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GUIDELINES FOR CONSTRUCTION USING FERRONICKEL SLAG FINE AGGREGATE CONCRETE

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ABSTRACT

Guidelines for construction using ferronickel slag (FNS)fine aggregate concrete, which have been drafted for the first time in Japan, are presented. Ferronickel slag(FNS)he aggregate is a by-product of the manufacture of ferronickel used in stainless steel, and is produced by cooling the molten slag with water or air and adjusting its grading for use in concrete to conform to Japanese Industrial Standards(JIS)A5011(Slag Aggregate for Concrete).In these guidelines, the general requirements for the construction of plain and reinforced concrete structures using FNS fine aggregates or FNS-mixed fine aggregates produced by mixing FNS fine aggregates and natural aggregates, are provided.

Keywords: guidelines, ferronickel slag(FNS)fine aggregates, ferronickel slag(FNS)-mixed fine aggregates, mixture ratio of FNS fine aggregates (FNS mixture ratio), ferronickel slag (FNS) fine aggregate concrete, Japanese Industrial Standards (JIS) A 5011 (Slag Aggregate For Concrete)

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of concrete.

PREFACE

Ferronickel slag is a by-product of the manufactureofferronicke1,a material used in stainless steel and nickel alloys. In the past, this slag was used mostly as a material for fertilizer and in such civil engineering projects as land reclamation, but in order to make more efficient use of fine and hard slag material, ferronickel manufacturers have been using ferronickel slag for concrete structures on an experimental basis since the 1980s. Studies on the use of ferronickel slag as concrete aggregate have been continuously carried out by a group led by the Japan Mining Industry Association. Data from various kinds of experiments and trial construction of concrete structures have been accumulated, establishing the necessary conditions for standardization. On the basis of these findings, standards for blast-furnace slag coarse aggregates and blast-furnace slag he aggregates were amended in October 1992to include standards for ferronickel slag fine aggregates as JIS A 5011 (Slag Aggregate for Concrete).

Under commission from the Japan Mining Industry Association, the Japan Society of Civil Engineers (JSCE) carried out a study on the efficient use of ferronickel slag as concrete fine aggregate for three years, beginning in 1983. However, in those days, actual use of ferronickel slag as concrete aggregate was very limited, and the necessity of studies on long-term stability was pointed out, leading to postponement of the practical use of ferronickel slag in construction. Now, in response to the standardization of ferronickel slag fine aggregates in JIS, JSCE Committee on Concrete has set up the Committee on Ferronickel Slag Aggregate under commission from the Japan Mining Industry Association. The Committee is in charge of preparing guidelines for construction using ferronickel slag

fine aggregate concrete. After conducting a broad investigation over the course of about a year and a half, the Committee has issued guidelines for the preparation of concrete using ferronickel slag fine aggregates or a mixture of ferronickel slag fine aggregates and natural fine aggregates, under the title "Guidelines for Construction Using Ferronickel Slag Fine Aggregate Concrete."

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GUIDELINES FOR CONSTRUCTION USING FERRONICKEL SLAG FINE AGGREGATE CONCRETE

CHAPTER I GENERAL

1.1 Scope

(1) These guidelines provide the general requirements for the construction of plain and reinforced concrete structures using ferronickel slag(FNS)fine aggregates or fine aggregates produced by mixing FNS fine aggregates and natural fine aggregates.
(2) Items that are not stipulated in these guidelines shall confirm to the Standard Specification for Design and Construction of Concrete Structures published by the Japan Society of Civil Engineers.

[Comments]
(1) Ferronickel slag(FNS)is aggregate produced by cooling the molten slag which is a by-product of ferronickel smelted from nickel ore in an electric furnace or rotary kiln, and the particle size of which is adjusted. Currently, fine aggregates alone are produced as aggregates for concrete.
These guidelines provide the standards for ferronickel slag fine aggregates conforming to Japan Industrial Standard(JIS)A5011(Slag Aggregate for Concrete)that are used in concrete for structures. Standards are shown for two cases of concrete preparation: one in which FNS fine aggregates are used as the entire fine aggregate component and another in which they are mixed with natural fine aggregates. In general, use of FNS fine aggregates is effective when they are mixed with natural fine aggregates such as pits and sea sands which require particle size distribution adjustment and reduction of chloride content.

