.

[Comments]: Refer to 10.4, Notes in the “Construction Edition” of the Standard Specifications for Concrete.

7.4 Underwater Positioning of Assembled Reinforcing Bars

(1) The assembled reinforcing bars shall be lifted with the minimum of deformation after being positioned, and accurately installed in the designated position.
(2) The separate reinforcing bar units shall be assembled under the water by means of a reliable jointing method.
(3) The position of the assembled reinforcing bar structure and the joint bars shall be inspected using a proper method.

[Comments]
Concerning (1): When lifting the assembled reinforcing bars, their design should be considered to minimize distortion. As a rule, it is considered proper to use a lifting frame to lift the assembled reinforcing bars.

To install the assembled reinforcing bars accurately in the designated position, marks may be made in advance as criteria for positioning, or surveying rods which can be observed from above the water may be attached. In locations where the installation may be affected by waves, it is necessary to be aware of the fact that accurate positioning will sometimes be difficult due to marine conditions on the day of the work, even though preparations are made in advance.

Concerning (2): Lap joints, screw knot reinforcing bar joints, screw process joints, etc., are considered highly reliable even under water. Lap joints should be laid out such that reinforcing bars at the actual joint come into contact with each other.

Concerning (3): It is important to check the layout of reinforcing bars placed underwater. A sit is often difficult to use a diver, other suitable equipment, such as under water television cameras, may be employed. In this case, it is preferable to mark the reinforcing bars before positioning under the water.

7.5 Time Before Placement

The reinforcing bars shall not be placed underwater long before the concrete will be placed.

[Comments]: If there in forcing bars remain underwater for more than several days before concrete placement, seaweed, shells, etc., will start to adhere to them and the bonding strength between concrete and the bars could be reduced. Therefore, the concrete should be placed as soon as possible after the reinforcing bars have been sunk into position.

CHAPTER 8 FORMWORK

8.1General

(1) The formwork shall be planned to minimize underwater operations entailed in assembly, erection, and stripping.
(2) The formwork shall have adequate strength and rigidity, and shall be designed and constructed so that the position, shape, and size of the completed structure is accurately secured.

[Comments]
Concerning (1): If the number of underwater operations involved in assembly, erection, and stripping of the form work is large, reliability, safety, and economy may be compromised. Therefore, it is important to plan the formwork on the basis of minimizing underwater operations, such as by assembling larger units in the air, attaching the formwork to reinforcing bars in the air before sinking, and omitting stripping operations after erection.
Concerning (2): Design drawings should be prepared for the formwork according to the construction plan, detailing the concrete placing schedule, the erection of formwork, whether the form work will be reused, and stripping. Construction should then be carried out according to the drawings. Also, the formwork should be designed and constructed so that it has adequate strength and rigidity to resist the load against it without deviating in shape and size. In particular, the strength design of the formwork should take into account the lateral pressure exerted by the antiwashout underwater concrete and the load imposed when lifting and sinking it after assembly in the air.

The design and construction of the formwork should also adhere to “Labor Safety and Hygiene Regulations “(Ordinance of the Labor Ministry).

8.2 Formwork

8.2.1 Materials

Materials used for the framework shall be selected by considering required strength, rigidity, durability, and workability economically.

[Comments]: Materials used for the formwork shall be of the required strength and rigidity, and shall have the minimum of damage, deformation, and corrosion. However, it is best to give the steel a corrosion-proof coating or to use corrosion-resisting materials when re-use of temporary formwork is intended, because steel formwork tends to corrode in the marine environment.

8.2.2 Design

(1) The formwork shall accurately retain its shape and position when a load acts on it.
(2) The formwork shall be of such construction as to allow easy assembly under water.
(3) In cases where the form work has to be stripped, the structure shall allow for easy stripping.

[Comments]
Concerning (1): The loads acting on the formwork include those imposed during lifting and installing

the formwork, the load resulting from lateral pressure of the fresh concrete, and the water current load.

The lateral pressure acting on the formwork may, as a rule, be assumed to be the water pressure at that depth, because the fluidity of the antiwashout underwater concrete is large and the setting time is long. However, when determining the lateral pressure based on known materials, past records or test data may be used.

The formwork should be designed so that it accurately retains its shape and position when the loads act on it. It is recommended that the form be designed to protect the finished surface of the concrete in cases where the structure is directly affected by water currents and waves, etc., after placement.

Concerning (2): Assembly of formwork under water will lead to inferior work efficiency, safety, reliability, etc. compared with work in air, since most of the work is done by divers. Accordingly, the form work should be pre-assembled in air as far as possible before installation., and construction of the formwork and joints should be designed to reduce the amount of diving work and to make operations easier by dividing it into units suitable for lifting and installation. As examples of simple techniques designed to reduce the amount of labor under the water, formwork lined with an expanded metal or cloth on its inner face has been developed, while sometimes the whole formwork is lifted in to position as one steel shell.

Concerning (3): To enable re-use of the formwork, construction should be such that assembly and stripping are easy when the time comes.

8.2.3 Assembly and Stripping

(1) The formwork shall be assembled such that it accurately retains its shape and such that cement paste or mortar will not leak.

(2) The form shall not be stripped until the concrete has reached a strength able to with stand the load acting on it.

[Comments]

Concerning (1): Since antiwashout underwater concrete is more fluid than ordinary concrete and takes longer to set, it is difficult to plug leaks if cement paste or mortar begin to escape. Therefore, the formwork should be assembled tightly so as not to allow leaks from gap at joints. To prevent gaps from forming due to deformation during lifting and installation, use of a lifting frame, etc. should be considered. In addition, it is necessary to pay attention to the foundations when they consist of spread sand, rubble mound, etc., and to leaks from gaps around the bottom of the formwork and establish measures against them in advance.

Concerning (2): The timing for stripping the formwork should be determined in consideration of the concrete strength and the loads acting on the structure. The manifestation of concrete strength may differ depending on the type of cement, concrete mix, type of antiwashout admixture and the amount used, temperature, etc. It is necessary to consider the contribution of dead weight, water current pressure, wave pressure, etc., to the loading to which the structure is subjected.

When not affected by flowing water and wave pressure, the stripping time may be taken to be the time at which the Compressive strength of the concrete exceeds the value shown in Table8.2.1. To judge whether or not the concrete has reached the required strength, the compressive strength of a specimen prepared underwater and cured under close to site conditions may be used as reference.

Table8.2.1 Reference Value of Compression Strength of Concrete to Determine the Timing for Stripping of Formwork

Example	Compressive strength of concrete (kgf/cm)
Sides of foundation, base concrete, etc.	35
Sides of w all, beam , etc.	50
Bottom face of slab, beam , etc.	140

CHAPTER 9 QUALITY CONTROL, INSPECTIONS AND CONSTRUCTION MANAGEMENT

9.1 General

To produce a concrete structure of the required quality using a method that is safe and reliable, the materials, reinforcing bars, machinery, facilities, and work operations for the antiwashout underwater concrete shall be properly controlled.

[Comments]: It is for quality control, inspection, and construction management to be performed effectively and systematically at all stage of the construction process. This should cover the concrete ingredients, steel, machinery, facilities, and work operations. As the quality of a structure built using antiwashout underwater concrete depends greatly upon the quality of the concrete and the construction method, it is essential that the concrete characteristics, methods of construction, machinery, and facilities, etc., at the site be properly controlled.

