SYNOPSIS

The Concrete Committee of the Japan Society of Civil Engineers (JSCE) organized Subcommittee in 1981 for the Research on Superplasticized Concrete, when JSCE was entrusted to make researches for concrete mixed with superplasticizer by related corporation. The subcommittee had been organized by four working groups, laboratory work, field work, bibliography and recommended rules. After the subcommittee had made extensive researches, recommended practice was drawn up in 1983 on the basis of the results of research works. The recommended practice includes guidelines on the use of superplasticized concrete and JSCE standards on quality standards for superplasticizers.

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PROPOSED RECOMMENDED PRACTICE FOR SUPERPLASTICIZED CONCRETE

CONTENTS

CHAPTER 1 GENERAL

Article 1 Scope of Application

This Recommended Practice presents general standards with regard to matters necessary to consider in particular in construction of concrete structures to which superplasticized concrete is applied.

Items not stipulated in this Recommended Practice shall be in accordance with the JSCE Standard Specifications for unireinforced and Reinforced Concretes and the JSCE Standard Specifications for Prestressed Concrete.

[Commentary]

Superplasticized concrete, similarly to high-strength concrete, represents a technology made possible by the advent of high-range water-reducing agents. A high-range water-reducing agent, is defined as a chemical admixture, which when added to concrete, produces an extremely high rate of water reduction compared with the case of using an ordinary water-reducing agent, to make possible manufacture of concrete of a low water-cement ratio, or, in case of a constant unit water content, makes possible manufacture of concrete of high fluidity, with high-strength concrete obtained by the former effect, and superplasticized concrete by the latter.

Since superplasticized concrete is a concrete with increased fluidity through the effect of addition of a high-range water-reducing agent (a high-range water-reducing agent used for the purpose of fluidization is called a superplasticizer) without increasing the unit water content, the labor and cost required for placement and consolidation with low-slump concrete are saved without lowering the quality of concrete, and there has been a trend in Japan also in recent years for it to be increasingly applied as a technology to improve the so-called placeability of concrete. For example, not only is a great improvement in placeability possible when applied to bridge abutments and bridge piers, retaining walls, water tanks, water purification facilities, tunnel linings, pavement slabs, etc., which can be constructed by ordinary methods, but it is also possible to adopt concrete pumps where it had been considered difficult with conventional

methods so that the scope of application is extremely broad. Further, since with superplasticized concrete the base concrete before superplasticization can be made of stiffer consistency than concrete that had been applicable with conventional construction methods, it is possible for unit water content and unit cement content to be reduced, while it is known to be effective for preventing temperature cracks which have often been considered as problems in recent years, and there is ample applicability in utilization from this aspect also.

However, superplasticized concrete is concrete with fluidity forcibly increased with a superplasticizer, so to speak, and its workability is considerably different from that of normal concrete. Therefore, if the purpose of use and limits to the effectiveness of superplasticized concrete are thoroughly studied and appropriate application is carried out, various effects and advantages can be obtained, but if the application is done thoughtlessly, not only would it be impossible to attain the purpose aimed for, but the strength and durability of the structure would be impaired.

This Recommended Practice, in view of the present state of technology concerning superplasticized concrete, and experience in application, points out matters that are especially required in construction applying superplasticized concrete to civil structures. Since superplasticized concrete is one variety of concrete, it is only natural that matters not stipulated in this Recommended Practice must be in accordance with the Standard Specifications for Concrete or the Standard Specifications for Prestressed Concrete.

Broadly divided, there are the following four methods of manufacturing superplasticized concrete:

① Superplasticizer is added after the agitator truck has arrived at the jobsite and agitating is done.

② Superplasticizer is added to the agitator truck at the concrete plant and agitating is done.

③ Superplasticizer is added to the agitator truck at the concrete plant, the concrete is hauled to the jobsite while agitating at low speed, and agitating is done after arrival at the jobsite.

④ Superplasticizer is added to the mixer at the concrete plant simultaneously with other materials, and mixing is performed.

From the aspects of mixing effect and quality control of superplasticized concrete, there would be no disagreement about the method of ④ being the best similarly to manufacture of ordinary concrete. However, the superplasticizers presently in practical use have the characteristics that rather than adding to the mixer simultaneously with the other materials and mixing, greater effectiveness is obtained by adding later to concrete already mixed once (so-called delayed addition), and that slump loss of superplasticized concrete is large and change in slump during hauling is great. Therefore, guides and the like now published in European and American countries have been standardized considering the methods of ① to ③, while in actual cases in Japan also, the method of ① is employed in an overwhelmingly large number of cases.

Therefore, it was decided that this Recommended Practice should be written taking performances up to the present into account, and for the moment, superplasticized concrete according to the manufacturing methods of ① to ③ considered. However, superplasticized concrete is still a new technology and there are many problems and technological developments remaining which need further study. The provisions given in this Recommended Practice are strictly methods that are presently conceivable as standard, or are prescribed based on performances, and the use of simultaneous-addition type superplasticizers which are presently undergoing research or are at the stage of being marketed in part, or the application of new methods such as the divided-addition method are not to be restricted. Superplasticized concrete based on new materials or new methods should be handled adapting this Recommended Practice.

Article 2 Definitions

Terms used in this Recommended Practice shall be defined as follows:

Base concrete — concrete prior to superplasticizing mixed to manufacture superplasticized concrete

Superplasticizing — adding of superplasticizer to a concrete mixed beforehand and agitating to increase fluidity

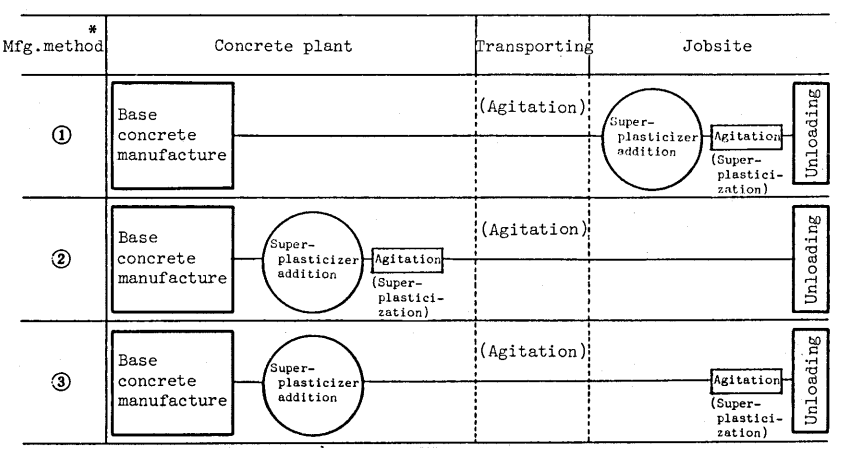
Superplasticizer — an admixture with its main purpose the increase of fluidity of concrete mixed beforehand through agitation upon its addition

Superplasticized concrete — a concrete with fluidity increased by agitation upon addition of superplasticizer to a concrete mixed beforehand

Slump increase — the difference between slump of base concrete and slump of superplasticized concrete, or, the difference in slumps immediately before and after superplasticization (cm)

[Commentary]

As stated in the commentary on Article 1, this Recommended Practice has as its object of consideration concrete that has once been mixed in a mixer to which superplasticizer is added and agitation is performed to fluidize it. Consequently, the manufacturing process of superplasticized concrete, as shown in Commentary Fig. 1, consists of first mixing stiff-consistency concrete in a mixer (called base concrete) and loading this in a truck agitator, following which superplasticizer is added to the truck agitator at the plant or after arrival of the jobsite, and agitation is performed to manufacture superplasticized concrete. Therefore, the definitions given in this article were estalibshed as the names of the actions at the respective stages or the concrete manufactured. Further, the Commentary of Article 4 should be referred to with regard to base concrete, the Commentary of Article 7 with regard to superplasticizer, and the Commentary of Article 3 with regard to superplasticized concrete.



*According to No. of manufacturing method in Commentary of Article 1.

Commentary Fig. 1 Method of manufacturing superplasticized concrete.

CHAPTER 2 QUALITY OF SUPERPLASTICIZED CONCRETE

Article 3 Superplasticized Concrete

Superplasticized concrete shall possess the required strength, durability, watertightness, and workability suited for the work, and have little scatter in quality.

[Commentary]

That superplasticized concrete must possess the strength taken as the basis in design of the structure, the required durability and watertightness, and moreover, have little scatter in quality is the same as the intent of Article 71 of the RC Specifications prescribing ordinary concrete.

However, the workability suitable for operations in case of superplasticized concrete is considerably different in nature from conventional concrete. In essence, since superplasticized concrete has as its matrix cement paste of extremely good fluidity with cement particles dispersed through the effect of a fluidifier with no increase in unit water content, the resistance to segregation is great even though the consistency is fluid. Accordingly, in case of superplasticized concrete it is considered permissible for slump to be made higher than for conventional concrete.

Article 4 Base Concrete

The quality of base concrete shall be that with which the concrete after superplasticization will satisfy the requirements concerning quality.

[Commentary]

It has been prescribed in Article 2 that concrete mixed beforehand for the purpose of making superplasticized concrete is to be called base concrete. Since superplasticized concrete is made by adding only superplasticizer to this base concrete, it is natural that the quality of superplasticized concrete will be affected by the quality of the base concrete. Particularly, the qualities such as strength, durability, watertightness, etc. of the superplasticized concrete will be in correspondence with the qualities and scatter of the base

concrete, so that it is extremely important for the quality of the base concrete to be made to requirements. However, the base concrete is not to be used directly, but on transformation into superplasticized concrete in all cases so that its workability must be selected giving consideration to the condition when superplasticization has been done. For example, in selecting the slump which constitutes the evaluation of consistency, it is necessary for the selection to be made considering the slump of the superplasticized concrete and the amount of increase in slump through the action of the superplasticizer, while in selecting the sand-aggregate ratio also, the selection must be made so that the concrete after superplasticization will have the workability suited for operations.

The term base concrete does not necessarily mean concrete immediately before superplasticization. Concrete after mixing will have changes occur in its slump and air content with elapse of time, and in case superplasticization is to be done after a certain amount of time has elapsed after mixing of the base concrete, it is important that the quality of the base concrete be decided giving consideration to these time-dependent changes.

CHAPTER 3 MATERIALS

Article 5 General

Materials that have been confirmed as to quality shall be used.

[Commentary]

Using suitable materials is fundamental to economically making concrete of the required quality. Tests or past performance will be the basis for judging the suitability of a material. However, by quality of a material is meant the quality at the time of use and a material about which storage is not prescribed in the chapter of course must still not be changed in quality.

Article 6 Cement

(1) Ordinary portland cement, high-early-strength portland cement, moderate heat portland cement, sulfate-resisting cement, blastfurnace slag cement and fly ash cement shall respectively conform with JIS R 5210, JIS R 5211 and JIS R 5213.

(2) A cement other than in (1) above shall be used on confirming its performance in the form of superplasticized concrete.

[Commentary]

Regarding (1) Results of experiments that the influence of the type of cement on superplasticization effect is not great have been reported. However, that superplasticization effect differs depending on characteristics of adsorption of superplasticizer to cement particles, that it has a relation to the initial hydration mechanism, and the performance record of use in superplasticized concrete were taken into consideration and the scope of application was limited to the abovementioned cements.

Regarding (2) With a cement other than in (1) above it is necessary for proper use to be made on confirming the effect of superplasticizer and examining the durability as concrete.

Article 7 Superplasticizer

The superplasticizer shall meet the requirements of the Japan Society of Civil Engineers standard, "Quality Standards for Superplasticizers for Concrete."

[Commentary]

Superplasticizers are available as standard and retarding types. In the Japan Society of Civil Engineers standard, "Quality Standards for Superplasticizers for Concrete," it is prescribed that the qualities of superplasticized concretes using these superplasticizers shall respectively be within a given limit in comparison with base concrete. Consequently, a superplasticizer must be tested in accordance with norms regarding the various test values in this standard, and moreover, the test values must be within the ranges given in the standard regarding all items.

Besides the above, the superplasticizer must not be a product having adverse influences on the respective effects through interaction with an air-entraining agent, water-reducing agent or an air-entraining water-reducing agent used in the base concrete.

Standard-type superplasticizers are for use in concrete projects in general and have been frequently used, and are widely used. A retarding-type superplasticizer produces both fluidifying and set-retarding effects and is used for delaying set of hot-weather concrete and in cases of long hauling times, or to alleviate slump loss after superplasticization, but when the dosage of superplasticizer is made large for greater slump increase or when a retarding-type water-reducing agent or air-entraining water-reducing agent has been used in the base concrete, there can be cases of marked retardation along with reduction in durability so that care must be exercised.

Superplasticizers are generally of liquid form, but products in powder or granular form are used at times for special purposes. The test items and testing methods of powder or granular superplasticizers are not prescribed in detail in the abovementioned standard so the Engineer is to decide them on judging the characteristics.

Article 8 Storage of Superplasticizer

(1) Superplasticizers shall be stored in a manner that trash and other impurities will not be mixed in, and that those in liquid form will not freeze or their moisture contents will not evaporate.

(2) A superplasticizer shall be tested before use in case storage has been long or abnormalities have been observed. In the event the prescribed performance cannot be obtained as a result of testing, that superplasticizer shall not be used.

[Commentary]

Regarding (1) A superplasticizer of liquid form may separate if it were to freeze. Also, if moisture were to evaporate, the concentration will vary, and there are cases when the surface layer hardens. In either case, it will become impossible for accurate batching of the superplasticizer to be done.

Regarding (2) A superplasticizer that has been sealed and stored may be used in case of temperature in a range of 5 to 35°C and when storage has been for less than one year. Abnormalities are mostly in case where judgments can easily be made as with separation and solidification of the surface layer. On rare occasions there may be cases of the influence of mildew. Also, there can be cases when discerning can be done from discoloration, lumping, and odor. In general, in case of sepration only, it would be possible for use to be made by restirring to a uniform condition. It is advisable for testing to be measurement of superplasticization effect. It may be considered there is no abnormality when there is no difference in superplasticization effect compared with product of normal condition.