The mixing ratio of FNS fine aggregates and natural fine aggregates varies depending on the particle size distribution of natural sand or the chloride content of sea sand. In these guidelines, the standard mixing ratio of FNS fine aggregates is determined to be up to50%,takingintoconsiderationthequality of fresh and hardened concrete.

(2) In the preparation of concrete using FNS fine aggregates, it is of course necessary to confirm the quality of the cement, water, coarse aggregates and admixtures, as well as natural fine aggregates, to be mixed, as in the production of conventional concrete. In the design calculation, consideration should
be given to the fact that the mass per unit volume of concrete using FNS fine aggregates is larger than that of conventional concrete.

1.2 Definitions

The following terms are defined for general use in these guidelines.

<u>Ferronickel slag fine aggregates</u>: Fine aggregates made by cooling the molten slag produced as by – product of ferronickel with water or air, and then adjusting its grading for use in concrete.

<u>Ferronickel slag-mixed fine aggregates</u>: Mixed fine aggregates that are made by mixing FNS fine Aggregates and natural fine aggregates in a designated ratio.

<u>Mixture ratio of FNS fine aggregates(FNS mixture ratio)</u>: Absolute volume ratio of FNS fine

aggregate
content to total the aggregates in ferronickel slag mixed (FNS-mixed)fine aggregates, expressed as a Percentage.

Ferronickel slag fine aggregate concrete: Concrete prepared by utilizing FNS fine aggregates or FNS-mixed fine aggregates as fine aggregates.

Conventional concrete: Concrete using natural and/or crushed aggregates alone for all the fine aggregates and coarse aggregates.

[Comments]

Ferronickel slag fine aggregates: Ferronickel is produced by either of two major methods: by electric furnace or rotary kiln. Ferronickel slags, the by-product of ferronickel, are classified into three types: slow-cooling granulation, wind granulation and water granulation slags, depending on the cooling method.

In electric furnace slow-cooling granulation, molten slags are discharged into a slow-cooling yard at a thickness of 1.5m, and cooled in air. Electric furnace wind granulation slags are obtained by rapidly cooling the molten slag by air flow; they are nearly spherical. Electric furnace water granulation slags are obtained by rapidly cooling molten slag with water; they are glassy and comprised of particles within a narrow range of size distribution that do not contain fine particles. In kiln water granulation slags, the half-molten mixture of ferronickel and slags discharged from the kiln is rapidly cooled with water and granulated to grain Size, the cooled mixture is then processed with a crusher, and ferronicke1
is separated from slags by the beneficiation process, making use of specific gravity and magnetic force.

With kiln water granulation, only several percent of the particles are over1.2mminsize, and since fine Grains are removed by hydraulic classifier, the amount of slag that is lost during a test for the amount of material in aggregates passing through a standard 75 μ m Sieve(washing test) is small.

Ferronickel slang-mixed fine aggregates: Since the distribution of particle size of FNS fine aggregates and natural fine aggregates is uneven, and their specific gravities also differ greatly, in these guidelines, particle size distribution after mixing of these two aggregates is expressed by using absolute volume.

Mixture ratio of ferronickel slang aggregates(FNS mixture ratio): When FNS fine aggregates are used For adjustment of particle size distribution of natural fine aggregates, it is appropriate to use absolute volume to determine the mixture ratio of the two fine aggregates, due to the unevenness of the particle size distribution in those aggregates and the large difference in specific gravities.

CHAPTER 2 OUALITY OF FERBRONIKEL SLAG FINE AGGREGATE CONCRETE

2.1 General

(1) Ferronickel slag fine aggregate concrete shall provide the required strength, durability, watertight-ness, and performance to protect reinforcing steels, with minimal variation in quality. It shall also provide suitable workability during concreting work.

(2) Standard FNS fine aggregate concrete shall be air-entrained(AE)concrete which contains an appropriate amount of air.

[Comments]

(1)and (.2) Even in the case of FNS fine aggregate concrete whose content of FNS fine aggregates (FNS mixture ratio) is less than 50%, AE concrete should basically be used in order to improve workability and durability. Ferronickel slag fine aggregate concrete with appropriate air content offer quality almost equivalent to that of conventional concretes.