9.2 Tests

9.2.1 Testing Method

Tests shall, as a rule, be conducted according to the following methods:
(1) Compressive strength tests shall be conducted in conformity with JIS A 1108 "Testing Method of Compressive strength for Concrete." And specimens for compression test shall be prepared in conformity with "Method of Preparing Specimens Under Water for Compressive Strength Tests for Antiwashout Underwater Concrete" of the Standards of the Japan Society of Civil Engineers.
(2) Slump flow tests shall be conducted in conformity with "Testing Method of Slump Flow for Concrete" of the Standards of the Japan Society of Civil Engineers. The slump flow value is the spread of the concrete five minutes after the slump cone has been with drawn.
(3) Suspended solids content shall be tested in conformity with "Testing Method of Antiwashout Properties Under Water of Antiwashout Underwater Concrete" of Attachment 2 of "Quality Standards of Antiwashout Underwater Admixtures for Concrete" of the Standards of the Japan Society of Civil Engineers.
(4) Tests other than those specified above shall be conducted in conformity with the methods provided for in the Standards of the Japan Society of Civil Engineers, JIS, and other guidelines.

[Comments]

<u>Concerning (1)</u>: The strength of antiwashout underwater concrete differs according to the shape, size, method of loading, etc., as in the case of ordinary concrete. Accordingly, compressive strength tests should be conducted in conformity with JIS A 1108 "Testing Method of Compressive Strength for Concrete" and specimens for the tests are to be prepared in conformity with "Method of Preparing Specimens Under Water for Compression Tests for Antiwashout Underwater Concrete." In the case where the underwater drop height is larger than 50 cm as a result of construction conditions, it is necessary to conduct tests using specimens prepared under water with the same drop height.
<u>Concerning (2)</u>: Slump flow should be measured to enable a judgment of the fluidity of the underwater antiwashout concrete. Slump flow tests should be conducted in conformity with "Testing Method of

Slump Flow for Concrete” of the Standards of the Japan Society of Civil Engineers. In cases where the slump flow is to be measured in an adverse testing environment, then care should be taken to ensure that measurements will not be affected by wind, vibration, direct sunlight, etc. Since these standards do not define the time of slump flow measurement as in this Guideline, it has been decided that measurement are to be taken five minutes after removing the slump cone.
Concerning (3): In cases where water pollution factors have to be controlled, such as turbidity and rise in pH in the periphery of the construction area, it is preferable to confirm the antiwashout properties of the concrete by the suspended solid quantity test. Suspended solid tests, as a rule, are conducted in conformity with ”Testing Method of Antiwashout Properties Under Water for Antiwashout Underwater Concrete“ of Attachment 2 of “Quality Standards of Antiwashout Underwater Admixtures for Concrete” of the Standards of the Japan Society of Civil Engineers. However, since results are not known for many hours, and facilities such as drying machines are required, this method is not necessarily considered practical for use under normal site conditions. Therefore, a turbidimeter may be used as a substitute for this test in cases where the concrete has a normal mix consisting of the same materials as when the relationship between suspended solids and turbidity is grasped in advance. Also, care should be exercised not to use turbidimeters with different modes of measurement, since different measurement modes may give large differences in readings.

9.2.2 Testing of concrete

(1) Prior to starting construction, the necessary tests on materials and the concrete shall be conducted, and the performance of the machinery and facilities shall also be checked.
(2) During construction, the following tests shall be conducted, as the occasion demands:
(a) Tests of the aggregates
(b) Slump flow tests
(c) Air content tests
(d) Compressive strength tests using concrete specimens prepared underwater
(e) Unit volume and weight tests of the concrete
(f) Suspended solid quantity tests
(g) Other tests
(3) To determine the timing for stripping of the formwork, the concrete strength shall be tested using specimens cured under water under the same conditions as the concrete at the site.
(4) Where necessary after completion of the work, tests shall be conducted using concrete specimens removed from the structure.

[Comments]
Concerning (1): Refer to Notes for 13.2.2 and 13.2.3 of the “Construction Edition” of the Standard Specifications for Concrete. In cases where material sand production facilities actually producing the concrete differ from those used for trial mixing, tests should be conducted on materials and concrete prior to construction to confirm that concrete of the required quality can be obtained. According to the circumstances, it may be necessary to amend the mix proportion determined through trial mixing. Prior to implementation of the these tests and actually producing concrete, it is important to confirm the performance of the machinery and facilities.
Concerning (2): To produce concrete of the required quality and uniformity, tests should be conducted on the materials and concrete during construction. The basic tests to confirm whether antiwashout underwater concrete of the required quality is being produced include tests of the aggregates, slump

flow tests, air content tests, and Compressive strength tests using specimens prepared underwater. It is also desirable to implement unit volume and weight tests, suspended solid tests, and others as the occasion demands. If any changes are noted in the test results, inspections and checks of the concrete ingredients, the production facility, and the method of production should be carried out and measures taken to ensure that concrete of required quality is obtained.
Concerning (3): To ascertain the timing for stripping the formwork, it is necessary to estimate the strength of the concrete in the structure. For this purpose, strength tests should be conducted using specimens cured under the same conditions as the concrete at the site. And where necessary, it is desirable to confirm through tests in advance the relationship between water temperature at the site and the manifestation of strength.
Concerning (4): In cases where there is some doubt that the concrete has the required quality and where the actual underwater drop height was greatly different from that planned, it is necessary to test the concrete of the structure after completing construction work to confirm whether the construction is suitable for the intended purpose of use. The method of testing the concrete after construction work has been completed is to do Compressive strength tests on cores cut from the structure.

9.2.3 Testing of reinforcing bars

The reinforcing bars shall be tested before use to confirm their quality.

[Comments]: Refer to Notes 13.2.4 (1) of the "Construction Edition" of the Standard Specifications for Concrete.

9.3 Management of Concrete and Inspections

9.3.1 Management of Concrete

(1) The management of concrete shall, as a rule, be carried out by measuring the Compressive strength at an early age. In this case, specimens shall be prepared under water and treated in such a manner as to represent the concrete in the structure.
(2) The Compressive strength value used for management purposes shall, as a rule, be the average value of three specimens taken from the same batch.
(3) The timing and frequency at which specimens shall be taken for tests is, as a ru1e, at least once every day or once every 20-100 m^3 of continuously placed concrete, and depends on the importance of the structure and the scale of the work.
(4) In cases where concrete quality is managed using test values, it is desirable to use a management chart.

[Comments]
Concerning (1): Compressive strength tests carried out for control purposes should be conducted at an early age wherever possible so that test results can be rapidly reflected on the later schedule. In cases where the water-cement ratio has been determined according to the required durability, it is preferable to control concrete by measuring compressive strength corresponding to water-cement ratio based on the relationship between cement-water ratio and compressive strength obtained in advance.
Concerning (2): Because antiwashout underwater concrete is placed in water, it is difficult to make up for deficiencies by adjusting the later schedule. For this reason, the frequency of tests is greater,

i.e. at least once every 100m^3, because control is of the greatest importance.
Concerning (3): To control antiwashout underwater concrete, it is recommended that a control chart be prepared for Compressive strength, slump flow, and other characteristics. Every effort should be made to discover abnormalities in the concrete quality as early as possible.

9.3.2 Quality inspection of concrete

(1) The deviations in slump flow and air content in the fresh concrete shall be with in the range shown in Table9.3.1 at the time of placing.