Article 9 Fine Aggregate

(1) Fine aggregate used shall conform to "Standard Specifications for Plain and Reinforced Concretes."

(2) In cases of using crushed sand and blast-furnace slag fine aggregate, they shall conform to the requirements of JIS A 5004 and JIS A 5012.

(3) Marine sand shall be approved by the Engineer taking into consideration the concentration of chlorides contained, the type of structure in which the sand is used, environmental conditions, and in addition, the influence on superplasticization effect.

[Commentary]

Regarding (1) In superplasticized concrete, fines of 0.15 mm and under in fine aggregate are necessary for securing workability. In the Commentary of the Standard Specifications for Reinforced Concrete the use of fine aggregate having little fines is allowed depending on the cement content, but this is not applied to superplasticized concrete, and it is advisable to use fine aggregate containing fines as indicated in standard gradations.

Regarding (2) For both crushed sand and blast-furnace slag sand, results of tests using them in superplasticized concrete have been obtained in which superplasticization effect can be expected. However, in case of crushed sand, it is necessary for care to be exercised since the dosage of superplasticizer will be increased if the fines content is high.

Regarding (3) It is known that when the chlorides in marine sand converted to sodium chloride are within 0.04 percent of the oven-dry weight of the marine sand the superplasticization effect is not greatly affected. However it is conceivable that there will be secondary effects such as increase in bleeding through superplasticization when marine sand of low fines content is used, and therefore, its use was made subject to approval of the Engineer based on tests or reliable data. When it has been recognized that there is much bleeding as a result of testing, the bleeding can be reduced by replacing a part of the marine sand with pit sand or through the combined use of a good-quality finely divided mineral powder to improve the workability of superplasticized concrete. However, it is suitable for the amount of the fine powder used to be not more than 10 percent by weight of fine aggregate. As an added note, the use of fine powder would not be limited to marine sand and is effective in cases of other fine aggregates also.

Article 10 Coarse Aggregate

Coarse aggregate not more than 40 m in maximum size out of aggregates conforming to "Standard Specifications for Plain and Reinforced Concretes" shall be used.

[Commentary]

The maximum size was made 40 mm or under taking into consideration that there are few cases of coarse aggregate larger than 40 mm having been used, that the tendency for segregation is increased when large-diameter coarse aggregate is used, and that there are few occasions for superplasticizing concrete with large-sized coarse aggregate. However, this does not mean that superplasticization effect and the merits of superplasticiation cannot be looked forward to if the maximum size were to exceed 40 mm.

Article 11 Admixtures

(1) Air-entraining agents, water-reducing agents and air-entraining water-reducing agents used as chemical admixtures shall conform to JIS A 6204.

(2) Fly ash used as an admixture shall conform to JIS A 6201.

(3) Expansive additives used as admixtures shall conform to JIS A 6202.

(4) Admixtures other than in (1), (2) and (3) above shall be checked as to quality, confirmed that the quality of concrete and the superplasticization effect will not be adversely affected, and be approved by the Engineer.

[Commentary]

Regarding (1) See the commentary for Article 7.

Regarding (2) It has been reported that superplasticization effect varies depending on factors such as the quality of fly ash and quantity of impurities. Therefore,

it is desirable for fly ash of good quality meeting JIS requirements to be selected, and for the performance to be ascertained through tests and by investigation of track records in case of a large quantity to be used.

Regarding (4) As a rule, an admixture on which reliable data concerning combined use with superplasticizer are not available is to be used only after confirming how it influences the superplasticization effect and quality of concrete.

CHAPTER 4 MIX PROPORTIONS

Article 12 General

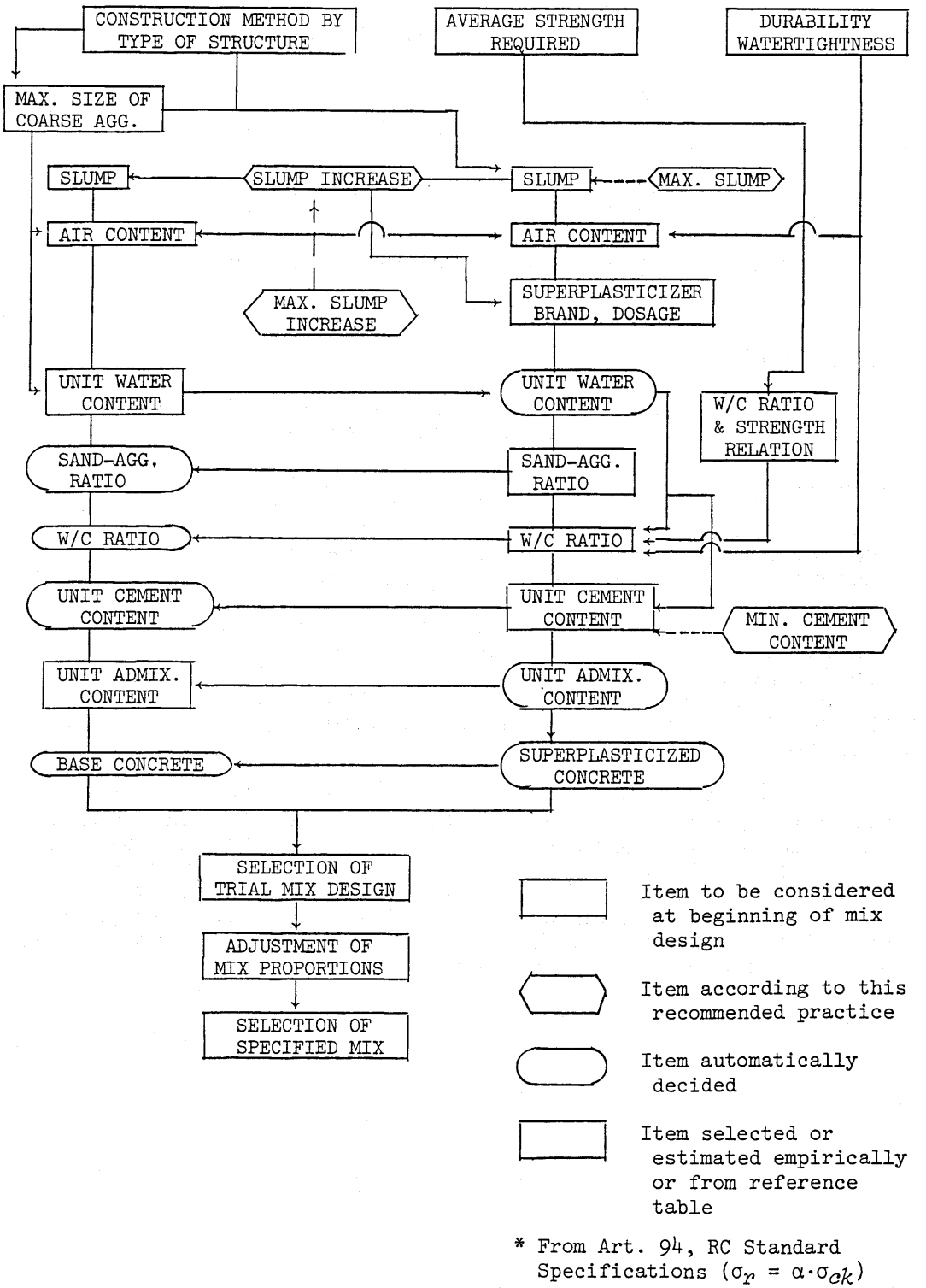
The mix proportions of superplasticized concrete shall be such as to provide the required strength, durability, watertightness, and workability suited for the work, and result in little scatter in quality, and the mix proportions of the base concrete and the dosage of superplasticizer shall be selected accordingly.

[Commentary]

Superplasticized concrete is manufactured by adding a superplasticizer to base concrete mixed using a mixer and the quality of the superplasticized concrete will naturally be affected by the quality of the base concrete. Particularly, the strength, durability, watertightness, and scatter in quality will correspond with the quality and scatter in quality of base concrete, and therefore, it will be extremely important that the quality of base concrete be as required.

In principle, the base concrete is to be air-entrained concrete, and it is desirable for its mix proportions and the dosage of superplasticizer to be determined by testing so that the concrete after superplasticization will possess the required strength, durability, watertightness, and workability suited for concreting operations.

Commentary Fig. 2 shows the concept to be followed in determining the specified mix for superplasticized concrete. This figure shows general principles, and in such cases as using ready-mixed concrete where an established mix design is to be the basis, the sand-aggregate ratio, unit water content, and unit cement content of the existing design can be modified in accordance with the increase in slump and the slump of superplasticized concrete.



Commentary Fig. 2 Concept for selection of superplasticized concrete mix proportions.

Article 13 Consistency

(1) The consistency of superplasticized concrete shall be that of a slump in a range suitable for the work, and as a rule shall be selected at not more than 18 cm.

(2) Slump increase shall in principle be not more than 10 cm, with 5 to 8 cm as standard.

(3) The consistency of base concrete shall be in a range not to be a hindrance to superplasticization of concrete.

[Commentary]

Regarding (1) Consistency corresponding to workability suitable for concreting operations will differ according to the size and shape of the structure, and the methods of handling and consolidating the concrete. If concrete of large slump is used, the concreting operation will be made easy, but bleeding will be increased, and the tendency for mortar or paste to segregate will become prominent. It will be necessary to use superplasticized concrete of low slump as much as possible within the range suitable for operations, and therefore, 18 cm and under was specified. However, this value may be exceeded if reliable information, performance records or test data are available indicating there are no adverse effects on concrete such as segregation.

Commentary Table 1 gives the standard ranges of slumps for superplasticized concrete, but if it can be confirmed that there are no adverse effects such as segregation of the concrete as mentioned above, a higher slump may be used upon obtaining the approval of the Engineer.

Commentary Table 1 Standard Ranges of Slump for Superplasticized Concrete (Slump at Place of Deposit of Concrete)

Type of structure			Slump (cm)
Massive concrete (e.g., large bridge pier, large foundation, etc.)			8- 12
Fairly massive concrete (e.g., bridge pier, thick wall, foundation, large arch, etc.)			10- 15
Thick slab			8- 12
Reinforced concrete in general			12- 18
Reinforced concrete of large cross section			8- 15
Prestressed concrete beam			10- 15
Watertight concrete			8- 15
Tunnel lining concrete			15- 18
Pavement concrete			nor more than 8
Artificial lightweight aggregate concrete	Reinforced concrete	Slab	12- 18
		Beam	12- 18
		Wall, column	10- 15
	Prestressed concrete beam		10- 15

Regarding (2) The increase in slump will be greater in accordance with larger dosage of superplasticizer, but if the increase is made too large segregation will tend to occur, and there will be a risk of strength and durability being impaired, so that it is desirable for not more than 10 cm to be standard and preferably about 5 to 8 cm. However, similarly to (1), if suitable information, performance records, or test data are available, the increase in slump may be made more than 10 cm upon obtaining the approval of the Engineer.

Regarding (3) In case of using a truck agitator for superplasticization of concrete, if the slump of the base concrete is too low, operations from addition of superplasticizer until completion of agitation would be hindered, while

it would be difficult to obtain a uniform superplasticized concrete. The quantity of superplasticizer required to obtain the same amount of slump increase will be larger when slump of base concrete becomes lower than about 5 to 6 cm. Consequently, it is desirable for slump of base concrete to be generally about 8 to 12 cm and at least 5 to 6 cm or higher.

Article 14 Air Content of Concrete

(1) The air content of superplasticized concrete shall be selected to be in a range of 4 to 7 percent of the volume of concrete in accordance with the maximum size of coarse aggregate and other factors.

(2) The air content of base concrete shall be selected at a level that the air content after superplasticization will satisfy the abovementioned requirement.

[Commentary]

Superplasticized concrete having a suitable amount of entrained air excels in workability and durability against meteorological conditions, and the principle is to be for air-entrained concrete to be used. The suitable air content in case of being subject to severe meteorological conditions is desirably about 4 to 7 percent of concrete volume after placement. The air content of superplasticized concrete may vary according to superplasticization and other conditions, and therefore, the air content of the base concrete must be decided by tests.

It should be paid attention to the fact that the air content of superplasticized concrete, similarly to ordinary concrete, will be reduced by about one-fourth to one-sixth in handling operations such as transporting and consolidating. Consequently, it would be advisable for air contents after superplasticization to be made the values given in Commentary Table 4, Article 17, of this Recommended Practice. However, the strength of superplasticized concrete will be reduced if air content is increased, while there is also a tendency for scatter in quality of concrete to be more extreme the more that air content is increased. Therefore, at a location where meteorological actions are not severe, or when applying superplasticized concrete to a case such as high-strength concrete,

it will be suitable for air content to be made as low as possible within limits of obtaining the required workability.

Article 15 Dosage of Superplasticizer

(1) The dosage of the superplasticizer shall be decided by tests to obtain the required amount of slump increase.

(2) As a rule, the superplasticizer shall be used in undiluted form.

[Commentary]

The dosage of superplasticizer required for obtaining the prescribed amount of slump increase will differ depending on the slump, cement content, admixture, gradation and particle shape of aggregate, transporting time, concrete temperature, etc., of the base concrete, and therefore, must be decided upon testing to obtain the required workability.

When the superplasticizer is used undiluted, the water-cement ratio of the superplasticized concrete may be considered as being practically unchanged, whereas when the superplasticizer is diluted there will be risk of the water-cement ratio being greatly increased depending on the degree of dilution. As for superplasticizer in powder or granular form, there are few cases of such use, and therefore, it was stipulated that the superplasticizer be used in undiluted liquid form.

Article 16 Water-Cement Ratio of Superplasticized Concrete

The water-cement ratio shall be selected at a level that the superplasticized concrete will satisfy requirements for strength and durability. With a structure required to be watertight the water-cement ratio shall be such as to satisfy the requirements for watertightness of the concrete.