When the FNS mixture ratio exceeds50%, it is very important to minimize the water-cement ratio of concrete. The unit water content needs to be reduced using air-entraining(AE)and water-reducing agent or air-entraining and high-range water-reducing agent to make AE concrete with appropriate air content. This is very important from the standpoint of improving workability and durability (freeze-thaw resistance).

Strength: The strength of FNS fine aggregate concrete varies depending on the kind of FNS fine aggregates, FNS mixture ratio, and the kind of cement used. However, FNS fine aggregate concrete with FNS mixture ratio of less than 50%offers almost the same strength as conventional concrete.

Durability: It has been pointed out that the freeze-thaw resistance tends to degrade when bleeding of concrete is excessive due to the FNS mixture ratio and other factors of concrete preparation, which is

also the case with conventional concrete. However, in the case of AE concrete with FNS mixture ratio of less than 50%,and with appropriate water-cement ratio and air content, FNS fine aggregate concrete offers almost the same level of freeze-thaw resistance as conventional concrete.

Watertighness: In order to obtain good watertightness with FNS fine aggregate concrete, it is important to suppress the bleeding. The water-cement ratio needs to be maintained below 55%,as in the case of conventiona1concrete. Use of an appropriate admixture to minimize the unit water content is also

important. Appropriately consolidated FNS fine aggregate concretes with low slump offer watertight-ness equivalent to that of natural aggregate concrete.

Mass per unit volume: Specific gravity of FNS fine aggregates is 1.05-1.25timesthat of natural fine aggregates. Therefore, mass per unit volume of FNS fine aggregate concrete is 3-6% larger than that of natural aggregate concrete, although it varies depending on the mix proportions of concrete and the FNS mixture ratio in fine aggregates, etc.

Workability: Air-entrained FNS fine aggregate concrete offers workability equivalent to that of conventional concrete when the FNS mixture ratio is 50% or less.

2.2 Strength

(1) In general, the strength of FNS fine aggregate concrete shall be based on test data at the age of 28 days.

(2) Compressive strength test, tensile strength test, and flexural strength test shall be performed in accordance with JIS A 1108,JIS A 1113,JIS A 1106,respectively. The specimens for these tests shall be prepared in accordance with JIS A 1132.

2.3 Limit of Chloride Content in Concrete

(1) The chloride content in a FNS fine aggregate concrete shall be expressed by the total amount of chloride ions contained in fresh concrete.
(2) In principle, the total amount of chloride ions in the FNS fine aggregate concrete shall be less than 0.30 kg/m^3 at mixing.

[Comments]
(1)and (2) FNS fine aggregates which conform to the requirements of JIS A5011(Slag Aggregate for Concrete) contain only negligible amounts of chloride ions. Therefore, in the case of using sea sands
as fine aggregates, the utilization of FNS fine aggregates is effective in reducing the total amount of chloride ions.

CHAPTER 3 FNS FINE AGGREGATE AND FNS-MIXED FINE AGGREGATES

3.1 General Requirements

FNS fine aggregates, natural fine aggregates and FNS-mixed fine aggregates shall provide good cleanliness, hardness, durability, and appropriate grading, and shall not contain harmful levels of deleterious substances which lower the quality of concrete and corrode the reinforcing steel. Quality of FNS fine aggregates shall be stable.

3.2 FNS Fine Aggregates

3.2.1 General

FNS fine aggregates shall conform to JIS A 5011.

[Comments]
In JIS A 5011(Slag Aggregate for Concrete), FNS fine aggregates are classified into four types shown in Table 3.1in Comments. Each type is expressed by a symbol such as FNS 2.5. The properties of these
FNS fine aggregatesarestipulatedinTable3.2 in Comments. Specific gravity in oven dry and mass per unit volume of the FNS fine aggregates tend to be larger than those of natural fine aggregates.

Commentary Table 3.1 in JIS A5011 Classification of FNS fine aggregates by particlesize.