Table 9.3.1 Allowable Deviations in Slump Flow and Air Volume

Slump flow	3.0 cm
Air content	+ 1.0%

(2) Inspection of concrete by compressive strength
(a)In cases where the quality of the concrete is checked based on test values, all test values obtained or a part of consecutive test values shall be checked.
(b) If the test values of compressive strength can be estimated to be below the design standard strength with the probability of less than 5%, the concrete may be considered to have the required quality. This check shall, as a rule, be based on the Compressive strength of 28-day-old specimens prepared underwater.
(3) If, as a result of this check, the quality of the concrete is judged to be improper, measures shall be taken to amend the mix proportion, to carry out performance tests of the machinery and facilities, to improve methods of operation, etc., and at the same time confirm whether the concrete already placed can achieve the intended quality. Suitable measures hall be taken where necessary.

[Comments]
Concerning (1): The allowable deviation in slump flow is determined in consideration of errors In materials quality control and errors in measurement. Also, only an upper limit is defined for allowable deviations of air content in consideration of its effects on strength.
Concerning (2): In cases where the water-cement ratio is determined based on the required durability, it may be considered that the concrete has the required quality as long as the measured strength corresponds to the designated water-cement ratio based on the relationship between cement-water ratio and Compressive strength as obtained in advance.
Concerning (3): Refer to Notes 13.4 (4) of the “Construction Edition” of the Standard Specifications for Concrete.

9.4 Construction Management

Construction management shall be applied to the following items as the occasion demands:
(a) Conditions of mixing
(b) Underwater drop height
(c) Water quality in area of placement
(d) Placing height and volume of concrete placed

[Comments]

Concerning (a): A simple method of managing the concrete quality is to check the quality as it is mixed by visual inspection. The condition of the mixed concrete is checked by eye and also, by dropping a small lump into a bucket, properties such as turbidity are verified visually. For this purpose, it is desirable to implement a similar test at the time of trial mixing before the start of construction, confirming how the mixed concrete looks and the turbidity in advance.

Concerning (b): It is necessary to measure the relationship between the discharge tip of the placing tool and the surface of the placed concrete, thus allowing the position of the discharge tip to be controlled such that the drop height is less than 50 cm. The concrete surface is measured using a sounding lead or an ultra sonic method, etc. The underwater drop height is measured visually by a diver, or it may be monitored by means of a submarine television system. When placing for reinforced concrete, it is better to control placing so as to minimize underwater dropping to prevent salinity from being drawn in.

Concerning (c): In cases where standard values have been established for the amount of suspended solids and pH on the periphery of the placing location during the work, it is necessary to measure the suspended solids and pH periodically, confirming that they are below the standard value. Also, it is important to visually observe the turbidity around the placing site during the work.

Concerning (d): When under taking control by measuring the final placing height, it should be remembered that there may be changes in the surface height due to continued flowing of the concrete after placing; and the level may fall as concrete leaks out from slight gaps in the formwork, etc. Adhesion of the concrete to conveying devices and the placing tool, as well as considerable leak age of mortar from joints in the formwork should also be considered.

9.5 Inspection of the Structure

After the completion of the concrete structure, it shall be inspected

[Comments]: An inspection of the underwater concrete structure should be carried out after completion in order to verify that it has been constructed to the true position, shape, size, etc., in accordance with the design. This inspection entails measurements by a diver and measurements using echo-sounders, etc.

CHAPTER 10 GENERAL MATTERS CONCERNING DESIGN

10.1 General

In designing concrete structures using antiwashout underwater concrete, the concrete's Characteristics, construction conditions, site environment, and other factors shall be thoroughly considered.

[Comments]: The characteristics of antiwashout underwater concrete are subject to variations depending on the type and proportion of antiwashout admixture, the concrete mix proportion, etc. In a construction, the characteristics required may differ depending on the environment and other conditions. The design should take these required characteristics fully into account. Matters not expressly provided for in this chapter should conform to the "Design Edition" of the Standard Specifications for Concrete.

10.2 Structural Details

10.2.1 Cover

(1) Cover shall be determined in consideration of the concrete's characteristics, the diameter of the reinforcing bars, the environmental conditions, possible construction error, and the importance of structure, etc.

(2) The minimum cover should be 7.5 cm as standard. However, it shall be greater than the diameter of the reinforcing bars and in excess of twice the maximum coarse aggregate size.

(3) In cases where there is a danger of erosion by flowing water, etc., or in a location subject to severe chemical action, the standard for minimum cover shall be 10 cm.

[Comments]

<u>Concerning (1)</u>: Refer to 10.2 (1) Notes of the "Design Edition" of the Standard Specifications for Concrete.

<u>Concerning (2)</u>: In the various Japanese guidelines concerning marine concrete structures, the suggested cover ranges from 7.5 cm up to 12.5 cm for the most corrosive environment, and many of the guidelines suggest a range of 7.0-8.0 cm. On the other hand, the Standard Specifications for Concrete provide for a cover greater than 10 cm to be on the safe side. This figure is given for the following reasons:

a) It is difficult to thoroughly compact concrete which is placed under water, so if the space between formwork and reinforcing bars is small, it is possible that the concrete may not penetrate thoroughly.

b) It is difficult to make judgments of the construction quality when working in water.

Unlike ordinary concrete, antiwashout underwater concrete has good self-leveling and filling properties. Therefore, placed concrete has a very good chance of penetrating all corners of the formwork and surrounding the reinforcing bars well. For this reason, this Guideline defines the standard minimum cover as 7.5 cm. However, to ensure that the concrete does penetrate into the formwork's corners, cover is also specified as larger than twice the maximum coarse aggregate size.

<u>Concerning (3)</u>: In cases where the concrete is subject to erosive action and severe chemical action, and where no special protective layer is provided, the minimum cover is specified as 10 cm. However, if a protective layer of recognized quality is applied to the concrete surface or if special corrosion-resistant

reinforcing bars of recognized effectiveness are used (such as epoxy resin-coated reinforcing bars) the minimum cover may be made 7.5 cm.

10.2.2 Spacing of reinforcing bars

The reinforcing bars shall be spaced so as to allow concrete to fully penetrate all concrete.

[Comments]: It is essential that the concrete flows completely around the reinforcing bars without compacting, and into all corners of the formwork. For this reason, it is desirable to space the reinforcing bars further apart than in ordinary concrete. The spacing of reinforcing bars is generally about 20-30 cm, and it is necessary to confirm the filling properties of the concrete through tests if the spacing is made closer than this.

10.3 Design Constants

10.3.1 Unit weight of concrete

The unit weight of concrete used for design calculation may be the values shown in Table10.3.1.

Table 10.3.1 Unit Weight of Antiwashout Underwater Concrete

In the case of non-reinforced concrete	2,250-2,300 kgf/m^3
In the case of reinforced concrete	2,350-2,400 kgf/m^3

[Comments]: Although the unit weight of antiwashout underwater concrete varies depending on the type of aggregate, the concrete mix proportion, etc., it is generally slightly lower than that of ordinary concrete. The values shown in Table 10.3.1 were determined with reference to past test results.

10.3.2 Young's modulus

The values of Young's modulus used in calculations of statical1y in determinate force or elastic deformation shall generally be the values shown in Table 10.3.2.