[Commentary]

The water-cement ratio of superplasticized concrete is approximately the same as the water-cement ratio of the base concrete. However, what is actually placed is superplasticized concrete, while it is possible for the strength and other physical properties of the concrete to become changed by superplasticization, and therefore, it was stipulated that the water-cement ratio for satisfying the requirements for strength and durability is to be determined with superplasticized concrete.

In case of determining water-cement ratio W/C based on compressive strength of superplasticized concrete, the relation between compressive strength and water-cement ratio is to be determined by tests as a rule, where the water-cement ratio with which the required compressive strength can be obtained is determined. These tests are to be performed with the materials and superplasticizer to be used in the project on superplasticized concretes using not less than three different water-cement ratios W/C in a range thought to be suitable, and the method of superplasticization is to conform to the method to be adopted on the job. However, in the event reliable data, performance records, etc. are available, the water-cement ratio for obtaining the required strength may be determined from the relation between water-cement ratio and strength of the base concrete upon approval of the Engineer.

In the event of selecting water-cement ratios on the basis of durability of the concrete, in case of using portland cement, the values are to be not more than given in Commentary Table 2, while in case of offshore concrete, they are to be not more than given in Commentary Table 3.

In the event of selecting water-cement ratio on the basis of watertightness of concrete, a ratio of not more than 0.55 is to be standard.

Commentary Table 2 Maximum Water-Cement Ratio of Superplasticized Concrete on Basis of Durability (General Construction)

Meteorological conditions / Cross section / Exposure condition of structure	Severe meteorological action or frequent cycles of freezing and thawing			Meteorological action not severe, air temperature below freezing point infrequent		
	Thin[2]	Ordinary[4]	Thick[3]	Thin[2]	Ordinary[4]	Thick[3]
(1) Portion continuously or frequently saturated with water[1]	0.50 (0.50)*	0.60 (0.55)*	0.60 (0.55)*	0.55 (0.50)*	0.65 (0.60)*	0.65 (0.60)*
(2) Ordinary exposure condition other than (1)	0.60 (0.55)*	0.65 (0.60)*	0.65 (0.60)*	0.60 (0.55)*	0.70 (0.65)*	0.70 (0.65)*

(3) Special case
(a) For concrete in contact with soil or groundwater containing not less than 0.2 percent of sulfates in terms of sulfuric acid radical.
(b) For concrete not exposed to meteorological actions such as a structure buried completely underground, it is not necessary to select water-cement ratio based on durability.

1) Portions of waterways, water tanks, bridge abutments, bridge piers, retaining walls, tunnel linings, etc., close to water surface and saturated by water, and other than these structures, girders, deck slabs, etc. at a distance from the water surface but saturated by water due to snowmelt, flowing water, water spray, etc.
2) Portion of structure with thickness of cross section not more than about 20 cm
3) Surface portion of massive structure
4) Portion other than according to 2) and 3)
* Figures in parentheses applied when using artificial lightweight aggregate

Commentary Table 3 Maximum Water-Cement Ratio of Superplasticized Concrete on Basis of Durability (Offshore Concrete)

Meteorological conditions / Cross section / Exposure condition of structure	Region with frequent cycles of freezing and thawing			Region with air temperature below freezing point infrequent		
	Thin[1]	Ordinary 3)	Thick[2]	Thin[1]	Ordinary 3)	Thick[2]
(a) Portion exposed to salt air Portion subjected to salt water spray	0.50	0.55	0.55	0.50	0.60	0.65
(b) Portion subjected to tidal action Portion washed by sea water	0.45	0.50	0.55	0.45	0.50	0.55
(c) Portion immersed in sea water at all times	0.55	0.60	0.65	0.55	0.60	0.65

1) Portion of structure with thickness of cross section not more than 20 cm
2) Surface portion of massive structure
3) Portion other than according to 1) and 2)

(Note) Water-cement ratios determined on basis of durability for unreinforced concrete made air-entrained concrete may be made higher than values in Commentary Table 3 by about 0.05.

Article 17 Unit Water Content of Base Concrete

The unit water content of base concrete shall be selected by testing based on consistency and slump increase of superplasticized concrete.

[Commentary]

The unit water content of base concrete needed to obtain the required slump will differ depending on the maximum size of coarse aggregate, gradation and particle shape of aggregate, type of admixture, air content, temperature of concrete, etc., while in case there is a necessity to make the sand-aggregate ratio higher than stiff-consistency concrete, the unit water content will be correspondingly increased. Accordingly, the unit water content is to be selected upon tests taking into consideration the method of superplasticization, slump increase, etc.

It will be permissible for the approximate standards of unit water content for base concrete to be in accordance with Commentary Table 4.

Commentary Table 4 Approximate Values of Unit Coarse Aggregate Volume, Sand-Aggregate Ratio, and Unit Water Content

G_{max} (mm)	Unit coarse agg. volume (%)	Air (%)	Using good-quality air-entraining agent		Using good-quality air-entraining water-reducing agent	
			Sand-agg. ratio, s/a (%)	Unit water content, W (kg)	Sand-agg. ratio, s/a (%)	Unit water content, W (kg)
15	53	7.0	46	170	47	160
20	61	6.0	42	165	43	155
25	66	5.0	37	155	38	145
40	72	4.5	33	145	34	135

(1) The values given in this table are for concrete using sand (fineness modulus about 2.80) and gravel of about ordinary gradation as aggregates, with water-cement ratio about 0.55, and slump approximately 8 cm.

(2) In case of materials used and quality of concrete differing from the conditions of (1), the values in the table above are to be corrected according to the following:

Item	Correction of s/a (%)	Correction of W (kg)
For every 0.1 increase (decrease) in F.M. of sand	Increase (decrease) by 0.5 percentage point	No correction
For every 1-cm increase (decrease) in slump	No correction	Increase (decrease) by 1.2%
For every 1 percentage point increase (decrease) in air	Decrease (increase) by 0.5- 1.0 percentage point	Decrease (increase) by 3%
For every 0.05 increase (decrease) in water-cement ratio	Increase (decrease) by 1.0	No correction
For every 1 percentage point increase (decrease) in s/a	-	Increase (decrease) by 1.5 kg
When using crushed sand	Increase by 3 to 5 percentage points	Increase by 9 to 15 kg
When using crushed sand	Increase by 2 to 3 percentage points	Increase by 6 to 9 kg

When based on unit coarse aggregate volume, for every 0.1 increase (decrease) in fineness modulus the unit coarse aggregate volume is to be decreased (increased) by 1 percentage point.

In case of using crushed blast-furnace slag, it will be permissible for the correction to be of about the same degree as for the case of using crushed stone indicated in the above table. (See Article 14 of "Proposed Recommended Practice for Design and Construction of Crushed Blast Furnace Slag Concrete," JSCE.)

Article 18 Unit Cement Content of Base Concrete

The unit cement content shall in principle be determined based on unit water content and water-cement ratio.

[Commentary]

It was stipulated that unit cement content is to be decided from water-cement ratio and unit water content of base concrete determined by the results of tests to obtain concrete having the prescribed strength, durability, and watertightness. Further, for superplasticized concrete to possess workability suitable for work and ample resistance to segregation, it is generally advisable for unit cement content (cement content + admixture content) to be not less than 270 kg/m^3 in case of maximum size coarse aggregate of 25 mm, and not less than 250 kg/m^3 in case of 40 mm.

Article 19 Sand-Aggregate Ratio of Base Concrete

The sand-aggregate ratio of base concrete shall be selected for unit water content to be a minimum within limits that the required workability will be obtained.

[Commentary]

Selection of the sand-aggregate ratio is one of the important factors in mix design of base concrete. In order to obtain the required workability without showing segregation in case superplasticization has been carried out, the sand-aggregate ratio must not be that corresponding to the consistency of the stiff-consistency concrete to be used as the base, but that for the consistency after superplasticization. Therefore, although the principle is for sand-aggregate ratio to be selected based on testing, it is permissible for the selection to be done referring to reliable data and performance records if they are available.

Regarding the approximate standard for the sand-aggregate ratio or the unit coarse aggregate volume, from Commentary Table 4, when the slump of superplasticized concrete exceeds 15 cm, it is advisable for the sand-aggregate ratio to be increased by 0 to 2 percentage points over the values in the table in case of slump of 15 cm, and 1 to 3 percentage points in case of 18 cm. Further, in case of placement by pump, it is advisable for sand-aggregate ratio to be made slightly higher than in the table in accordance with the type of the concrete pump, the distance pumped by pipeline, etc.

Further, in case there is an extreme lack of fines in the fine aggregate, workability will not be improved even if the

sand-aggregate ratio is increased, and it will be necessary to consider the use of finely divided mineral admixtures such as fly ash and rock powder.

Article 20 Unit Content of Admixture

The unit content of an admixture other than a superplasticizer shall be decided in accordance with the directions of the Engineer.

[Commentary]

See commentary on Article 102, RC Specifications.

Article 21 Method of Indicating Mix Proportions

(1) The method of indicating the mix proportions, in general, shall be according to Table 1.

Table 1 Method of Indicating Mix Proportions

Max. size coarse agg. (mm)	Range of slump (cm)		Range of air content (%)	
	Base concrete	Superplasticized concrete	Base concrete	Superplasticized concrete

Water-cement ratio W/C	Sand-agg. ratio (%)	Unit Content (kg/m³)		
		Water W	Cement C	Fine agg. S

Unit Content (kg/m³)				
Coarse agg. G		Admixture		
(mm) | (mm)	(mm) | (mm)	Finely divided mineral admix.	Chemical admix.	Superplasticizer

Note: 1) Slumps and air contents are those before and after superplasticization.

2) The dosages of chemical admixture and superplasticizer are to be in units of ml or g, and are not to be on diluted or dissolved bases. The volume of superplasticizer is to be ignored in calculation of yield of concrete.

(2) The specified mix shall be on the basis of all of the fine aggregate passing a 5-mm sieve, and all of the coarse aggregate retained on the 5-mm sieve, both being in saturated, surface-dry condition.

(3) When converting from specified mix to field mix, the moisture conditions of the aggregates, the quantity of fine aggregate retained on the 5-mm sieve, and the quantity of coarse aggregate passing the 5-mm sieve shall be taken into consideration.

[Commentary]

Regarding (1) The reason not only the proportions of the various materials, but also maximum size of coarse aggregate, and the ranges of slumps and air contents before and after superplasticization are prescribed to be given in the method of indicating mix proportions is because these are factors for selecting mix proportions. Water used for dissolving or diluting a chemical admixture is to be considered as part of the unit water content.

The dosage of a superplasticizer is normally about 0.5 to 1 percent of the weight of cement at most and may be ignored in calculation of the volume of yield on mixing of concrete. Also, the superplasticizer need not be considered as part of the unit water content.

In the table on the mix proportions, it is also desirable for the type of structure, specified concrete strength, average strength required, type of cement, fineness modulus of fine aggregate, type of coarse aggregate, void ratio of coarse aggregate, types of chemical admixture and superplasticizer, transporting time, method of superplasticization,

season of placement, use of concrete pump, etc., to be noted.

Regarding (2), (3) See (2), (3) in Commentary, Article 103, RC Specifications.

CHAPTER 5 BATCHING, MIXING, AND TRANSPORTING OF BASE CONCRETE

Article 22 General

A plan on batching, mixing, and transporting of base concrete shall be established prior to start of the work, and the approval of the Engineer obtained.

[Commentary]

It is necessary for manufacturing and transporting plans for base concrete to be set up prior to start of work comprehensively considering the type of structure, the total volume of concrete, placement rate and meteorological conditions in order that the required superplasticized concrete will be obtained. For details, the commentary on Article 114 of the RC Specifications should be referred to.

Article 23 Batching and Mixing of Base Concrete

The individual materials for the base concrete shall be correctly batched in order that the prescribed quality will be obtained, and shall be thoroughly mixed until the concrete as mixed will be of uniform quality.

[Commentary]

See Chapter 12 of the RC Specifications.

Article 24 Transporting

(1) Base concrete shall be transported quickly by a method with which segregation will be as little as possible. Transporting time shall be within limits that superplasticized concrete of the required quality will be obtained, and the transporting shall be performed to complete superplasticization and unloading within 1.5 hours from

starting to mix the base concrete. However, the limit to transporting time may be changed upon obtaining the approval of the Engineer.

(2) The vehicle for transporting concrete shall be such that unloading can be performed with ease. In case the transporting distance is long and in case superplasticization is to be performed using the transporting vehicle, a truck agitator shall be used.

(3) In case of using a truck agitator for superplasticization, the quantity of concrete to be loaded shall be selected giving consideration to agitating performance of the truck agitator.

(4) The truck agitator shall be capable of maintaining the mixed concrete in an adequately uniform state, and easily and completely discharging the concrete without occurrence of segregation. In the event samples are collected separately at one-quarter and three-quarter points of the load during discharge and slump tests are performed, the difference in the slumps of the two shall be within 3 cm.

[Commentary]

Regarding (1) In superplasticization of base concrete, the degree of hydration of cement will be a major factor. Normally, from immediately after mixing of base concrete until about 60 to 90 minutes later, the fluidification effect of the superplasticizer is practically unchanged, but when the time of addition is delayed beyond the limit, the effect of the superplasticizer will be decreased, and slump loss after superplasticization will be great. This timing will vary depending on temperature, humidity, transporting conditions, and other factors. Accordingly, even when it is concrete for which transporting, fluidifying and unloading are completed within 1.5 hours, depending on the condition of the concrete on transporting to the placement location, and the condition of the concrete already placed, considerations must be given so that concrete can be placed continuously under the same conditions at all times by shortening the time from mixing to completion of placement, improving transporting methods and transporting means, and protecting concrete that has already been placed.