Classification	Rangeof size (mm)	Symbol
5 mm FNS fine aggregate	5.0 or smaller	FNS 5
2.5 mm FNS fine aggregate	2.5 or smaller	FNS 2.5
1.2 mm FNS fine aggregate	1.2 or smaller	FNS 1.2
5.0-0.3mmFNS fine aggregate	5.0-0.3	FNS 5-0.3

Commentary Table 3.2 in JIS A5011 Quality of FNS fine aggregates.

	Item	Specified value
Chemical Composition	Calcium oxide (asCaO)%	15.0 or less
	Total sulfur(as S)%	0.5 or less
	Total iron (as FeO)%	13.0 or less
	Magnesium oxide (as MgO)%	40. 0 or less
	Metalhc iron (as Fe) %	1.0 or less
Physical properties	Specific gravity in oven dry	2 .7 or larger
	Water absorption%	3.0 or less
	Mass per unit volumekg/1	1.50 or larger
	Alkali-silica reactivity	Harmless

3.3.2 Grading

(1) FNS fine aggregates shall be classified according to the range of size shown in Table3.1. Sieve analysis of FNS fine aggregates shall be carried out in accordance with JIS A 1102.

Table 3.1 Range of size distribution of FNS fine aggregates.

Type \ Nominal size of sieve(mm)	Mass of particles passing though sieves (%)						
	10	5	2.5	1.2	0.6	0.3	0.15
5mm FNS fine aggregate	100	90～100	80～100	50～90	25～65	10～35	2～15
2.5mm FNS fine aggregate	100	95～100	85～100	60～95	30～70	10～45	2～20
1.2mm FNS fine aggregate	-	100	95～100	80～100	35～80	15～50	2～25
5-0.3mm FNS fine aggregate	100	95～100	45～100	10～70	0～40	0～15	0～10

(2) The fineness modulus of FNS fine aggregates shall not vary bymorethan0.20 from that used when the concrete mix proportions were determined.

[Comments]

5mm FNS fine aggregates and 2.5 mm FNS fine aggregates can be used as aggregates for concrete by themselves.

3.2.3 Limit on loss in the test for amount of material in aggregates passing through standard 75 μm sieve

The limit on material loss in the test of the amount of FNS fine aggregate passing through a standard 75 μm sieve (washing test) shall be 7.0% in terms of mass percentage. The washing test shall be carried out in accordance with JISA 1103.

[Comments]

The amount of material lost in the washing test varies significantly depending on the manufacturing method used for FNS. It is small when the FNS is produced by water cooling methods, such as electric furnace water granulation and kiln water granulation, and relatively large when the FNS is produced using electric furnace slow-cooling granulation.

In order to suppress the bleeding, a mixture of an appropriate amount of fine particles is desirable. Conversely, however, an excessive fine particle content leads to the reduction of flowability, and as a result an increased amount of water is required to obtain the appropriate slump. For these reasons, the limit on loss of materials in the washing test is set at 7.0%.

3.3 Ferronickel Slag-Mixed Fine Aggregates

3.3.1 General

(1) FNS fine aggregates that are used for ferronickel slag-mixed fine aggregates shall conform to the requirements in Item 3.2.

(2) Natural fine aggregates that are used for ferronickel slag-mixed fine aggregates shall conform to the requirements described in the Standard Specification for Design and Construction of Concrete Structures (Compilation for Construction),except for grading and chloride content.

(3) Ferronickel slag-mixed fine aggregates shall be uniformly mixed and satisfy properties such as durability and limits on deleterious substance content described in the Standard Specification for Design and Construction of Concrete Structures (Compilation for Construction). The particle size distribution shall conform to the requirements in Item3.3.2.

[Comments]

(1) FNS fine aggregates which conform to the requirements in JIS A 5011 (Slag Aggregate for Concrete) are of good and uniform quality, containing only negligible amounts of dust and dirt, mud, organic impurities, and chloride. Hence, use of FNS fine aggregates is effective for the adjustment of particle size distribution of natural fine aggregates and the reduction of chloride content of sea sands.

(2) In these guidelines, the principal aims of mixing two kinds of aggregates are the reduction of chloride content and adjustment of particle size distribution, which result in marked improvement in the quality of fine aggregates. In the preparation of ferronickel slag-mixed fine aggregates, great care must of course be taken to ensure the quality of the natural fine aggregates that are mixed with FNS fine aggregates.