Table 10.3.2 Young's Modulus of Antiwashout Underwater Concrete

Design standard strength (kgf/cm^2)	180	240	300
Young's modulus Ec	2.0	2.3	2.5

[Comments]a; The Young's modulus of antiwashout underwater concrete is slightly smaller than that of ordinary concrete of the same compression strength. This may be attributed to the fact that the unit water content of antiwashout underwater concrete is larger than that of ordinary concrete, resulting in a larger cement paste content in the concrete. The values shown in Table 10.3.2 were determined with reference to past test results.

10.3.3 Drying shrinkage

Drying shrinkage need not be considered.

[Comments]: Since the unit water content is larger and much of the water added at the time of mixing remains in the hardening mass (because bleeding is lower), the drying shrinkage is 20-30% larger than with ordinary concrete when exposed to air. However, the subject of this Guideline is structures which are permanently submerged in water, so the concrete is not in an Environment where drying shrinkage can take place. Thus it was determined that drying Shrinkage need not be considered.

10.3.4 Creep coefficient

The creep co efficient of the concrete shall, as a rule, be determined through tests.

[Comments]: The creep coefficient is affected by the materials used, the concrete mix proportion, the age, the temperature, and the cross-sectional dimensions of structural members, etc. According to past underwater creep tests, some reports say that the creep coefficient up to about 200 days after the application of stress is smaller than 1.0; however, there is a lack of adequate test cases. Accordingly, it was determined for this Guideline that the creep coefficient should, as a rule, be determined through tests. However, if reliable data can be otherwise obtained, this may be used, too.

CHAPTER 11 CONCRETE REQUIRING SPECIAL CONSIDERATION

11.1 Mass Concrete

11.1.1 General

In the design and construction of mass concrete, the thermal stress and thermal cracking resulting from the cement's heat of hydration shall be thoroughly examined prior to drawing up the plans for design and construction

[Comments]: Even when mass concrete is placed underwater using antiwashout underwater concrete, it is important to examine the thermal stress and thermal cracking arising due to heat of hydration. In particular, since the measures which can be used to control thermal cracking under water are severely restricted and it is not easy to discover, repair, or evaluate the harmful effects of cracking, it is important to examine the question at the design stage and reflect the results in the construction plan.

The basic measures which can be used to control cracking in antiwashout underwater mass concrete range from design measures, through the selection of materials, to the method of construction, just as in the case of mass concrete in air. It is desirable to quantitatively grasp the effects of these conditions on the occurrence of cracking, to evaluate the requirements of cracking control, and to adopt the most suitable methods. It is particularly important to take measures which place emphasis on the careful examination and selection of materials in advance.

11.1.2 Control of thermal cracking

(1) To control thermal cracking without impairing the functionality and characteristics of the structure, suitable construction methods shall be selected.

(2) In the selection of materials and mix proportion, the temperature rise of the concrete shall be minimized with in the range of satisfactory concrete quality.

(3) In drawing up the construction plan, a suitable method for controlling thermal cracking shall be selected after examining the block division, the time interval between placing, the sequence of placing, and the placing temperature.

[Comments]

Concerning (1): In the case of mass concrete design and construction using antiwashout underwater concrete, it is necessary to control thermal cracking according to the use, functionality, and characteristics of the structure. To achieve this, it is necessary to examine the over all design and construction procedure, the selection of materials (including the type of cement), the admixtures, and the aggregates. Proper selection of the mix, the block divisions and the positions of joints, the time interval between placing, the formwork material and construction method, the method of curing, and the measures taken against flowing water is also a requirement.

Concerning (2): The calorific output of antiwashout underwater concrete is proportional to the unit cement quantity, as in the case of ordinary concrete. Accordingly, to reduce the temperature rise, It is necessary to select materials and a mix which keeps the unit cement quantity as small as possible with in the range of satisfactory concrete quality. Since the unit cement quantity is larger than in ordinary concrete, it is also desirable to use cement of flow calorific output, such as moderate-heat Portland cement, blast-furnace slag, fly-ash, etc Concrete made with such low calorific output cements gain strength at greater age compared with ordinary Portland cement, so it is recommended that the design standard strength be given for older concrete, i.e. at about 91 days. Since there are cases where low calorific cement has been used with large quantities of fly-ash and blast-furnace slag in the foundations of large-scale bridges, records of such work should be utilized.

As the water-cement ratio is reduced, there is a greater tendency for cracking to occur in the concrete due to the temperature rise. Therefore, an optimum water-cement ratio should be selected so as to hold down the temperature rise. However, it is necessary to take into account possible problems of durability as the cement-water ratio is increased.

Concerning (3): Even with antiwashout underwater mass concrete, the mechanism of thermal cracking resulting from heat of hydration is the Same as in ordinary mass concrete. In other words, thermal cracking results from inward or outward restriction of shrinkage which arises due to the temperature changes. Accordingly, the larger the temperature change in the placed block and the greater the rigidity of the bedrock or older concrete that restricts the newly placed concrete, the greater the risk of cracking. These factors are affected by the size of the placed block, the lift, the time interval between placing, and the placing sequence, etc. In the case of antiwashout underwater mass concrete, it is preferable to place in several blocks with an appropriate placing sequence, lift height, and time interval. Consequently, a construction plan should be drawn up which reduces the risk of cracking, at the same time bearing in mind the supply capacity of the concrete plant, the heat radiation conditions, and the restriction conditions, etc. It is also desirable to minimize the placing temperature of the concrete from the viewpoint of controlling thermal cracking. Methods of precooling include using chilled water, ice, cooled aggregate, and liquid nitrogen or a combination of these; however, the reduction in placing temperature should take into full account the timing of construction, the structural components, the concrete mix proportion, and economic factors.

11.1.3 Checks for the occurrence of thermal cracking

(1) The possibility of thermal cracking shall be checked using records of past experience or the appropriate thermal cracking index.

(2) The adiabatic temperature rise shall, as a rule, be obtained through tests in consideration of the type of cement used, the unit cement quantity, the placing temperature, etc. The heat characteristics used in thermal analysis of antiwashout underwater concrete shall be correctly evaluated based on the materials and mix of the concrete, etc.

(3) The values of tensile strength, Young's modulus, and creep coefficient assumed for the antiwashout underwater concrete shall be correctly evaluated in consideration of the type of cement, the water-cement ratio, the concrete's age, etc.

(4)Thermal analysis and thermal stress analysis for antiwashout underwater concrete shall be performed using a method suitable for the type of structures, and its importance, Shape, and size.

[Comments]

Concerning (1): The occurrence of thermal cracking in antiwashout underwater mass concrete should be evaluated based on probability using the thermal cracking index as provided for in 15.3.2 of the "Construction Edition." of the Standard Specifications for Concrete. However, structures of low-importance and structures which are known through long experience to present no problems need not be subject to special examination.

Concerning (2): Since available test data concerning adiabatic temperature rise in antiwashout underwater concrete are limited, it was determined that the adiabatic temperature rise should, as a rule, be obtained through tests. However, in cases where reliable values of adiabatic temperature are available as a result of increased experience and greater avail ability of test data, such values may be used as reference. Since the thermal constants of antiwashout underwater concrete, such as coefficient of thermal conductivity, coefficient of thermal diffusion, specific heat, etc., are particularly affected by dampness and the properties of the aggregate and the unit aggregate quantity, it is desirable to determine the thermal constants in consideration of this. In the absence of suitable test values or data, the examination may proceed using thermal constants equivalent to those of ordinary concrete.