Regarding (3) In case of using a truck agitator in agitating for fluidification, the mixing efficiency will be greatly affected by the quantity of concrete loaded. Therefore, the quantity to be loaded must be decided taking into consideration slump of base concrete, amount of slump to be increased, time required for agitation, etc.

CHAPTER 6 MANUFACTURE OF SUPERPLASTICIZED CONCRETE

Article 25 General

A plan on the timing and method of introducing the superplasticizer and the method of agitating shall be established prior to start of the work, and the approval of the Engineer obtained.

In superplasticization of the concrete, atigating shall be thoroughly done until the concrete has become of uniform quality.

[Commentary]

Prior to start of concrete work, thorough planning must be done on the method of manufacturing superplasticized concrete, that is, the timing and method of introducing the superplasticizer, and the method of agitating. Work must be executed according to the plan to obtain superplasticized concrete of the required quality.

When using a mixer of good mixing performance installed at the jobsite or a truck agitator to thoroughly agitate until superplasticized concrete of uniform quality is obtained, the equipment should be well-maintained and have the prescribed performance, and agitating must be done thoroughly at high speed or medium speed for an appropriate length of time.

Article 26 Superplasticizing of Concrete

Superplasticizing of concrete shall be done by one of the methods below.

(1) Superplasticizing is done adding superplasticizer to base concrete at the jobsite.

(2) Superplasticizer is added at the place of manufacture of base concrete and superplasticizing is done at that place.

(3) Superplasticizer is added at the place of manufacture of base concrete, transporting is done while agitating at low speed, and superplasticizing is done after arrival at the jobsite.

[Commentary]

There are three methods of superplasticizing concrete, (1), (2), and (3). The mix proportions and the quality of the concrete, the method of placement, and the volume to be placed must be considered, and the method most suited to the transporting time from the concrete plant to the jobsite, and to the concrete manufacturing capacity must be selected.

The method of (1) is one in which superplasticizer is added at the jobsite, and agitating for fluidification is done using the truck agitator used for transporting the base concrete, directly rotating at high speed for the required length of time, or superplasticization is done installing an agitating facility (for example, continuous mixer) for fluidification at the jobsite. In general, a truck agitator is used. The rule for this method is to add superplasticizer of a given quantity which has been determined beforehand, but depending on the case, it is possible for introduction of superplasticizer to be controlled according to variation in slump and variation in quality during transporting of the base concrete, and to easily change the slump of the superplasticized concrete in accordance with the location to be placed, which are advantageous points of this method. However, the method of fluidifying at the jobsite may involve the problem of noise and exhaust gas due to high-speed revolutions of the truck agitator.

The method of (2) consists of mixing base concrete at the concrete plant, followed by addition of superplasticizer of the prescribed quantity to the wet hopper or truck agitator, and transporting upon fluidifying at the time of shipping.

The method of (3) consists of mixing base concrete at the concrete plant followed by addition of the prescribed amount of superplasticizer to a wet hopper or a truck agitator and directly transporting while agitating at low speed, then on reaching the jobsite fluidifying by agitating for the prescribed length of time, and unloading. This method has the advantage that practically all of the fluidification is completed while transporting at times, so that the agitating time after arrival can be shortened.

The methods of (2) and (3) make it possible to avoid the trouble of controlling introduction at the jobsite and the problem of noise due to high-speed revolution of the truck agitator, but when the transporting time becomes long the time-dependent variations in slump and air content of superplasticized concrete will be large and there will be risk of

placement being hindered so that thorough consideration must be given to the matter beforehand.

In the event concrete should become segregated due to excessive addition of superplasticizer, it is advisable to continue low-speed agitation with the truck agitator, unloading only after confirming that the prescribed slump has been obtained.

Article 27 Apparatus Used for Superplasticization

(1) The agitating apparatus used in superplasticizing shall demonstrate ample agitating performance, and be capable of easy and complete discharge without causing segregation.

(2) The batching apparatus used for the superplasticizer shall possess the required accuracy, be inspected prior to start of work and periodically during work for batching accuracy, and be adjusted to be within the required tolerance for batching.

(3) The apparatus for introduction of the superplasticizer shall be such that the superplasticizer can be introduced accurately and efficiently into the base concrete.

[Commentary]

Regarding (1) It is most common for a truck agitator to be used in agitating for fluidification. The truck agitator used must be adequately maintained, and the performance must meet the requirements of Article 24(4). It is permissible to use a constant feed apparatus for concrete designed especially for superplasticizing and a continuous mixer equipped with a continuous adding apparatus for the superplasticizer.

Regarding (2) The batching method and batching apparatus for superplasticizer must be selected to match the method of superplasticizing, the scale of the work, and the rate of placement. In order for the superplasticizer to be batched within the required tolerance, the capacity and accuracy of the dispensing equipment itself must be appropriate.

It is only natural for the batching apparatus for the superplasticizer to be inspected prior to the work and adjusted so that batching can be done with the required accuracy. Even if the apparatus has been adjusted in this way, there can be cases while it is being used for it to start working abnormally or to lose its accuracy. Therefore, periodic inspections must be carried out and readjustments made as necessary.

Regarding (3) It is necessary to select an introduction method and introduction apparatus matching the scale of the work and the rate of placement.

For introduction of superplasticizer, the method of adding the required amount of superplasticizer inside the hopper of the truck agitator with an automatic dispensing apparatus by merely pressing a button is often used. In such case, it is desirable for the automatic dispensing apparatus for the superplasticizer to have good accuracy in measurement and be of simple construction. It must also be such that the superplasticizer will be kept as much as possible from sticking to the vicinity of the hopper mouth.

Article 28 Batching of Superplasticizer

(1) As a rule, the superplasticizer shall be used in undiluted form and be measured out by mass or volume for each batch.

(2) Errors in measuring the superplasticizer shall be within 3 percent of the quantity for a single batch.

[Commentary]

Regarding (1) Although there are superplasticizers in powder form, commercial products are almost all in liquid form, and it was decided that superplasticizers should be used in liquid form and undiluted. Although the principle is for a material to be measured by weight, there are cases when measuring can be done fairly accurately even though measured by volume, and therefore, it was decided that superplasticizers may be batched by volume.

Regarding (2) The tolerance for admixture solutions in Article 106 of the RC Specifications was adapted here.

Article 29 Agitating of Superplasticized Concrete

In principle, agitating for superplasticization shall be performed using an apparatus meeting the requirements of Article 27 and the time required for superplasticization shall be determined by testing.

[Commentary]

Uniformity of superplasticized concrete is to be judged by slump tests on collecting samples from the one-quarter and three-quarter points of discharge of individual batches of concrete superplasticized by a truck agitator or an agitating apparatus, and the agitating time in such case is to be set so that the difference between the two will be not more than 3 cm.

The agitating time adopted for a truck agitator at an ordinary construction site is generally about 1 to 2 minutes at high speed and about 2 to 3 minutes at medium speed.

Since sufficient agitation cannot be performed if loading is done in excess of the capacity of the truck agitator, the quantity to be loaded on the truck agitator is to be that which can be sufficiently agitated, while from the aspect of controlling the dosage of superplasticizer, it is desirable for the quantity loaded to be constant at all times.

Regarding efficiency of agitation by truck agitator, the revolutions will differ greatly depending on the type, degree of antiquation, etc., with efficiency considerably decreased by wear of drum blades. The time required for superplasticization will also differ according to the slump of base concrete, and therefore, it was made the rule that the time is to be determined by testing.

The noise during agitation for fluidification by truck agitator is a great problem, and in use in urban areas it is necessary for thorough consideration to be given such as to lengthen the time by agitating at medium speed instead of high speed, or to install noise barriers.

In case of using a continuous mixer as the agitating apparatus for superplasticization, it must be provided with a constant feed apparatus for concrete and the quantity of flow of concrete inside the mixer made constant, while it must

be possible for superplasticizer to be continuously batched in a manner that it will be added uniformly to the concrete. Compared with when agitating by truck agitator there are such advantages as that the noise can be reduced considerably and that ascertaining the quality of the concrete is made easier. Needless to say, it will be necessary to obtain the approval of the Engineer regarding the type of continuous mixer, the agitating efficiency of the mixer, and method of ascertaining uniformity.

Article 30 Refluidification of Superplasticized Concrete

In principle, superplasticized concrete shall not be refluidified.

[Commentary]

Refluidification of superplasticized concrete will mean risk of adding superplasticizer in excess of the permissible limit, and since it is conceivable for segregation to occur due to excessive addition, or adverse effects to be caused regarding setting characteristics, durability, long-term strength, etc., of concrete, it was stipulated that this is not to be done as a rule. However, if for some reason placement of concrete is delayed and the slump of the superplasticized concrete has dropped extremely, it is permissible for superplasticizer to be re-added to the superplasticized concrete in the truck agitator and agitating done to return to the prescribed slump just once, subject to approval of the Engineer.

CHAPTER 7 READY-MIXED CONCRETE

Article 31 General

In the event of using ready-mixed concrete for the base concrete, in addition to following this Recommended Practice, JIS A 5308 shall be followed.

[Commentary]

In JIS A 5308, "Ready-Mixed Concrete," the materials, varieties, names, qualities, mix proportions, manufacture, quality control, testing method, inspection, etc. for ready-mixed concrete are prescribed in detail, and concrete meeting all of these requirements is to be called ready-mixed concrete. On the other hand, superplasticized concrete is manufactured by adding superplasticizer to base concrete and mixing, the methods of manufacture being the three kinds below as specified in Article 26, and in all of these cases it is normal for a truck agitator to be used in agitating for fluidification.

① Superplasticizer is added to base concrete of the jobsite for fluidification.

② Superplasticizer is added at the place of manufacture of base concrete, and fluidification is done on the spot.

③ Superplasticizer is added at the place of manufacture of base concrete, transporting is done while agitating at low speed, and fluidification is done after arriving at the jobsite.

When the restricting conditions of the sites are collated in this manner, in case of using ready-mixed concrete as the base concrete, since it is not possible to discharge all of the base concrete from the truck agitator, the inspection at the so-called unloading site in JIS A 5308 cannot be carried out, and when ready-mixed concrete is used as superplasticized concrete, a truck agitator is used for mixing (agitating), and similarly, the provisions for mixer and mixing prescribed in JIS A 5308 cannot be met, so both base concrete and superplasticizer cannot be handled as ready-mixed concrete. However, under present circumstances, concrete construction

not using ready-mixed concrete is unthinkable, and when using ready-mixed concrete as the base concrete for manufacturing superplasticized concrete, the provisions of this Recommended Practice are to be followed, and regarding matters related to the form of ordering and handling the concrete is to be handled as ready-mixed concrere following JIS A 5308.

However, in case of installing a mixer at the jobsite as the agitating apparatus for superplasticization, where it is possible to inspect concrete after unloading, it is needless to say that base concrete can be handled as a standard product according to JIS A 5308 or as a special order product.

Article 32 Selection of Plant

The matters listed below shall be taken into consideration in selection of a ready-mixed concrete plant.

(1) In principle, the plant shall be a JIS mark-authorized plant, and shall possess facilities for manufacturing base concrete of the required quality and the capability for quality control.

(2) The plant shall be staffed at all times by a technician having the qualifications of a senior concrete engineer or a Concrete engineer, or knowledge and experience at least equivalent to the first two.

(3) The plant shall be at a distance from which transporting, superplasticization, and unloading of base concrete can be done within the prescribed length of time.

[Commentary]

Much of the quality of superplasticized concrete is decided by base concrete. Also, as indicated in Chapter 5, there are cases when qualities different from ordinary concrete are demanded of base concrete. Accordingly, technology of a high level is required for manufacture and quality control of base concrete, and therefore, (1) and (2) of this article was stipulated.

Regarding transporting distance, it is necessary for the plant to be selected taking into account the time required for superplasticization, and unloading must be done within 1.5 hours from start of mixing.

Article 33 Stipulations Regarding Quality

In the event of ordering base concrete from a plant as ready-mixed concrete following JIS A 5308, the matters necessary for obtaining the required qualities as base concrete shall be selected as suited on discussions with the producer.

With regard to the matters necessary for obtaining the required quality, they shall be according to the following other than JIS A 5308.

(1) Case of adding superplasticizer at the jobsite

(i) Method of inspecting base concrete
(ii) Otherwise, matters not meeting the requirements of JIS A 5308

(2) Case of adding superplasticizer at the ready-mixed concrete plant

(i) Nominal strength of base concrete immediately after mixing, age, assuring the nominal strength slump, and air content
(ii) Unit mass immediately after mixing in case of lightweight concrete
(iii) Method of inspecting base concrete
(iv) Otherwise, matters not meeting the requirements of JIS A 5308

(3) In case the ready-mixed concrete plant is in charge of measuring and adding of superplasticizer, and superplasticization work, the following shall be decided.

(i) Variety and brand of superplasticizer
(ii) Dosage of superplasticizer
(iii) Method of measuring and adding superplasticizer
(iv) Amount of slump increase

[Commentary]

In case of ordering base concrete from a plant as ready-mixed concrete following JIS A 5308, the specifications of quality will naturally differ according to the process of superplasticization to manufacture superplasticized concrete, that is, whether the purchaser or the producer performs the work of measuring and adding the superplasticizer and carrying out the superplasticization operation. Also, even though a case of the purchaser performing the work, the specification of quality will naturally differ depending on whether the superplasticization process is carried out after arrival at the jobsite or in the ready-mixed concrete plant. In this article, the stipulations on quality are given for the respective cases, and (1) is applied to the case of the purchaser fluidifying at the jobsite, (2) to the case of the purchaser fluidifying at the plant, and (3) to the case of the producer carrying out the superplasticization work. In the case of (3), it does not matter at whichever location the fluidification is done.

Regarding (1),(2) In Article 112 of the RC Specifications it is stipulated that when ordering ready-mixed concrete, the following matters are to be specified as suited in addition to the combination of nominal strength and slump.