(3) Quality of the ferronickel slag-mixed fine aggregates can be ensured by evaluating that of FNS fine aggregates and natural fine aggregates prior to mixing.

When preparing ferronickel slag-mixed fine aggregates with the aim of adjusting the particle size distribution, the mixture ratio of FNS shall be determined on the basis of the results of sieve analysis of eachaggregatesothattheparticlesizedistributionofthemixtureiswithintherangeregulatedin Item

3.3.2. When ferronickel slag-mixed fine aggregates are prepared with the aim of reducing chloride content, the mixture ratio of FNS fine aggregates and sea sand shall be determined so that the chloride content of the mixture becomes less than 0.02 % of absolute dry mass in terms of the content of chloride
ions.

Grading: Refer to Comments in Item 3.3.2

Durability: FNS fine aggregates conforming to the requirements stipulated in JIS A 5011 (Slag Aggregate for Concrete) have been determined to be harmless with respect to alkali-silica reaction. However, in the case where natural fine aggregates which are proved to be harmful are used as the Ferronickel slag-mixed fine aggregates, deleterious expansion might occur in the resulting concrete. Preventive measures against the alkali-silica aggregate reaction in such concrete have not been studied sufficiently. Therefore, the use of natural fine aggregates that have been judged to be harmless is recommended until sufficient data are obtained and safety is ensured.

3.3.2 Grading of ferronickel slag-mixed fine aggregates

(1) Grading of ferronickel slag-mixed fine aggregates shall conform to standards shown in Table 3.3

Table 3.3 Standard grading of FNS slag-mixed fine aggregates.

Nominal size of sieve(mm)	Volime percent passing through sieve (%)	Nominal size of sieve (mm)	Volime percent passing through sieve (%)
10	100	0.6	25-65
5	90-100	0.3	10-35
2.5	80-100	0.15	2-10
1.2	50-90		

Note: 1) When more than 50% of material passing through 0.15 mm sieve is FNS fine aggregates, this range may be 2-15%.

(2) Mix proportions of concrete shall be changed when the fineness modulus of ferronickel slag-mixed fine aggregates varies by more than 0.20 from that used at the time of determining the mix proportions.

[Comments]

(1) In Table3.3,gradingis shown in volume percent. This is because the particle size distribution of mixed fine aggregates which contain aggregates with different specific gravities must in principle be expressed in terms of absolute volume.

The larger the difference of specific gravities and the particle size distribution between the FNS fine Aggregates and natural fine aggregates used, the larger the difference in the particle size distributions of ferronickel slag-mixed fine aggregates between that obtained in terms of absolute volume and that obtained in terms of mass. In particular, the difference becomes large with the sieve size where the difference in the particle size distribution of the two types of fine aggregates used is the largest. Generally, when FNS fine aggregates (specific gravity in oven dry: 2.7-3.2) and natural fine

Aggregates (specific gravity in oven dry:2.5-2.6) are mixed, the percent passing through each sieve varies by a maximum of 3%, depending on whether the size distribution is obtained in terms of mass or absolute volume. Difference in terms of fineness modulus might be more than 0.1.

3.4 Storage and Handling

3.4.1 General

(1) FNS fine aggregates, natural fine aggregates and ferronickel slag-mixed fine aggregates of different types and with differentgradingshallbestoredseparatelywithpartitionsbetweenthem.
(2) Receiving, storage and handling of FNS fine aggregates and ferronickel slag-mixed fine aggregates shall be carried out with great care so that they are not contaminated with dirt or mixed with foreign matter. Also, segregation of large particles from small ones shall be prevented.
(3) Storage facilities of FNS fine aggregates and ferronickel slag-mixed fine aggregates shall be of the appropriate size in terms of storage capacity, and provided with appropriate drainage, so that the surface water content of fine aggregates shall be maintained at a certain level.

3.4.2 Ferronickel slag-mixed fine aggregates

In the preparation of the ferronickel slag-mixed fine aggregates, FNS fine aggregates and natural fine aggregates shall be mixed using an appropriate method so that the particle size distribution becomes uniform.