Concerning (3): The mechanical characteristics of antiwashout underwater concrete, such as tensile strength, Young's modulus, and creep coefficient, are affected by the type of cement, the water-cement ratio, the type of aggregate, the thermal hysteresis, and age, so they should be determined through tests in advance. In cases where such tests are not conducted, the relationship between these mechanical characteristics and age may be obtained using the method provided for in 15.3.5 of the "Construction Edition" of the Standard Specifications for Concrete. However, the effective Young's modulus may be obtained using a formula (as provided for in Notes 11.1.1). This formula was derived in consideration of the fact that the Young's modulus of antiwashout underwater concrete is lower than that of ordinary concrete, and f(t) was made the same as that of ordinary concrete.

$$E_c(t) = \psi(t) \times 1.35 \times 10^4 \sqrt{f'_c(t)} \tag{11.1.1}$$

where, E_c : Effective Young's modulus at the age of t days (kgf/cm^2)

$\psi(t)$: Correction to Young's modulus in consideration of creep effects

Up to the age of 3 days y(t) = 0.73

After the age of 5 days y(t) = 1.00

$f'_c(t)$: Compression strength of concrete at the age of t days (kgf/cm^2)

The effective Young's modulus at any point in time, such as at the age of 4 days, maybe obtained proportionally, i.e. the intermediate value between the ages of 3 days and 5 days.

Concerning (4): The analysis of temperature and thermal stress for antiwashout underwater concrete should be in conformity with 15.3.4 and 15.3.6 of the "Construction Edition" of the Standard Specifications for Concrete. However, it can be assumed that the coefficient of thermal conductivity on the surface of the concrete differs from that in air by a large margin, so the literature or past measurements may be used as reference.

11.2 Placing During Freezing Weather or in Cold Water

11.2.1 General

When placing concrete during freezing weather or in cold water, appropriate measures shall be taken, as the occasion demands, regarding materials, mix, mixing, conveying, placing, protection, and formwork, etc., to ensure that the antiwashout underwater concrete has the required quality.

[Comments]:The fluidity of fresh concrete and the time of strength manifestation are affected by temperature, so the precautions described in this section will be necessary if the average day time temperature is below 4 ^{o}C and the average water temperature is below 5 ^{o}C. The term "placing during freezing weather or in cold water" refers to cases where there is a large difference between the concrete temperature and atmospheric temperature, or between the concrete temperature and water temperature, as follows:

1 When both atmospheric temperature and water temperature are low.

2 When atmospheric temperature is low, but water temperature is approximately normal.

3 When atmospheric temperature is approximately normal but water temperature is low.

When the atmospheric temperature is low, the concrete temperature will fall as the concrete is force-fed, so its fluidity will be reduced. Also, when the water temperature is low and the concrete temperature drops abruptly during placing, its fluidity may drop similarly, while a delay in setting time, delay in manifestation of strength after hardening, etc., will also be apparent. If the concrete temperature drops by about 10 ^{o}C, the slump flow appears to drop by about 3-5 cm. The setting time and hardening reaction will be considerably delayed when the water temperature is below 5 ^{o}C.

11.2.2 Materials

(1) The cement used for concrete which is to be placed in cold water shall be ordinary Portland cement or high-early-strength Portland cement.

(2) In cases where an accelerator is used, its characteristics shall be confirmed and its method use examined.

[Comments]

Concerning (1): When concrete is to be placed in cold water, the cement should be selected such that the design standard strength is secured at the designed age. Normal or high-early strength Portland cement is selected as the standard because its manifestation of strength is little delayed at the initial stage, even under low temperatures.

If the atmospheric temperature is low although the water temperature is approximately normal, a suitable cement may be selected from among those provided for in Chapter 3.

Concerning (2): Since records of cases where an accelerator has been used in antiwashout Underwater concrete are limited, a thorough examination of the accelerator's ingredients and action is necessary before it can be used, and it should be shown that it would present no problems.

11.2.3 Mix proportion

In the selection of mix proportion, changes in fluidity from changes in concrete temperature shall be taken in to consideration.

[Comments]: The fluidity of antiwashout underwater concrete falls as the temperature of the concrete drops. Accordingly, when planning the mix proportion, it is necessary to take into account how much the slump flow of the fresh concrete will change.

11.2.4 Transportation and placing

Conveying and placing shall be carried out so as to minimize the reduction in concrete temperature.

[Comments]a; When placing concrete during freezing weather, its temperature may fall during conveying and placing. Thus, measures should be taken to reduce this problem, and it is necessary to minimize the time between mixing and placing.

When a concrete pump is used, the mortar sometimes freezes and adheres to the inner wall of the piping, causing unforeseen failures. To prevent this, it may be necessary to insulate the piping, preheat the pipe using hot water prior to placing, or clean the pipe immediately after the completion of placing.

11.3 Hot Weather Concreting

11.3.1 General

In placing concrete during the heat of summer, appropriate measures shall be taken as regards materials, mix proportion, mixing, conveying, placing, etc., to ensure that there is no reduction in quality of the concrete.

[Comments]a; Various changes occur in antiwashout underwater concrete at high temperature. These include reduction in slump flow during conveying and loss of antiwashout properties due to a lowering in consistency. The former is a result of accelerated hydration of the cement and the latter arises because the viscosity of the antiwashout admixture solution falls. Suitable measures should be taken.

11.3.2 Materials

The materials shall be selected with consideration to those that keep down the temperature of the concrete.

[Comments]: It is desirable to consider storing the concrete ingredients away from direct sunlight, or cooling them with water sprays, etc. Where it takes many hours to transport the concrete, it is recommended that a delayed-type antiwashout admixture be used to ensure that fluidity is retained, or that a retarder be used in combination with the standard antiwashout admixture.

11.3.3 Mix proportion

In considering the mix, changes in concrete characteristics due to the high temperature shall be taken into account.

[Comments]: In some cases, antiwashout underwater concrete loses some of its antiwashout properties underwater and turbidity is increased as the concrete temperature rises. To prevent these problems from occurring, it is necessary to make corrections to the mix proportion by reducing the unit water content, increasing the quantity of antiwashout admixture, etc. If the actual work is to be performed at midsummer, special care should be exercised.

11.3.4 Temperature after mixing

The temperature of the concrete after mixing shall be such that the concrete will be at the desired temperature at the time of placing when effects such as meteorological conditions and conveyance time are considered.

[Comments]: When estimating the fresh concrete temperature from the temperature of the materials, calculations may be made using the formula given in Notes 16.2 of the “Construction Edition” of the

Standard Specifications for Concrete.

11.4 Combined Steel and Reinforced Concrete

11.4.1 General

In the construction of combined steel and reinforced concrete, consideration shall be given to thorough filling by the concrete.

[Comments]: Steel-framed reinforced concrete as discussed in this section means any reinforced concrete incorporating a steel frame, regard less of whether it is calculated in the cross-sectional design. As these frames spread horizontally like a flange, it is necessary to pay attention so that concrete can be filled to corners.

The reference literature for the design and construction of steel-framed reinforced concrete includes "Standards for the Design of Structures" of the Japan Society of Railway Facilities, "Specifications for Highway Bridges-Commentary II, Steel Bridge Edition" and "Handbook for Construction of Steel Highway Bridges" of the Japan Society of Highways.

11.4.2 Fabrication of structural steel

In the fabrication of structural steel, consideration shall be given to construction methods, shape, etc.