(1) Case of standard product

(a) Type of cement
(b) Type of aggregate
(c) Maximum size of coarse aggregate
(d) In case of lightweight concrete, unit mass of concrete

and as necessary,

(e) Maximum or minimum temperature of concrete

(2) Case of special-order product

In addition to (a) to (e) above

(f) Age assuring the nominal strength
(g) Type of admixture
(h) Air content
(i) Other necessary matters

When ordering base concrete, besides stipulating in regard to the above items, taking the quality after superplasticizations into consideration, it may be necessary to provide stipulations about the following:

(j) Sand-aggregate ratio
(k) Fines of 0.15 mm and under in fine aggregate
(l) Unit water content
(m) Unit cement content

With base concrete, the method of obtaining samples for inspection at the point of unloading generally does not conform to JIS A 5308, and therefore, this must be decided upon discussions with the producer. As a method to replace JIS A 5308, the method of Article 34(3) may be applied. Regarding the base concrete in case of addition at the plant, since the quality immediately after mixing will be the basis, it is necessary for the matters in this article to be decided.

Regarding (3) In case measuring and adding superplasticizer, and performing the fluidification operation are consigned to the ready-mixed concrete plant, besides deciding the matters in the article, it will be necessary to distinctly define the allocation of work, and the extents of responsibilities to be borne.

The system of a ready-mixed concrete plant making and selling superplasticized concrete has hardly ever been implemented, but as superplasticized concrete becomes more common, it is expected that this system will be increasingly adopted in the future. When ordering superplasticized concrete by this system it will be necessary for discussions to be held with the producer and provisions to be made as suited.

① Slump and air content of base concrete immediately after mixing

② Nominal strength of superplasticized concrete at the point of unloading, age to assure the nominal strength, slump, and air content

③ In case of lightweight concrete the unit mass of superplasticized concrete at the point of unloading

④ Variety and brand of superplasticizer

⑤ Dosage of superplasticizer

⑥ Method of fluidification

⑦ Method of quality control

⑧ Methods of inspecting base concrete and superplasticized concrete

⑨ Otherwise, items not meeting the requirements of JIS A 5308

Article 34 Acceptance Inspection

The acceptance inspection for base concrete shall be according to the items below in addition to following JIS A 5308.

(1) The acceptance inspection shall be carried out at the place of addition of superplasticizer prior to the addition.

(2) Tests shall be performed on slump, air content, unit mass (in case of lightweight concrete), compressive strength and any other item specially designated.

(3) The method of collecting samples for the tests shall be according to ① or ② below.

① In case of collecting from the hopper, JIS A 1115 (Method of Sampling Fresh Concrete) shall be followed.

② After high-speed revolution of the truck agitator for 30 seconds, sampling shall be done from the flow after discarding one handcart load of concrete first discharged from the transporting vehicle.

[Commentary]

JIS A 5308, 9. "Inspection" concerns the quality inspection to be carried out by the producer, but it can be applied to the acceptance inspection by the purchaser. It is necessary for the base concrete to be subjected to a quality inspection following the provisions of JIS A 5308, and also a proper acceptance inspection prior to addition of superplasticized concrete. Since the stability of the consistency of base concrete is of importance in manufacture of superplasticized concrete, it is desirable for the number of slump and air content tests performed to be increased from the beginning of placement until manufacture becomes stabulized.

Collection of samples for acceptance tests of base concrete generally cannot be done according to the provisions of

JIS at the point of unloading, and therefore, the two methods stipulated under (3) of the article would be adopted. Which of these methods is to be selected will depend on the situations at the plant and jobsite, or the method of fluidification, and it will be advisable to ascertain at the time of making trial mixes that the required quality of the superplasticized concrete can be secured.

CHAPTER 8 TRANSPORTATION AND PLACEMENT OF SUPERPLASTICIZED CONCRETE

Article 35 General

This chapter shall be applicable to transporting and placing of superplasticized concrete at the jobsite.

Prior to start of the work a plan on transporting and placing superplasticized concrete at the jobsite shall be established and the approval of the Engineer obtained.

Transporting and placing superplasticized concrete shall be performed by methods with which segregation and quality variation will be as small as possible, with transporting done quickly, placing done immediately, and consolidating done thoroughly.

[Commentary]

This chapter gives the general standards regarding matters necessary in particular in transporting and placing at the jobsite from fluidification of concrete until placement. The method of superplasticization is to be according to Article 26, Superplasticization of Concrete, and transporting outside the jobsite according to Article 24, Transporting. Regarding matters not especially stipulated, the provisions of Articles 114 to 126 of the RC Specifications must be followed.

The plan for transporting and placing superplasticized concrete must be formulated comprehensively considering the configuration of the structure, the total volume of concrete, placing capacity, formwork, meteorological conditions, etc., so that concrete of the required quality will be obtained. Particularly, it is necessary for the considerations below to be given with people concerned made thoroughly aware of the considerations beforehand.

(1) Methods of transporting and placing of concrete after superplasticization

(2) Placement blocks and placement sequence

(3) Volume of superplasticized concrete to be placed and rate of placement

(4) Method of finishing superplasticized concrete, timing of finishing, and method of curing

(5) Method of communication and measures to be taken in case of contingency

In transporting superplasticized concrete, it is necessary for a method allowing transporting to be done quickly to be selected so that variations in quality, such as in consistency and workability, will be as small as possible. It is important that the best method in accordance with the method of manufacturing superplasticized concrete is selected.

For transporting superplasticized concrete, it is advisable to use concrete pumps which generally have high placing speeds compared with other transporting facilities since slump loss accompanying elapse of time is large compared with ordinary concrete. When other methods are to be used, it is necessary for considerations to be given that segregation of concrete will not occur.

With superplasticized concrete it is the principle throughout for placement to be done immediately after fluidification. As a general measure, the limits from superplasticization until finishing placement are 30 minutes when outside air temperature is under 25°C, and 20 minutes when outside air temperature is 25°C or higher. However, when the quality of concrete has been secured through a special measure, it is permissible to prolong these times. Special measures include using a retarding agent or a retarding type water-reducing agent, and using a superplasticizer of small slump loss.

Article 36 Concrete Pump

In case of using a concrete pump, the type shall be selected taking into consideration the quality of the superplasticized concrete, transporting distance, pipeline layout plan, volume of placement at one time, rate of placement, consolidation, etc.

[Commentary]

By using superplasticized concrete, it is possible for large improvements to be made in placement properties such as pumpability, placement, and consolidation. However, if

a mistake is made in selection of the type of concrete pump, proper pumping will be difficult, and not only can clogging of the concrete pump occur and efficiency of placing and consolidating work be lowered, but also, the placement blocks, placement rate, and consolidation orginally planned can become inappropriate, and defects in construction such as cold joints liable to be produced.

Through the adoption of superplasticized concrete, it becomes possible for concrete that had previously been of stiff consistency and difficult to pump to be transported by pump. Concrete pumps in recent years have become of high performance, but the types presently in use are of various capabilities, so that the type must be selected taking into consideration quality of superplasticized concrete, transporting distance, pipeline layout plan, volume of placement at one time, rate of placement, consolidation, etc.

An example of the method of selecting the type of concrete pump is shown below.

In case of selecting the type of concrete pump based on the pumping load applied to the pump, it is advisable to calculate the load using the equation below and select a pump having a theoretical discharge pressure exceeding this load.

$$P = KL + 12\,KM + 8\,KH + 8\,KT + 4\,KN$$

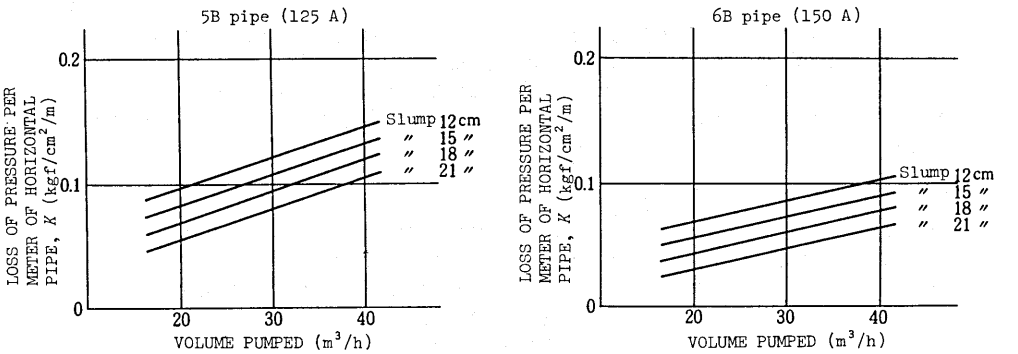
Symbols
- P; pumping load applied to concrete pump (kgf/cm^2)
- K; loss of pressure in pipe per 1 m of pipeline ($kgf/cm^2/m$)
- L; actual length of pipeline (m)
- M; number of 90-deg bends (m/bend)
- H; height pumped (m)
- T; number of tapered pipes (m/tapered pipe)
- N; number of flexible hose (m/flexible hose)

(Note) The loss of pressure in the pipe per meter of pipeline is according to reliable data. The K of superplasticized concrete in general is shown in Commentary Fig. 3.

To suspend pumping during transporting by concrete pump has an extremely adverse effect on quality. Therefore, in setting up a pumping plan, the ready-mixed concrete supplier, pumper, and placer must hold thoroughgoing discussions prior to construction, and it must be made possible for pumping to

be done continuously from start of placement until finish.

When clogging of the concrete pump has been recognized, placing is to be discontinued immediately, and as a rule, that concrete is not to be placed. (See Article 30, Refluidification of Superplasticized Concrete.)



Commentary Fig. 3 Loss of pressure in pipe per meter of pipeline for superplasticized concrete, K (kgf/cm^2/m).

Article 37 Preparations for Placement

(1) The approval of the Engineer shall be obtained with regard to the arrangements of reinforcement, formwork, and other items prior to placement of superplasticized concrete.

(2) Prior to placement of superplasticized concrete, it shall be confirmed that transporting and placing equipment and personnel adequately match plans and transporting machinery and placing machinery can be properly used.

(3) Prior to placement of superplasticized concrete, the transporting apparatus, placing equipment, and the interiors of forms shall be cleaned to prevent introduction of foreign matter into the superplasticized concrete. A place where there is risk of absorption occurring on coming into contact with superplasticized concrete shall be moistened prior to placement.

[Commentary]

See the commentary of Article 123 in the RC Specifications.

Article 38 Placement

(1) Placement of superplasticized concrete shall be performed in accordance with the placement plan established under Article 35.

(2) In carrying out placement work of superplasticized concrete care shall be exercised not to disturb the reinforcement in place.

(3) When superplasticized concrete deposited inside the form moves, it shall be confirmed that segregation does not occur.

(4) The superplasticized concrete within a single block shall be placed continuously until placement has been completed at a rate that consolidation can be sufficiently performed.

(5) As a rule, superplasticized concrete shall be placed in a manner that the surface in any single block will be approximately horizontal.

(6) In case the height of the form is large, the height of free fall shall be made as small as possible to prevent segregation, and to prevent adherence and hardening of superplasticized concrete on reinforcing bars and forms at the upper part of the location of placement.

(7) In case of placing superplasticized concrete in two or more layers, the superplasticized concrete of the upper layer shall be placed before the superplasticized concrete of the lower layer begins to harden.

(8) In case there is water rising to the top and collecting during placement of superplasticized concrete, superplasticized concrete shall not be placed on top unless the water has been removed by a suitable method.

(9) In case of continuously placing concrete of large height such as in walls and columns, the consistency and rate of rise of the surface shall be adjusted in order to minimize segregation during placement and consolidation.

[Commentary]

Regarding (1), (2), (4), (5), (8), (9) See the commentary on Article 124 of the RC Specifications.

Regarding (3) Since the consistency of superplasticized concrete is wet, it will move from the location of placement to a fairly distant spot when introduced into the form. When this property is skillfully taken advantage of, placing time and labor can be economized compared with ordinary concrete, and this is one of the merits of superplasticization. However, in this case, the precondition is that the concrete is not to segregate, and it is necessary for this to be confirmed.

Regarding (6) Superplasticized concrete is said to have high resistance to segregation even though consistency is wet, but when concrete is dropped from above, it will strike against forms and reinforcement and is liable to

segregate so that it is necessary to make the height of free fall as small as possible.

Regarding (7) In cases such as the block of concrete being placed being of large area with the superplasticized concrete of the lower layer beginning to harden, there will be risk of cold joints being produced if the superplasticized concrete of the upper layer is placed without any preventive measures being taken, so that the concrete of the upper layer must be placed within a length of time that the concretes of the various layers will become monolithic. Although the time will depend on the quality of the superplasticized concrete, as a rule, when the outside air temperature is under 25°C, the time is to be within 60 minutes, and when 25°C or higher, within 40 minutes. However, when special measures have been taken such as using a retarding agent in the superplasticized concrete for the lower surface, the time may be extended within limits that revibration can be performed on the superplasticized concrete of the lower layer.

Article 39 Consolidation

(1) In principle, an internal vibrator shall be used for consolidation of superplasticized concrete, but where it is difficult to use an internal vibrator as in a thin wall, other tools shall be used in combination.

(2) Superplasticized concrete shall be thoroughly consolidated immediately after placement, and be made to reach around reinforcing steel and into corners of the form.

(3) When placing concrete in two or more layers, in consolidation by vibration, interior vibrators shall be thrust about 10 cm into the superplasticized concrete of the lower layer.

(4) The spacing of insertion of vibrators when using internal vibrators for consolidation and the vibration time at one location shall be at intervals in a range that vibration effects will overlap and for lengths of time that ample vibration effects will be obtained.

[Commentary]

Regarding (1) Superplasticized concrete is used mostly with the main objective to improve working properties. The most important thing in working concrete is to consolidate the concrete so that it will be dense and uniform, and the use of superplasticized concrete does not mean that consolidation by vibrator can be omitted. It was thus made the rule that internal vibrators are to be used. Further, depending on the configuration of the structure, the construction, etc., it will be advisable to use auxiliary equipment such as form vibrators and mallets.