CHAPTER 4 MIX PROPORTIONS

4.1 General

Mix proportions of FNS fine aggregate concretes shall be determined so as to minimize the unit water content within the range where the required strength, durability, watertightness and workability can be provided.

4.2 Water-Cement Ratio

(1) When the water-cement ratio is determined on the basis of the compressive strength of concrete, it shall be determined according to the Standard Specification for Design and Construction of Concrete Structures (Compilation for Construction).
(2) When the water-cement ratio of concrete containing less than 50% ferronickel slag fine aggregates is determined on the basis of the freeze-thaw resistance, it shall be less than those shown in Table 4.1.

Table 4.1 Maximum water-cement ratio of AE concrete when determining water-cement ratio on the basis of freeze-thaw resistance of concrete.

Exposure Condition of structure \ Cross section \ Weather condition	Severe weathering or frequency cycles or freezing and thawing		Moderate weathering or infrequency frequency freezing	
	Thin	Ordinary	Thin	Ordinary
(1)Portions continuously or freqendy saturated with water	55	60	55	65
(2)Portions exposed to ordinary conditions and excluded from (1)	60	65	60	65

Note: 1) Structures such as waterways, water tanks, bridge abutments, retaining walls and tunnel Linings which are located close to water surfaces, and portions of these structures that are frequently saturated with water, as well as such portions of structures as girders and deck slabs which are located at a distance from the water surface but can often be saturated with water due to melting of snow, water now and water splashing.

2) Portions of structures whose cross-sectional thickness is not more than about 20 cm.

(3) When the water-cement ratio of concrete with a FNS mixture ratio higher than 50% is determined on the basis of the freeze-thaw resistance, it shall in principle be determined through testing.

(4) When the water-cement ratio is determined on the basis of the water tightness of concrete, it shall be determined according to the Standard Specification for Design and Construction of Concrete Structures (Compilation for Construction).

[Comments]

(2) The freeze-thaw resistance of FNS fine aggregate concrete tends to degrade as the water-cement ratio becomes larger, as in the case of conventional concrete. It has been verified by previous tests that freeze-thaw FNS resistance equivalent to that obtained with natural fine aggregate concrete can be obtained if the FNS mixture ratio is less than 50% and water-cement ratio and air content are appropriately selected.

(3) Freeze-thaw resistance of FNS fine aggregate concrete tends to degrade as the FNS mixture ratio increases beyond 50%. It is important to reduce the unit water content as much as possible by using air entraining and water reducing admixture or high-performance AE water reducing admixture.

4.3 Slump and Sand Aggregate Ratio

(1) The slump of FNS fine aggregate concrete shall be made as small as possible within the range suitable for concreting work.

(2) Sand aggregate ratio shall be determined so as to minimize the unit water content within the range which provides the required workability.

[Comments]

According to the results obtained in the previous experiments, the water content of concrete using electric furnace wind granulation slag aggregate can be almost the same as or rather smaller than that of the concrete obtained using river sands since the raw particles originating from electric wind granulation process are of spherical shape. Conversely, when electric furnace water granulation and kiln water granulation are mixed, the unit water content of the concrete can be almost the same as or slightly larger than that obtained using river sands.

4.4 Air Content of AE Concrete

(1) Standard air content of FNS fine aggregate concrete shall be 4-7%, depending on the maximum size of coarse aggregates and other factors.
(2) Air content tests of AE concrete shall be conducted in accordance with JISA 1116,JISA 1118 and JISA 1128.

4.5 Expression of Mix Proportions

(1) Mix proportions of concrete shall be indicated using the form shown in Table 4.2.

Table 4.2 Form for expressing mix proportions.

Max,size of coarse aggregate (mm)	Range of slump (cm)	Range of air content (%)	Water-cement ratio W/C (%)	Sand aggregate ratio s/a (%)	Unit content (kg/m^3)							
					Water W	Ce-ment C	Cementi-tious admix-ture	Fine aggregate S		Coarse aggregate G		Chemical admix-ture
								Natu-ral	FNS	mm mm	mm mm	
								(%)				

Note:1) When admixtures possessing pozzolanic reaction or latent hydraulicity are used, water-cement ratio is to be the water/(cement+ admixture)ratio.
2) When using ferronickel slag-mixed fine aggregates, mix proportions of FNS fine aggregates and natural fine aggregates shall be indicated separately in the upper column of the table above, or unit content of ferronickel slag-mixed fine aggregates and FNS mixture ratio in ( ) shall be indicated in the lower layer of the column.
3) Amount of undiluted and undissolved chemical admixtures used shall be indicated in m1/ m^3 or g/m^3.