[Comments]: To ensure that the concrete fills the structure thoroughly, it is best to provide holes in the corners of the structural steel to prevent water or air from being trapped. This point should be considered in advance at the design stage .When transporting the structural steel, care should be exercised to prevent corrosion or deformation, and consideration should be given to installation of the steel at the planned position and with the required accuracy.

11.4.3 Placing of concrete

In the placing concrete around steel frames, consideration shall be given to the sequence and method of placing.

[Comments]: When placing the concrete, it is recommended that the concrete be allowed to flow slowly from one direction only, gradually filling the structure. This prevents water and air from being driven into corners and leaving voids in the concrete. The plan for placing should be drawn up with scrupulous care, and the concrete placed accordingly. In order to allow placing in this way, it is desirable to produce concrete with good fluidity; however, care should be taken to prevent segregation of the concrete.

11.5 Concrete for Repair and Reinforcement

11.5.1 General

In cases where the concrete is to be used for repair or reinforcement, the characteristics of the concrete and the method of performing the work shall be selected corresponding to the damage, the purpose of the repair, and environmental conditions, etc.

[Comments]: In selecting the quality of antiwashout under water concrete used for repairs and the method of performing the work, the characteristics of the location (structure, bedrock, etc.), the extent of damage, the cause of the damage, and the environment should be investigated, as well as looking into the effectiveness of the repairs, the effects on the surrounding environment, workability, and economy, etc.

The types of damage to structures include the following:
(1) Erosion caused by soil and sand, flowing water, waves, etc.
(2) Stripping of concrete due to corrosion of steel, including steel sheet pile sand reinforcing steel.
(3) Damage due to the impact of water craft, etc.

The method of applying concrete for repairs in tidal areas should conform to 11.7 “Construction in Tidal Zones” in this Guideline.

11.5.2 Repair and reinforcement

(1) The concrete shall be of suitable quality for the repair and reinforcement operations.
(2) For repairs and reinforcement, damaged portions shall be removed and cleaned thoroughly before the concrete is placed.

[Comments]: Concerning (1): Since the antiwashout underwater concrete used for repair and reinforcement work sometimes has to be placed in tight locations and on small structural members, workability characteristics such as filling properties and self-leveling properties suitable for the application should be taken into account in addition to factors such as strength and durability. For example, in repairing deteriorated banks or scoured sections of boat landing stages where the concrete is graded, concrete of dry consistency is suitable, while repairs of scoured undersides and backs of structures where the exposure is narrower demands concrete of wet consistency with good self-leveling properties. If the structural member is particularly small or where space is very restricted, antiwashout underwater mortar may be used.
Concerning (2): Repairs and reinforcement should be performed such that the required bonding between the location (structure, bedrock, etc.) and the new antiwashout underwater concrete is achieved. Also, to achieve the designated bonding strength, it is important to remove foreign matter from the placing location and expose the sound portion of the structure or bedrock. The deteriorated concrete, loosened aggregate, slime, seaweed, and shells, etc. may be removed by the use of air lifts, high pressure jets, or submerged pumps.

11.6 Placing in Flowing Water

In cases where the concrete has to be placed in flowing water, suitable measures shall be taken to stop the placed concrete flowing away.
[Comments]: Even antiwashout underwater concrete washes away under the influence of continuous strong currents. However, some reports say that where the flow velocity is about 30-50 cm/s, washing-out can be prevented to a degree by using a normal tremie and concrete pump for placing. Accordingly, it has been decided that when it is unavoidable, concrete may be placed in flowing water after thoroughly investigating the flow velocity at the location and considering a method of preventing the placed concrete from washing-out. These methods include the following:
1) Method in which the antiwashout properties of the fresh concrete are improved by increasing the

amount of antiwashout admixture.

2) Method in which the surface of the concrete in contact with the flowing water is protected with formwork, protective sheeting, etc.

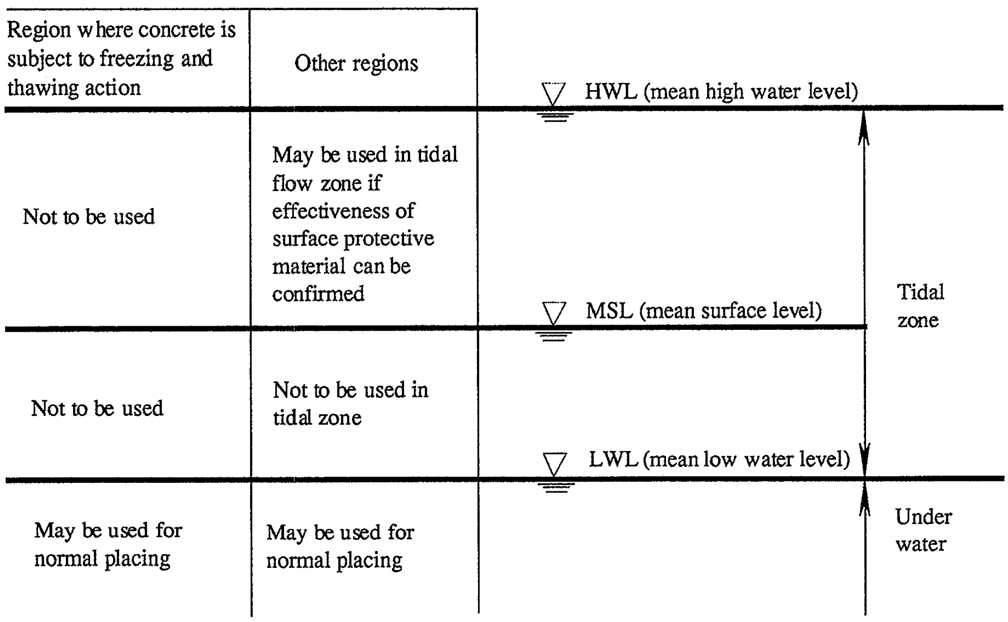
Depending on the placing conditions, it may be necessary to consider implementing the work with a suitable combination of methods 1 and 2 above.

11.7 Placing in Tidal Zones

11.7.1 General

In cases where concrete is to be placed in a tidal zone, suitable measures shall be taken as regards mix proportion, placing etc. In areas where the concrete would be subject to freezing and thawing action, placing shall not be done in the tidal zone.

[Comments]: Although antiwashout underwater concrete is used basically for structures which are always submerged in water, it has been determined that placing may go ahead in a tidal zone when moisture content is guaranteed by using corrosion-resistant steel pipe piles, etc. as a lining. However, this is provided that the provisions of this section are adhered to. Fig. 11.7.1 shows the scope of application of this section. That is, while antiwashout underwater concrete may be used up to the mean surface level (MSL), it is not to be used in areas where it would be subject to freezing and thawing action.



Since the tidal zone is an environment where both physical and chemical action is severe, the possibility of corrosion in the steel materials is high. Therefore, it is necessary to use concrete that has excellent durability. In cases where antiwashout underwater concrete is placed below mean surface level with ordinary concrete above sea level, the switching point between the two types of concrete should be planned in advance and suitable measures taken to ensure that the placed concrete is monolithic. The placing method should minimize the incorporation of sea water by avoiding dropping from above the surface and by placing concrete without a drop under the water.

To prevent corrosion of the steel material in the concrete, it is necessary to use an appropriate method to the maintain designated cover. It is also advisable to examine the use of rust-resisting reinforcing bars. The concrete or mortar in contact with the formwork should, as a rule, be of equal or superior quality than the main concrete.