Regarding (2) At inaccessible places for concrete such as where reinforcement is densely arranged, it is necessary not only for the superplasticized concrete to have good workability with respect to quality, but also, it must be carefully consolidated.

Regarding (3) Even with superplasticized concrete, internal vibrators must be inserted at uniform spacings as much as possible, and into the lower layer of superplasticized concrete so that adequate effect will be obtained, just as in the case of ordinary concrete. This is effective in preventing the occurrence of cold joints.

Regarding (4) Superplasticized concrete has high slump compared with ordinary concrete, and it can easily happen that vibrations of vibrators will not be applied uniformly. The result will be defects in the concrete. Therefore, while observing the condition of the concrete, vibration is to be performed within limits that vibration effects will overlap, and for lengths of time that adequate effects of vibration will be obtained. With respect to the intervals at which internal vibrators are to be inserted, they can generally be made larger than for ordinary concrete within limits that concrete will be made uniformly plastic and that vibration is seen to be effective.

Article 40 Additional Placement

(1) In case of placing superplasticized concrete on top when superplasticized concrete in place has begun to harden somewhat, the work shall be executed carefully according to the directions of the Engineer in order that the superplasticized concretes of the upper and lower layers will be made integral.

(2) In the event that concrete of a slab or beam is continuous with concrete of a wall or column, to cope against shrinkage and settlement of the superplasticized concrete in the wall or column, it shall be standard practice to place the superplasticized concrete of the slab or beam after settlement has ended following placement of the superplasticized concrete for the wall or column.

Placement in the same manner shall be carried out in the case of a structure with a cantilevered portion.

[Commentary]

Regarding (1) See the commentary on Article 126 of the RC Specifications.

It is necessary for attention to be paid since the time when superplasticized concrete begins to harden differs compared with ordinary concrete depending on the variety of superplasticizer, the time until superplasticization, etc.

Regarding (2) Since there are differences in the degrees of settlement of superplasticized concrete depending on the variety of superplasticizer, the placement block, the placement rate, the configuration of the structure, etc., it is important for superplasticized concrete of upper layers such as cantilevered portions to be placed after settlement of superplasticized concrete at lower parts has ended.

CHAPTER 9 FINISHING AND CURING

Article 41 General

(1) Superplasticized concrete, after placement, shall be finished to the prescribed height and configuration, and shall be adequately cured in order not to be subjected to the harmful effects of low temperature, drying temperature variation, etc.

(2) Finishing and curing of superplasticized concrete shall be performed so as not to miss the proper timing.

[Commentary]

Regarding (1), (2) Compared with ordinary concrete of the same slump, disappearance of moisture from the surface and drying are often hastened in case of superplasticized concrete, so that it is necessary to pay attention not to miss the timing for surface finishing and curing, and for considerations to be given to the work program including such matters as personnel assignments and method of surface finishing.

Regarding other matters in general, they may be considered in the same manner as for ordinary concrete.

Article 42 Surface Finishing

(1) Surface finishing of superplasticized concrete shall not be done until, after completion of consolidation, water risen to the top surface has disappeared or has been disposed of.

(2) After the finishing work, cracks that have occurred up to the time that the concrete has begun to harden shall be eliminated by tamping or refinishing.

[Commentary]

See the commentaries of Articles 155 and 156 of the RC Specifications.

Regarding (1), (2) Generally speaking, bleeding of superplasticized concrete is of the same degree or slightly less than of ordinary concrete and there is a tendency for the timing of finishing to be hastened. However, depending on the materials and mix proportions, there are cases when bleeding will be excessive. Although it is extremely important to carry out the work so that water will not appear at the top surface of concrete, when a large quantity of water does rise, removing this water is important for preventing occurrence of surface cracks after finishing. Also, there are cases when cracks are liable to occur due to settling of concrete, and refinishing may be required.

Article 43 Curing

After superplasticized concrete has been placed, measures shall be quickly taken to prevent drying of the surface, and especially, moist curing at early age shall be performed with care.

[Commentary]

See the commentaries for Articles 127 and 128 of the RC Specifications.

With concrete, when the surface after placement dries at a very early time and moisture at the interior is lost, hydration reaction of cement will not occur sufficiently, while if only the surface dries out rapidly due to direct rays of the sun and wind, cracks will be produced. Superplasticized concrete often dries out at the surface more quickly than ordinary concrete, and therefore, special attention should be paid to prevention of surface drying at an early age, and blocking off the sun and wind must be done until hardening has occurred to a degree that the surface will not be damaged, even by laying tarpaulins or curing mats.

As for other matters in general, they may be considered in the same manner as for ordinary concrete.

CHAPTER 10 FORMWORK AND SHORING

Article 44 General

Formwork and shoring shall be designed and constructed to possess the prescribed strengths and rigidities, and for the location, configuration, and dimensions of the completed structure to be secured with accuracy.

[Commentary]

See the commentary on Article 141 of the RC Specifications.

Article 45 Formwork

(1) The lateral pressure of fresh superplasticized concrete shall be considered in design of formwork.

(2) Formwork for superplasticized concrete shall be constructed carefully in a manner that paste will not leak from joints.

(3) In case of placing superplasticized concrete in a sloping member, top forms shall be installed as necessary.

[Commentary]

Regarding (1) See (3) of the commentary on Article 142 of the RC Specifications.

According to experiments, lateral pressure was approximately 62 percent of liquid pressure (2.4 x height) when base concrete of slump of 5 cm was fluidified to slump of 12 cm, approximately 85 percent of liquid pressure when slump was similarly fluidified from 8 to 18 cm, and approximately liquid pressure when fluidified from 12 to 21 cm. In view of these facts, it is advisable for forms to be designed to resist liquid pressure in case of superplasticized concrete. However, depending on the slump, there are cases when liquid

pressures such as mentioned above are not obtained, and if reliable information, performance records, or test data are available, formwork may be designed referring to the lateral pressures in those cases.

Regarding (2), (3) In general, while superplasticized concrete has high viscosity, on the other hand, the fluidity is greatly increased by factors such as vibration during consolidation. Therefore, it is necessary for careful construction to be performed so that cement paste will not leak from joints of forms and joints of sheaths used for prestressed concrete, etc.

When placing superplasticized concrete of wet consistency in sloping members, care is necessary since there are cases when finishing will be difficult unless top forms are provided at places of smaller inclination angles than with ordinary concrete.

CHAPTER 11 CONCRETES REQUIRING SPECIAL CONSIDERATIONS

Article 46 General

When placing mass concrete, cold weather concrete, hot weather concrete, prestressed concrete, watertight concrete, pavement concrete, composite steel and reinforced concrete, artificial lightweight aggregate concrete, offshore concrete, underwater concrete and concrete factory products with superplasticized concrete, the work shall be done appropriately giving consideration to the special natures of these concretes.

[Commentary]

When placing mass concrete, cold weather concrete, hot weather concrete, prestressed concrete, watertight concrete, pavement concrete, composite steel and reinforced concrete, artificial lightweight aggregate concrete, offshore concrete, underwater concrete, and concrete factory products using superplasticized concrete, there will be cases in which it will not be possible to apply the provisions of Chapter 1 to Chapter 10 without modification. This chapter describes the standards for matters that are especially necessary regarding these concretes.

Article 47 Mass Concrete

Mass concrete shall be placed paying special attention to materials, mix proportions, mixing, transporting, and placing.

[Commentary]

Regarding Materials and Mix Proportions In case of mass concrete, it is necessary for mix proportions of low cement content to be used in order to prevent occurrence of cracks due to heat of hydration of cement. When placing mass concrete with superplasticized concrete, it is possible for slump to be made slightly high compared with normal mass concrete, and moreover, use mix proportions with unit cement content lower than in the past. However, there is a report that in case the amount of fines in the concrete is small

the slump increase due to addition of superplasticizer becomes small, and it is important that in deciding on mix proportions it is confirmed beforehand using materials to be employed in the project that the required effects can be obtained.

In case the effect of adding superplasticizer cannot be obtained, it is advisable to consider the use of a fine aggregate with a high content of fines 0.15 mm and under, or a finely divided mineral admixture such as fly ash. It has been reported that when fly ash is used replacing cement, besides unit water content and temperature rise due to heat of hydration being reduced, and strength at long-term age being increased, pumpability is improved.

Moderate heat portland cement and portland blast-furnace slag cement are used at times for mass concrete to lower heat of hydration, but it has been reported that if in the range of Article 6 the effect of superplasticizer is no different from that with ordinary portland cement.

Regarding Mixing, Transporting and Placing With mass concrete, the volume of concrete placed will be large and even in an ordinary case it is necessary for considerations to be given so that placing operations will proceed smoothly. Since slump loss after fluidification is large compared with ordinary concrete in case of superplasticized concrete, the work execution program on mixing, transporting, fluidifying of base concrete, and transporting and placing of superplasticized concrete must be carried out with special care to prevent cold joints from occurring.

Article 48 Cold Weather Concrete

Cold weather concrete shall be placed paying special attention to materials, mixing, and transporting.

[Commentary]

Regarding Materials With cold weather concrete, it is important that concrete is not frozen at the early stage of setting and superplasticizer used for cold weather concrete must be standard type as a rule, while time of setting is not to be prolonged more than necessary.

Regarding Mixing and Placing When placing cold weather concrete with superplasticized concrete, the mix proportions can be selected in accordance with Chapter 4. However, superplasticization effect is generally reduced when air temperature or concrete temperature is low, and therefore, transporting equipment or placing plans must be selected with care in order that the temperature of base concrete will not be lowered during transport.

Other If superplasticized concrete were to be placed with slump of about the same degree as ordinary concrete, it is possible to reduce unit water content compared with the ordinary concrete, and the effect of this in prevention of freezing is great. However, when the temperature of concrete is being raised using warm water, the concrete temperature immediately after mixing is lowered in accordance with water reduction and therefore, a countermeasure must be provided.

Article 49 Hot Weather Concrete

Hot weather concrete shall be placed paying special attention to mixing, transporting, and placing.

[Commentary]

When the time from mixing of base concrete until addition of superplasticizer is long, the effect of the superplasticizer is small while slump loss after fluidification is large, and it is said that such influences are especially great in case of high temperature.

Therefore, with hot weather concrete, it is necessary for the time from mixing of base concrete until superplasticization and completion of unloading, and the time until completion of placement of superplasticized concrete to be prescribed more severely than concrete in general. Regarding these times, 40 minutes for the former and 20 minutes for the latter are to be standard.

In case of using a retarder or a retarding-type superplasticizer, it will be permissible to extend these times similarly to ordinary concrete. (See Commentary, Article 35.)

Article 50 Prestressed Concrete

Prestressed concrete shall be placed paying special attention to transporting and placing.

[Commentary]

Compared with reinforced concrete, prestressed concrete, requires concrete of high strength, and the practice adopted is to carefully place concrete with rich mix proportions and low slump. However, because of the difficulty of obtaining aggregate of good quality in recent years, cases of using concrete of richer mixes have increased, and there is fear of the quality of prestressed concrete structures being lowered from aspects such as temperature cracks. Also, even with prestressed concrete, placement by concrete pump has increased with the aim of rationalization of construction. When superplasticized concrete is used for such prestressed concrete, working properties can be improved and concrete of good qualtiy can be obtained so that the use of pumps is increasing.

When prestressed concrete is placed with superplasticized concrete, the range of slump may be made 10 to 15 cm and work carried out in accordance with the provisions of other chapters of this Recommended Practice. However, prestressed concrete members have thin cross sections with reinforcing bars and prestressing tendons or sheaths arranged at narrow spacing so that transporting, placing, and consolidating superplasticized concrete must be done with special care to prevent occurrence of parts not filled.

The slump increase effect of addition of superplasticizer to rich concrete is equal to that in case of concrete in general, and it is possible to select mix proportions in accordance with the provisions of Chapter 4.

Article 51 Watertight Concrete

Watertight concrete shall be placed paying special attention to mix proportions and placement.

[Commentary]

Regarding Mix Proportions To place watertight concrete using superplasticized concrete has the advantages not only of making it possible for placement to be done by pump, but also of making consolidation easy and obtaining concrete of uniform quality. However, if the slump after fluidification is too high, there will be cases of segregation and increased bleeding, so that for watertight concrete it is advisable for slump of superplasticized concrete to be held to 15 cm and under with the slump of base concrete about 8 cm.

In the event segregation occurs even with slumps in this range, measures must be taken such as to improve the gradation of aggregate, change the sand-aggregate ratio, and use a suitable admixture.

Regarding Placing Since placement will be made easier through the use of superplasticized concrete, there will be risk of cold joints being formed due to increased work quantity, and therefore, the placement plan must be established with special care.

Article 52 Pavement Concrete

Pavement concrete shall be placed paying special attention to the mix proportions and transporting.

[Commentary]

Regarding Mix Proportions When using superplasticized concrete for pavement concrete, the slump after fluidification is to be not more than 8 cm as a standard. Stiff consistency concrete generally has a tendency of being difficult to fluidify so that thorough examinations must be made prior to the work in selecting mix proportions for the base concrete and the dosage of the superplasticizer.

Further, since superplasticized concrete has the property of becoming flowable when subjected to vibrations, in case the grade of the pavement surface is steep it is advisable to consider reducing the slump of the superplasticized concrete, reducing the dosage of the superplasticizer, or increasing the ratio of coarse aggregate used.

Regarding Transporting and Placing As a rule, truck agitators are to be used for transporting and fludifying base concrete. In such case, the construction of the plant must be such that concrete can be easily introduced from the mixer to the truck agitator. It is permissible, upon thoroughly examining the control setup, for about half of the dosage of superplasticizer to be added to the base concrete in the mixer and mixed to facilitate introduction of the concrete to the truck agitator. Further, since stiff consistency concrete is to be fluidified, selection of the type of truck agitator and of the amount of concrete to be loaded must be carefully done.