(2) In the specified mixes, fine aggregates shall be defined as those entirely passing through a 5mm sieve and coarse aggregates as those retained as a whole on a 5mmsieve. Both aggregates shall be in a saturated surface-dry state.
(3) When converting specified mixes into job mixes, the following points shall be taken into account: the moisture content of aggregates, the quantity of fine aggregates retained on a 5 mm sieve, the quantity of coarse aggregates passing through the 5 mm sieve, and the quantity of water used to dilute chemical admixtures.

CHAPTER 5 MIXING AND CONVEYING

5.1 Mixing

The proper order for charging materials into a mixer and the mixing time shall be appropriately determined in advance.

5.2 Conveying

Concrete shall be conveyed in such a manner as to ensure the least possible segregation of materials and least change concrete properties.

CHAPTER 6 READY-MIXED CONCRETE

6.1 General

As a rule, the ready-mixed concrete used shall conform to JIS A 5308.

CHAPTER 7 PLACING AND CURING

7.1 Placing and Consolidation

(1) Placing of FNS fine aggregate concrete shall be performed in such a manner as to ensure the least possible segregation of materials.
(2) FNS fine aggregate concrete shall be sufficiently consolidated immediately after placement. As a rule, internal vibrators shall be used for consolidation.

[Comments]
(1)and (2) When FNS fine aggregates are used as the entire fine aggregate component, or concrete with large FNS mixture ratio is used, or placement is carried out in cold weather, caution shall be taken
to minimize the bleeding. Excessive vibration applied to the concrete at the time of consolidation may increase bleeding and promote aggregate segregation. Therefore it is important to determine the proper consolidating time.
When concrete is conveyed over a long distance using a pump system and a large pressure load is expected to be imposed, it is important to select the type of concrete pump and piping system in advance.
The equivalent horizontal distance in conveying using a pump system is the same as that of conventional concrete in the case of horizontal conveying. However, in the case of vertical pumping, a vertical rise of 1m is roughly equivalent to 5 m of horizontal distance compared to about 4 m for conventional concrete, according to the experimental results.

7.2 Curing

FNS fine aggregate concrete shall be sufficiently cured to ensure the required quality in terms of strength, durability, and watertightness. After placement, proper temperature and humidity for the hydration of cement must be maintained for a certain period to protect concrete from harmful effects.

CHAPTER 8 OUALITY CONTROL INSPECTION

8.1 Ouality Control and Inspection

Quality control and inspection of FNS fine aggregate concrete shall be performed in accordance with the Standard Specification for Design and Construction of Concrete Structures(Compilation for Construction).

[Comments]

FNS fine aggregates: When FNS fine aggregates and natural fine aggregates are stored separately, each

aggregate shall be tested periodically. Care should be taken in the maintenance of grading so that the size distribution at the time of use will not differ from that assigned when the mix proportions were determined. In case of a change in the grading, the mix proportions shall be adjusted appropriately.
FNS-mixed fine aggregates: When premixed aggregates are used, the quality of each fine aggregate before mixing shall be checked to assure the quality of mixed aggregates. As a means of determining the FNS mixture ratio, a method using specific gravity separation with heavy liquid has been reported.

CHAPTER 9 GENERAL DESIGN REOUIREMENTS

9.1 General

Design calculation of FNS fine aggregate concrete structures shall be performed according to the Standard Specification for Design and Construction of Concrete Structures (Compilation for Design).

[Comments]

Comparison of the physical properties of FNS fine aggregate concrete with those of conventional concrete shows the Young's modulus to be almost the same as or slightly larger than, and creep and drying shrinkage nearly equal to those of conventional concrete.

In cases where natural coarse aggregates are used, the mass per unit volume of FNS fine aggregate concrete shall be determined by test, since it varies within the range of 2350～2450kg/m^3,depending on the type of FNS fine aggregates and FNS mixture ratio.