To prevent permeation of chlorides, oxygen, etc., after the concrete has been placed, it is desirable to fit a protective cover of confirmed effectiveness, e.g. FRP, as a permanent formwork.

Notes Fig.11.7.1 Scope of Application of Antiwashout Underwater Concrete in Tidal Zones

11.7.2 Water-cement ratio

The water-cement ratio of the concrete shall be smaller than 45% as standard.

[Comments]: Since reinforced concrete in the tidal zone is in a more severe environment than submerged concrete, the water-cement ratio should be smaller. The water-cement ratio should be below 45% as standard, under the same considerations as when placing ordinary concrete for marine concrete structures, which are given in the Standard Specifications for Concrete.

The unit cement quantity in antiwashout underwater concrete is generally more than the 330kg/m^3as determined for marine concrete from durability considerations, With the larger unit cement quantity, there is greater possibility of cracking due to thermal stress arising from the heat of hydration, especially where the cross section is large, and proper consideration should be given to this.

In case where it can be checked from experience records or test results, the correct water-cement ratio may be determined by adding about 5-10% to the value determined from durability considerations. Also, the maximum water-cement ratio of non-reinforced concrete as determined from durability considerations may be used by adding about 10%, as in the case of marine concrete.

11.7.3 Construction joints

Construction joints shall, as a rule, be avoided in tidal zones.

[Comments]: It has been determined that construction joints are unsuitable for use in tidal zones because they could adversely affect the durability of the structure. However, in case where use of construction joints is unavoidable for various circumstances, 22.4 in the “Construction Edition.” of the Standard Specifications for Concrete should be adhered to.

Standards of the Japan Society of Civil Engineers

Quality Specifications for Antiwashout for Underwater Concrete

1. Range of Applications

These standards specify the quality of antiwashout admixtures for underwater concrete (here after referred to as anti washout admixtures).

2. Terminology

The terminology used in this standard is defined in JIS A 0203 (concrete terminology). In addition, the following definitions are adopted.

(1) Antiwashout admixture for under water concrete: An admixture which increases the viscosity of the concrete with which it is mixed, giving the concrete antiwashout properties water.

(2) Antiwashout underwater concrete: Underwater concrete mixed with an antiwashout admixture to make it highly resistant to underwater separation.

(3) Slump flow: Spreading of a sample that occurs when a slump cone filled with a sample in accordance with the procedure specified by JIS A 1101 (Method of Test for Slump of Concrete) is raised immediately after filling.

(4) Level of underwater washout: Index representing the level of underwater washout for fresh concrete or fresh mortar which is dropped in to water.

3. Types

Antiwashout admixtures can be categorized as standard types or delayed-action types on the basis of their effects on the setting of concrete.

4. Quality

4.1 Performance: The performance of an antiwashout admixture must be tested by the procedure specified in 5.1 and must conform with the specifications listed in Table 1.

4.2 Total alkali content: The total alkali content in an antiwashout admixture must be evaluated by the procedure specified in 5.2, and must be below 0.30 kg/m^3.

4.3 Chloride ion content: The chloride ion content in an antiwashout admixture must be tested by the procedures specified in 5.3 and must be below 0.20kg/m^3.

4.4 Safety: Antiwashout admixtures must conform with the following stipulations.[3)]

Note (3): There is very little possibility of the deleterious and poisonous substances specified here being contained in antiwashout admixtures. However, in view of the fact that antiwashout admixtures are mainly used in underwater concrete, which tends to affect ecosystems, these provisions have been set forth to ensure safety. Accordingly, the tests specified here are not required if the level of safety specified here has already been confirmed by a public organization and there have been no significant alterations in the raw materials or manufacturing processes used in the production of the admixture since the said confirmation of its safety,

(1) Deleterious sub stance content: To determine the deleterious substance content in antiwashout admixtures, tests must be conducted on items specified in "Substances Related to the Protection of Human Health (Harmful Substances)," listed in the Environmental Standards stipulated by Article 9 of Basic Regulations for Measures against Public Pollution. The tests must use a solution containing more than 0.01% of the antiwashout admixture, and must be performed in accordance with the method specified in the regulations. The test results must satisfy the Environmental Standards.

Suggestion: When a concrete mixture specified in 5.1.2 is tested by the method specified in 5.2, the concentration of the antiwashout admixture is more than 200 times the free admixture concentration in water if the amount of the suspended substance is 50mg/l.

(2) Toxicity: The toxicity of antiwashout admixtures is to be evaluated through acute oral toxicity tests using mice or rats. The value of LD_{50} must be above 5000mg/kg.

Suggestion: LD_{50} represents the dose of a substance per unit of body weight which is fatal to 50 % of test animals. Generally, a substance with an LD_{50} value of 5000 mg/kg or higher is not considered to be harmful. Toxicity tests can be conducted in accordance with "Guidelines for toxicity tests of chemical substance," issued by the Organization for Economic Cooperation and Development (OECD).

5.Tests

5.1 Concrete tests: Concrete tests are to be conducted by the procedure specified below, with two batches of concrete mixed for each type of concrete.

5.1.1 Test Materials: The following materials are to be used in the test.

(1) Cement: The cement used must conform with JIS R 5210 (Portland cement). Three different brands of ordinary Portland cement should be selected at random and used in equal amounts.

(2) Aggregate: The aggregate must be clean, hard and durable, and must not contain harmful amounts of dust, dirt, organic impurities, or salts. Crushed stone can be used as coarse aggregate and sand as fine aggregate. These must be of the quality indicated in Table 2. Since aggregate consists of an appropriate mixture of small and large grains, grain size must be with in the range in Table 3.

(3) Water: Tap water or water which satisfies item 4 of the Waterworks Law (water quality standard) shall be used as the mixing water.

(4) Antiwashout admixture : The sample of the underwater washout admixture used must be representative of the quality of the particular brand.

(5) Superplasticizer: The specifications of the superplasticizer must be conform with the Japan Society of Civil Engineers (JSCE) "Standard Superplasticizers for Concrete." In addition, each antiwashout admixture product used must be designated by the manufacturer.

5.1.2 Mix proportions: Mix proportions must be determined in accordance with the following stipulations.

(1) Water-cement ratio: The water-cement ratio is to be set at 55%.

(2) Slump flow: The slump flow of concrete after the addition of superplasticizer must be adjusted to 50 ± 3 cm five minutes after the lifting of the slump cone.

(3) Unit contents for cement and water: In principle, the unit contents for cement and water are to be set at 400 and 220 kg/m^3, respectively.[13] However , concrete of the required quality cannot be obtained under these mixing conditions, the unit water content can be adjusted within a range of less than

11kg/m^3, with the water-cement ratio maintained at 55%.

Note(13): The amount of solid component in the superplasticizer is determined by the method specified in Annex 1 (Testing Method
for Content of Solid Component in Superplasticizer). The nonsolid component of the superplasticizer is considered as part of the unit water content.

(4) Sand-aggregate ratio: The sand-aggregate ratio shall be 40%.

(5) Unit content of antiwashout admixture: The unit content of an antiwashout admixture shall be within the range recommended by the manufacturer in the interest of preventing deterioration of water quality.

(6) Unit content of superplasticizer: The unit content of superplasticizer shall be in the amount which produces the required slump flow in the mixed concrete.