For transporting of concrete at the jobsite it will be necessary to select a method by which transporting can be quickly done with as little segregation of concrete and variations in quality such as consistency and workability as possible.

Article 53 Other Concretes Requiring Special Considerations

When placing composite steel and reinforced concrete, artificial lightweight aggregate concrete, offshore concrete, underwater concrete and concrete factory products with superplasticized concrete, the approval of the Engineer shall be obtained.

[Commentary]

At present, there are still not many cases of composite steel and reinforced concrete, artificial lightweight aggregate concrete, offshore concrete, underwater concrete, and concrete factory products having been placed with superplasticized concrete. However, it is thought there would be great advantages if superplasticization were to be used for these concretes, and therefore, it was stipulated that superplasticized concrete can be used on obtaining the approval of the Engineer.

Regarding Composite Steel and Reinforced Concrete Composite steel and reinforced concrete has a large quantity of steel arranged in a complex manner. Consequently, placing concrete is very difficult compared with reinforced concrete in general. With superplasticized concrete, slump can be increased without impairing quality, while fluidity is improved by vibration so that improvement in working efficiency and

quality can be looked forward to when used for composite steel and reinforced concrete.

However, if slump is made excessively high, or overvibration is done, the mortar portion of concrete will segregate and flow, to involve risk of it becoming impossible to place concrete of uniform quality, and therefore, the work must be done carefully following the provisions of Article 38 of this Recommended Practice.

Regarding Artificial Lightweight Aggregate Concrete It is said that the slump increase action of superplasticizer when using artificial lightweight aggregate will not be different from cases of using natural aggregates. Consequently, when placing artificial lightweight aggregate concrete as superplasticized concrete, it will suffice to carry out the work in accordance with the provisions of Chapter 3 to Chapter 10 of this Recommended Practice.

Regarding Offshore Concrete When placing offshore concrete as superplasticized concrete, the work may be done in accordance with the provisions of Chapter 3 to Chapter 10 of this Recommended Practice. However, since offshore concrete is placed and used at locations where actions of meteorological and marine phenomena are severe, special care must be exercised in carrying out the work.

Regarding Underwater Concrete When placing underwater concrete in the form of superplasticized concrete, the principle is to place by a method using a tremie or concrete pump or a method using a bottom-opening box or bottom-opening bag, and the slumps shown in Commentary Table 5 are to be standards.

Commentary Table 5 Standard Ranges of Slumps when Placing Underwater Concrete as Superplasticized Concrete

Placement method	Range of slump (cm)
Tremie, concrete pump	15- 21
Bottom-opening box, bag	13- 18

Regarding other matters, they are to be according to the provisions of Chapter 3 to Chapter 8 of this Recommended Practice. However, underwater concrete involves numerous matters specific to underwater concrete such as that the

concrete must be high in viscosity, that it is difficult to confirm the concrete placed, etc., and it is necessary for special care to be exercised regarding selection of materials and mix proportions, and otherwise, the work as a whole.

Regarding Concrete Factory Products In manufacturing concrete factory products the time from mixing until placement is extremely short compared with cases of general construction in the field. Consequently, superplasticized concrete is seldom used. However, because of advantages such as that vibrating operations can be performed in a short period of time and that noise during vibration can be reduced, there are cases when superplasticized concrete is used. In such cases also, placement can be done adapting the provisions of Chapter 3 to Chapter 10.

Recently, there have been cases of special types of mixers used for delayed addition of superplasticizer aiming to economize on the use of chemical admixtures and cements, and it is advisable to utilize the Recommended Practice in selection of mix proportions, etc.

CHAPTER 12 QUALITY CONTROL AND INSPECTION

Article 54 General

Materials for concrete, reinforcing steel, machinery and equipment, work operations, etc. shall be controlled to economically build concrete structures having the required qualities.

[Commentary]

In order to economically build a concrete structure conforming to its purpose of use, it is important for concrete materials, reinforcing steel, machinery and equipment, operations, etc., to be controlled.

Particularly, in case of a concrete structure, it is not a simple matter to re-do the work once concrete has been placed, and therefore, it is important to control the materials used, maintain machinery and equipment in good condition, carefully perform work in accordance with the principles given in this Recommended Practice concerning fabrication and assembly of reinforcing bars, batching, mixing, transporting, placing, curing, etc., conduct the various tests prescribed in Articles 55 and 56 according to the direction of the Engineer, and quickly take appropriate steps when it becomes questionable that the prescribed conditions can be satisfied.

Superplasticized concrete has a consistency that differs from the base concrete which is its basis, and therefore, as a rule, the abovementioned tests are to be performed on both base concrete and superplasticized concrete.

Article 55 Tests of Concrete

(1) Prior to start of work, tests of materials and tests for selecting mix proportions for concrete shall be performed, and the performances of machinery and equipment confirmed in accordance with the directions of the Engineer.

(2) The following tests shall be performed during the work as directed by the Engineer.

(a) Aggregate tests
(b) Slump tests

(c) Air content tests
(d) Unit weight tests of concrete
(e) Compressive strength tests of concrete
(f) Other tests

(3) In order to determine the appropriateness of curing, and the timing of form removal, or to confirm whether safe when loading at an early age, strength shall be tested using specimens cured as much as possible under the same conditions as the concrete in the field.

If as a result of these tests the strengths obtained are substantially lower than the strengths of specimens standard-cured, the method of curing concrete in the field shall be revised in accordance with the directions of the Engineer.

(4) Upon completion of the work, when necessary, nondestructive tests of concrete, and tests of concrete specimens cut out from the structure shall be performed as directed by the Engineer.

[Commentary]

Regarding (1) Before starting work, it is extremely important for economically making concrete of the required quality to carry out tests to determine whether or not materials are suitable, and tests for selecting mix proportions of concrete (trial mix tests). The timing of the tests, and the varieties and methods of testing will differ according to the type and scale of the project, construction period, etc., and it will be necessary to follow the directions of the Engineer concerning these matters. When testing materials in a large-scale project, it will be necessary for tests to be performed not only to ascertain the qualities, but also uniformities of materials. In case the qualities of materials to be used are known from past work or the results of other appropriate tests, the suitabilities of the materials and mix proportions of concrete may be determined based on those examples.

Regarding (2), Aggregate Tests See the commentary on Article 184 of the RC Specifications.

Regarding Slump Tests Slump tests are necessary for judging the workability of concrete at the jobsite, and in general, it is possible to judge whether or not uniform concrete has been made based on these tests.

Superplasticized concrete will have consistency different from that of base concrete to be the basis and slump tests must be performed on both base concrete and superplasticized concrete.

Regarding slump of base concrete, frequent tests are necessary at the beginning of placement until manufacture becomes stable, while subsequently, it is desirable for one test to be made for about every 50 m^3.

Regarding slump of superplasticized concrete, besides performing tests at about the same frequency as base concrete, it is to be confirmed by visual inspection whether workability after fluidification is appropriate.

Regarding Air Content Tests With air-entrained concrete, even when using the same materials and working with concrete of the same mix proportions, the air content can differ considerably if the gradation of aggregate or other factors should vary ever so slightly. This variation in air content will greatly affect the workability, strength, etc., of the concrete.

In this case, air content tests are to be carried out for both superplasticized concrete and base concrete, and especially regarding air content of superplasticized concrete, frequent checks are necessary similarly to slump tests, and it is desirable for one test to be made for about every 50 m^3.

Regarding Unit Weight Tests of Concrete See (2) of the commentary on Article 184 of the RC Specifications.

Regarding Compressive Strength Tests of Concrete Strength tests of concrete are necessary for ascertaining the quality of the concrete. There are various types of strength tests for concrete, and it is desirable for tests to be made of the kind of strength required most in accordance with the purpose of the concrete, although strengths other than compressive strength can be judged approximately by compressive strength.

In general, quality control of superplasticized concrete is stipulated to be carried out using the results of compressive strength tests of superplasticized concrete, but in a special case, compressive strength tests must be performed on base concrete also.

The compressive strength of a concrete will differ according to the configurations and dimensions of specimens, and the methods of loading, and it is normal for the strength to

be determined by the testing method given in JIS A 1108, "Method of Test for Compressive Strength of Concrete." Further, in a general case, a structure is designed based on compressive strength at the age of 28 days so that it is suitable for the quality of concrete to be judged by the compressive strength at 28 days, but in quality control it is important for results of tests to be quickly reflected in control of the work process, and it is desirable for control to be exercised employing a method by which test results can be obtained at an early stage, such as with compressive strength at early age or compressive strengths of specimens cured in warm water, according to the directions of the Engineer.

Regarding Other Tests See (2) of the commentary on Article 184 of the RC Specifications.

Regarding (3), (4) See (3) and (4) of the commentary on Article 184 of the RC Specifications.

Article 56 Testing Methods

Other than when directed by the Engineer, tests shall be performed by the methods prescribed in JIS.

[Commentary]

See the commentary on Article 186 of the RC Specifications.

Article 57 Report

The results of tests shall be reported to the Engineer without delay.

[Commentary]

See the commentary on Article 187 of the RC Specifications.

Article 58 Control of Concrete Based on Compressive Strength

(1) Control of concrete based on compressive strength, in a general case, shall be exercised using compressive strength at an early age. In such case, the specimen shall be collected in a manner to be representative of the concrete in the structure.

(2) The test value of compressive strength used in control of concrete, in a general case, shall be the average value of compressive strengths of not less than two specimens taken from the same batch.

(3) The timing and frequency of sampling for tests shall be as directed by the Engineer.

(4) It shall be desirable for a control chart to be employed when controlling the quality of concrete based on test values.

[Commentary]

See the commentary on Article 188 of the RC Specifications.

Article 59 Control of Concrete Based on Water-Cement Ratio

(1) Control of concrete based on water-cement ratio shall be exercised employing the water-cement ratio obtained on analysis of fresh concrete. The method of test shall be that approved by the Engineer.

(2) The test value of water-cement ratio used in control of concrete shall be the average value of water-cement ratios of not less than two samples taken from the same batch.

(3) The timing and frequency of sampling for tests shall be in accordance with the directions of the Engineer.

(4) It shall be desirable for a control chart to be employed when controlling the quality of concrete based on test values.

[Commentary]

See the commentary on Article 189 of the RC Specifications.

In the case of superplasticized concrete, it is said that the error in estimation of water-cement ratio is small when the hydrometer method is used for testing water-cement ratio.

Article 60 Quality Inspection of Concrete

(1) When checking the quality of concrete based on test values, all of the test values obtained and a part of consecutive test values shall be checked as a single set in accordance with the directions of the Engineer.

(2) In the event the water-cement ratio has been selected based on compressive strength, for checking the quality of concrete, if it is possible to estimate at a reasonable level of significance that the test values of compressive strength in a general case will not be less than $0.8\sigma_{ck}$ with a probability of P_a or more, and not less than σ_{ck} with a probability of P_b or more, it may be considered that the concrete possesses the required quality.

This check, in a general case, shall be based on compressive strength at the age of 28 days.

The timing and frequency of sampling for tests, and the number of specimens for obtaining test values shall be in accordance with the directions of the Engineer.

(3) In the event the water-cement ratio has been selected on the basis of durability and watertightness, for checking the quality of concrete, if the average water-cement ratio determined from test values is lower than the required

water-cement ratio, or the compressive strength is higher than that corresponding to the required water-cement ratio, it may be considered that the concrete possesses the required quality.

(4) In the event the quality of the concrete is not suitable as a result of inspection, modification of mix proportions, checking of performances of machinery and equipment, improvement of working methods and other appropriate measures shall be taken in accordance with the directions of the Engineer, whether the concrete placed in the structure is capable of fulfilling the role required of it shall be ascertained, and appropriate measures taken as necessary.

[Commentary]

See the commentary on Article 190 of the RC Specifications.

JSCE STANDARDS

QUALITY STANDARD FOR SUPERPLASTICIZERS FOR CONCRETE

1. Scope of Application

This Standard shall be applicable to superplasticizers to be added to concrete that has been mixed beforehand.

2. Meanings of Terms

The meanings of the principal terms used in this Standard shall be as follows:

(1) Superplasticizer: An admixture with its main purpose the increase of fluidity of concrete mixed beforehand through agitation upon its addition.

(2) Superplasticization: Adding of superplasticizer to a concrete mixed beforehand and agitating to increase fluidity.

(3) Superplasticized Concrete: A concrete with fluidity increased by agitation upon addition of superplasticizer to the concrete mixed beforehand.

(4) Base Concrete: A concrete prior to superplasticization mixed to manufacture superplasticized concrete.

3. Quality Requirements

A superplasticizer shall be tested in accordance with 4 and the resultant superplasticized concrete shall meet the requirements in Table 1.

Table 1

Item			Type of superplasticizer	
			Standard	Retarding
Test condition	Slump (cm)	Base concrete	8±1	
		Superplasticized concrete	18±1	
	Air (%)	Base concrete	4.5±0.5	
		Superplasticized concrete	4.5±0.5	
Difference in bleeding (cm^3/cm^2)			0.1 max.	0.2 max.
Difference in time of setting (min)		Initial	-30 to +90	+60 to +210
		Final	-30 to +90	+210 max.
Slump loss with time (15 min) (cm)			4.0 max.	4.0 max.
Air loss with time (15 min) (%)			1.0 max.	1.0 max.
Compressive strength ratio[1] (%)		Age 3 days	90 min.	90 min.
		Age 7 days	90 min.	90 min.
		Age 28 days	90 min.	90 min.
Length change ratio[1] (%)			120 max.	120 max.
Resistance to freezing and thawing[1] (relative dynamic modulus of elasticity ratio, %)			90 min.	90 min.

Note: 1) The values include allowance for normal variation in test results and signify that superplasticized concrete should possess qualities comparable to those of base concrete.

4. Testing

4.1 Method of Testing

The tests shall be performed making two batches each of base concrete and superplasticized concrete obtained by superplasticizing base concrete and comparing the qualities of the two kinds of concrete.