5.1.3 Procedure for making concrete: Concrete should be prepared according to the procedure specified in JIS A 1138 (Method of Making Test Sample of Concrete in the Laboratory).

5.1.4 Mixing: Mixing must be carried out under the following conditions.

(1) Mixer: The mixer used should be of the forced-mixing type. Test-purpose concrete produced by using such a mixer in accordance with JIS A 1119 (Method of Test Constituents in Freshly Mixed Concrete), should have a unit mass per volume difference for mortar of less than 0.8 % and a unit weight difference for aggregate in concrete of less than 5%.

(2) Amount mixed: The amount of concrete mixed at one time shall be larger than 85 liters.

(3) Method of mixing: The following procedure shall be used in the mixing of concrete.

(a) Cement, antiwashout admixtures, fine aggregates, half of the fine aggregate, and coarse aggregates are to be thrown into the mixer[14)] and mixed for 30 sec.

Note (14): In general, the constituents are charged into the mixer in the following order: half of the coarse aggregate, half fine aggregate, cement, antiwashout admixture, half of the fine aggregate, and half of the coarse aggregate.

(b) The mixer shall be stopped for the addition of water and then started once again. The appropriate mixing time is determined taking into consideration the uniformity of the concrete and the solubility of antiwashout admixtures in water[15)]

Note(15): As the mixing time can greatly depend on the solubility of antiwashout admixtures, it is important to give adequate consideration to these points.

(c) When a superplasticizer is required, mixing can be continued for an additional one minute following addition of the superplasticizer.

(4) Temperature after mixing: Temperature after the completion of mixing should be $20 \pm 3^{o}C$.

5.1.5 Samples: The entire volume of the mixed sample should be emptied onto the mixing board and mixed again with shovels to yield uniform concrete; then tests should be performed immediately. A sample of approximately 20 liters should be separated from rest and set on a mixing board when the remixing with shovels is completed.[16)] After 30 min or 2hrs, this sample should be remixed until it becomes uniform (the required mixing time depends on the type of antiwashout admixture used).

Immediately afterward (i.e., at 30 min or 2 hrs from the completion of the initial mixing), the sample should be tested by slump flow testing.

Note (16): Drying-out of the sample should be minimized by such measures as covering it with a vinyl sheet.

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5.1.6 Testing of concrete

(1) Slump flow: The slump flow test shall be performed by the "Slump Flow Testing Method for Concrete" specified in the JSCE Standards). The slump flow shall be measured 5 min after the lifting of the slump cone. Tests shall be performed once immediately after the completion of mixing and once again after the passage of 30 min or 2 hrs for each batch of concrete.

(2) Air content: The air content shall be measured in accordance with JIS A 1128 (Method of Test for Air Content of Fresh Concrete by Pressure Method (Air Chamber Pressure Method)) once for each batch of concrete.

(3) Bleeding rate: Tests of bleeding rate shall be conducted in accordance with JIS A 1123 (Method of Test for Bleeding of Concrete). The number of samples prepared from each batch shall be one.

(4) Level of underwater washout: Underwater washout tests shall be performed in accordance with Annex 2 (Underwater Washout Tests for Antiwashout Underwater Concrete), once for each batch of concrete.

(5) Setting time: Tests of setting time shall be conducted in accordance with JIS A 6204, Annex 1 (Setting Time Measuring Method for Concrete). The number of samples prepared from each batch of concrete shall be one.

(6) Compressive strength: Tests of compressive strength shall be performed in accordance with JIS A 1108 (Method of Test for Compressive Strength of Concrete) on the 7th and 28th days of material age. The size of the sample shall be 10cm in diameter and 20cm high. The samples shall be of types (a) and (b) below, and the number of samples prepared from the same type of concrete for each batch shall be three for each material age.

(a) Samples prepared underwater: Samples shall be prepared in accordance with the standards of JSCE, "Preparation Procedure for Underwater Samples for Compressive Strength Tests of Antiwashout Underwater Concrete."

(b) Samples prepared in air: With the exception of preparation in air, the preparation procedure for this type sample is exactly the same as that for underwater concrete samples.

5.1.7 Calculation of concrete test results: Calculation of concrete test results should be conducted under the following conditions.

(1) Bleeding rate: The bleeding rate is to be expressed as the mean value of the bleeding rates obtained in 5.1.6(3).

(2) Air content: The air content is to be expressed as the mean value of the air content obtained in 5.1.6(2).

(3) Amount of reduction in slump flow over time: The amount of decrease in slump flow shall be calculated, using the following equation, from the mean value of slump flow at the time of measurement in 5.1.6(1)

Amount of decrease in slump flow over time (cm) = $F_0 - F_e$

where F_0: slump flow of concrete immediately after the completion of mixing

F_e : slump flow of concrete 30 min or two hrs after the completion of mixing

(4) Level of underwater washout: In the calculation of the underwater washout percentage, mean values are calculated for the mass of suspended matter and pH obtained by the method specified in 5.1.6(4). Then the mass of the suspended matter is rounded to an integer, and the pH is represented down to the first digit below the decimal point.
(5) Setting time: The setting time shall be represented by the mean values of the starting time and completion time in 5.1.6(5).
(6) Compressive strength of specimens prepared underwater: The compressive strength of specimens prepared underwater shall be represented by the mean value of the compressive strength of specimens prepared underwater, obtained by following the procedure in 5.1.6(6).
(7) Ratio of strength in water to strength in air: The ratio of strength in water to strength in air should be calculated through the following equation, using the mean values of compressive strength under various conditions determined in 5.1.6(6). The value should be rounded at one digit below the decimal point and represented as an integer, in accordance with JIS Z 8401 (Method for Rounding Figures).

$$\text{Ratio of strength in water to strength in air}(\%) = \frac{f_w}{f_a} \times 100$$

Where f_w :compressive strength of specimens prepared underwater
f_a : compressive strength of specimens prepared in air

5.2 Total alkali content: In the calculation of the total alkali content, the total alkali content of an antiwashout admixture is measured, following the method specified in Annex 3 (Testing Method for Measurements of Total Alkali Content and Chloride Ion Content in Antiwashout Admixtures for Underwater Concrete). The total alkali content of concrete due to the addition of the underwater antiwashout admixture should also be determined, and the figures rounded down to two digits below the decimal point, in accordance with JIS Z 8401.

$$R_m = A \times \frac{R_a}{100}$$

where R_m : total amount of alkali in concrete due to underwater antiwashout admixture (kg/m^3)
A : unit content of underwater antiwashout admixture defined in5.1.2(5)(kg/m^3)
R_a : total amount of alkali in underwater antiwashout admixture(%)

5.3 Chloride ion content: In the determination of the chloride ion content, the chloride ion content in an antiwashout admixture shall be determined by the method specified in Annex 3 (Testing Method for Measurements of Total Alkali Content and Chloride Ion Content in Underwater Antiwashout Admixtures for Concrete), and the chloride ion content of concrete due to an underwater antiwashout admixture is calculated through the following equation. The results should be rounded off at two digits below the decimal point.

$$Cl^-{}_m = A \times \frac{Cl^-{}_a}{100}$$

where Cl^-_m : chloride ion content of concrete due to antiwashout admixture (kg/m^3)

A : unit content of antiwashout admixture defined in 5.1.2(5)(kg/m^3)

Cl^-_a : chloride ion content of antiwashout admixture(%)