4.2 Materials Used in Testing

4.2.1 Cement[2]

Three brands of normal type portland cement, each of which is produced by different manufacturing companies and conforms to JIS R 5201 (Portland Cement), shall be used in equal proportions for mixing a concrete.

Note: 2) When the reference concrete of 8 cm slump prescribed in JIS A 6204 (Chemical Admixtures for Concrete) is made with the materials of 4.21 and 4.22, the air content of the concrete shall be 2.0 % or less. If the air content is more than 2.0 %, select different cement and/or aggregates.

4.2.2 Aggregates

Aggregates shall be clean, hard, and durable, free of harmful quantities of trash, dirt, organic impurities, chlorides, etc., with coarse aggregate being gravel or crushed stone, and fine aggregate sand, having the qualities given in Table 2.

Aggregates shall consist of large and small particles suitably mixed, with gradations in the ranges given in Table 3.

Table 2

Item / Kind of aggregate	Oven dry spec. grav.[3]	Absorption[3]	Solid vol. ratio for particle shape, judgment[4] (crushed stone)(%)	Clay lump content[5] (%)	Loss in washing test[6] (%)	Inorganic impurities[7]	Soundness[8] 5 times (%)	Chloride[9] (as Nacl) (%)
Coarse aggregate	2.5 min.	2.0 max.	57 min.	0.25 max.	1.0 max.	-	10 max.	-
Fine aggregate	2.5 min.	3.0 max.	-	1.0 max.	2.0 max.	not to be darker than reference	8 max.	0.02 max.

Note: 3) According to JIS A 1109 (Methods of Test for Specific Gravity and Absorption of Fine Aggregate) and JIS A 1110 (Methods of Test for Specific Gravity and Absorption of Coarse Aggregate)
4) According to provisions of 5.7 of JIS A 5005 (Crushed Stone for Concrete)
5) According to JIS A 1137 (Method of Test for Clay Contained in Aggregate)
6) According to JIS A 1103 (Method of Test for Amount of Material Passing Standard Sieve 74 μm in Aggregate)
7) According to JIS A 1105 (Method of Test for Organic Impurities in Fine Aggregate)
8) According to JIS A 1122 (Method of Test for Soundness of Aggregate by Use of Sodium Sulfate)
9) According to provisions of 4.5 of JIS A 5002 (Light Weight Aggregates for Structural Concrete). In this case, the quantity of sample is to be 1000 g.

Table 3

Kind of aggregate	Percentage of mass passing sieve (%) Nominal size of sieve[10] (mm)									
	25	20	15	10	5	2.5	1.2	0.6	0.3	0.15
Coarse aggregate	100	90- 100	55- 75	25- 45	0- 5	0- 2	-	-	-	-
Fine aggregate	-	-	-	-	100	85-100	60- 80	30- 50	15- 25	2- 10

Note: 10) These sieves are respectively the standard sieves 25.4 mm, 19.1 mm, 15.9 mm, 9.52 mm, 4760 μm, 2380 μm, 1190 μm, 590 μm, 297 μm and 149 μm stipulated in JIS Z 8801-1982 (Standard Sieves).

4.2.3 Water

Water used for mixing shall be potable.

4.2.4 Air-entraining agent

Air-entraining agents shall conform to JIS A 6204 (Chemical Admixtures for Concrete).

4.3 Mix Proportions of Base Concrete

4.3.1 Unit Cement Content

The unit cement content shall be 300 kg/m^3. However, when crushed stone is used as coarse aggregate, the cement content shall be increased by 20 kg/m^3.

The unit cement content calculated by 4.9.1 shall not differ from the above by more than 5 kg/m^3.

4.3.2 Unit Water Content

The unit water content shall be such that slump 15 minutes after completion of mixing will be 8±1 cm.

4.3.3 Sand-Aggregate Ratio

The sand-aggregate ratio shall be a value in the range of 40 to 50 percent which provides good workability after superplasticization.

4.3.4 Dosage of Air-entraining Agent

The dosage of air-entraining agent shall be selected for air content of 4.5±0.5 percent 15 minutes after completion of mixing.

4.4 Method of Making Concrete

The method of making concrete shall be according to JIS A 1138 (Method of Making Test Sample of Concrete in the Laboratory). The temperature in the laboratory shall be 20±3°C, and the volume of concrete per batch 15 ℓ larger than that required for tests.

4.5 Mixing

4.5.1 Mixer

The mixer used for mixing shall be tested according to JIS A 1119 (Method of Test for Variability of Constituents in Freshly Mixed Concrete), and be such that when mixed for 1.5 minutes with a forced-mixing type mixer, or 3 minutes with a tilting type mixer, the difference in unit mass of mortar in the concrete will be not more than 0.8 percent and the difference in unit coarse aggregate quantity in the concrete will be not more than 5 percent.

4.5.2 Method of Using Air-entraining Agent

The air-entraining agent shall be dissolved in mixing water and introduced into the mixer on mixing.

4.5.3 Mixing Quantity

The quantities of mixture per batch[11] of base concrete and superplasticized concrete shall be identical.

Note: 11) Approximately 100 ℓ of concrete shall be necessary as the quantity to be mixed per batch.

4.5.4 Mixing Time

Base concrete shall be mixed for 1.5 minutes with a forced-mixing type mixer or for 3 minutes with a tilting-type mixer after all materials have been introduced into the mixer.

4.5.5 Temperature of Concrete

The temperature of concrete shall be 20±3°C.

4.6 Superplasticization of Concrete

4.6.1 Dosage of Superplasticizer

The dosage of superplasticizer shall be determined referring to the quantity specified by the manufacturer as a guide to provide a slump of 18±1 cm immediately after superplasticization.

4.6.2 Air Content of Superplasticized Concrete

The air content immediately after superplasticization shall be 4.5±0.5 percent.

4.6.3 Method of Superplasticization

At 15 minutes after completing the mixing of base concrete[12], the predetermined amount of superplasticizer in undiluted form shall be sprinkled evenly on the surface of the concrete in the mixer, and the base concrete shall be superplasticized agitating for not more than 30 seconds with a forced-mixing type mixer or not more than 60 seconds with a tilting-type mixer.

Note: 12) Up to this time the sample shall be left standing in the mixer with the mouth of the mixer covered with a moist cloth.

4.7 Sample

In the case of base concrete, its mixing operation shall be resumed at 15 minutes[12] after the completion of the initial mixing for additional 15 seconds in case of a forced-mixing type mixer or 30 seconds in case of a tilting-type mixer, and, then, the entire volume of the batch shall be discharged onto a mixing pan. In the case of superplasticized concrete, the discharging of mixture shall be made immediately after superplasticization. The samples for the tests shall be taken immediately after the discharged concrete is made uniform by shoveling.

Approximately 30 ℓ of concrete mixture shall be left on the mixing pan for the tests of slump and air content to be measured at 15 minutes after superplasticization[13]. The mixture shall be made uniform by shoveling immediately before the sampling is made for the tests.

Note: 13) The samples for these tests shall be representative of the mixture and kept separately on the mixing pan with some proper means such as a cover of vinyl sheet provided to minimize the moisture evaporation from the sample.

4.8 Tests of Concrete

4.8.1 Slump

Slump tests shall be conducted according to JIS A 1101 (Method of Slump Test for Concrete). The tests shall be performed with samples prepared in accordance with 4.7 for individual batches of concrete, and the averages of the respective results shall be taken to be the slumps of that variety of concrete at the prescribed times.

4.8.2 Air Content

Tests of air content shall be performed according to JIS A 1118 (Method of Test for Air Content of Fresh Concrete by Volumetric Method) or JIS A 1128 [Method of Test for Air Content of Fresh Concrete by the Pressure Method (Air Chamber Pressure Method)].

The tests shall be performed with samples prepared in accordand with 4.7 for individual batches of concrete and the averages of the respective results shall be taken to be the air contents of that variety of concrete at the prescribed time.

4.8.3 Unit Mass

Tests of unit mass shall be performed as a rule according to JIS A 1116 [Method of Test for Unit Weight and Air Content (Gravimetric) of Fresh Concrete][14].

The tests shall be performed twice on concrete of each batch, and the average value of the results shall be taken as the unit mass of that batch.

Note: 14) In case of testing air content by the air chamber pressure method, the unit mass may be determined from the sample filled in the vessel for the air content test.

4.8.4 Bleeding

Tests of bleeding shall be performed according to JIS A 1123 (Method of Test for Bleeding of Concrete). The tests shall be performed for each batch of concrete, and the average value of the results shall be taken as the bleeding of that variety of concrete.

4.8.5 Time of Setting

Tests of time of setting shall be performed according to Appendix 1 (Method of Test for Time of Setting of Concrete) of JIS A 6204. The tests shall be performed on each batch of concrete, and the average value of the results shall be taken as the time of setting of that variety of concrete.

4.8.6 Compressive Strength

Compressive strengths tests shall be made at the ages of 3, 7, and 28 days according to JIS A 1108 (Method

of Test for Compressive Strength of Concrete). Specimens shall be made according to JIS A 1132 (Method of Making and Curing Concrete Specimens), and shall be cured in moist condition at a temperature of 20±3°C until strength tests are conducted. The number of specimens shall be four for each age (two from each batch), and the average values of the results shall be taken as the compressive strengths for that variety of concrete.

4.8.7 Length Change

Tests for length change shall be made according to JIS A 1129 (Method of Test for Length Change of Mortar and Concrete). Specimens shall be stripped approximately 24 hours after casting, and shall be cured until the age of 7 days in a moist condition at temperature of 20±3°C. Measurement of the initial length shall be performed at the age of 7 days, immediately after withdrawing the specimen from the moist condition. After measurement of the initial length the specimen shall be kept in a room at temperature of 20±3°C and humidity of 60±5 percent to measure length changes. The number of specimens shall be three for each variety of concrete, and the average value of results at 3 months of storage shall be taken to be the length change ratio of that variety of concrete.

4.8.8 Resistance to Freezing and Thawing

Tests for resistance to freezing and thawing shall be according to Appendix 2 (Method of Test for Freezing and Thawing of Concrete) of JIS A 6204, and the relative dynamic modulus of elasticity shall be measured. The number of specimens shall be three for each variety of concrete and the average value of the results at 200 cycles of freezing and thawing shall be taken to be the relative dynamic modulus of elasticity of that variety of concrete.

4.9 Calculation of Results

4.9.1 Unit Cement Content

Unit cement content shall be calculated from the unit mass of the concrete determined according to 4.8.3 using the equation below, and shall be expressed as an integer rounding off the first decimal place according to JIS Z 8401 (Rules for Rounding Off of Numerical Values).

Unit cement content shall be calculated for the concrete of each batch, and the average value of the results shall be taken to be the unit cement content of that variety of concrete.

$$\text{Unit Cement Content } (kg/m^3) = W_c \times \frac{W}{W_b}$$

where, W_c: quantity of cement per batch (kg)
W: unit mass of concrete determined according to 4.8.3 (kg/m^3)
W_b: total mass of concrete materials per batch (kg)

4.9.2 Difference in Bleeding

The difference in bleeding shall be calculated from the amounts of bleeding determined according to 4.8.4 using the equation below.

$$\text{Difference in Bleeding } (cm^3/cm^2) = B_f - B_b$$

where, B_f: bleeding of superplasticized concrete (cm^3/cm^2)
B_b: bleeding of base concrete (cm^3/cm^2)

4.9.3 Difference in Time of Setting

The difference in time of setting of concrete shall be calculated from the times of initial and final sets determined according to 4.8.5 using the equation below, and shall be expressed with integers.

$$\text{Difference in Time of Setting (min)} = T_f - T_b$$

where, T_f: initial or final time of setting of superplasticized concrete (cm^3/cm^2)
T_b: initial or final time of setting of base concrete (cm^3/cm^2)

4.9.4 Slump Loss with Time

The slump loss with time shall be calculated from the slumps determined according to 4.8.1 using the equation below.

$$\text{Slump Loss with Time (cm)} = H_f - H_e$$

where, H_f: slump of concrete immediately after superplasticization (cm)
H_e: slump of concrete 15 minutes after superplasticization (cm)

4.9.5 Air Loss with Time

The air loss with time shall be calculated from the air contents determined according to 4.8.2 using the equation below.

$$\text{Air Loss with Time } (\%) = E_f - E_e$$

where, E_f: air content of concrete immediately after superplasticization (%)
E_e: air content of concrete 15 minutes after superplasticization (%)

4.9.6 Compressive Strength Ratio

The compressive strength ratio shall be calculated from the compressive strengths determined according to 4.8.6 using the equation below, and shall be expressed as an integer rounding off the first decimal place according to JIS Z 8401 (Rules for Rounding Off of Numerical Values).

$$\text{Compressive Strength Ratio } (\%) = \frac{S_f}{S_b} \times 100$$

where, S_f: compressive strength of superplasticized concrete (kgf/cm^2)
S_b: compressive strength of base concrete (kgf/cm^2)

4.9.7 Length Change Ratio

The length change ratio shall be calculated from the length changes determined according to 4.8.7 using the equation below, and shall be expressed as an integer rounding off the first decimal place according to JIS Z 8401.

$$\text{Length Change Ratio } (\%) = \frac{L_t}{L_b} \times 100$$

where, L_t: length change of superplasticized concrete (%)
L_b: length change of base concrete (%)

4.9.8 Relative Dynamic Modulus of Elasticity Ratio

The relative dynamic modulus of elasticity ratio shall be calculated from the relative dynamic moduli of elasticity determined according to 4.8.8 using the equation below, and shall be expressed as an integer rounding off the first decimal place according to JIS Z 8401.

Relative Dynamic Modulus of Elasticity Ratio (%)

$$= \frac{M_f}{M_b} \times 100$$

where, M_f: relative dynamic modulus of elasticity of superplasticized concrete (%)

M_b: relative dynamic modulus of elasticity of base concrete (%)