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RECOMMENDED PRACTICE FOR CONCRETE CONTAINING AIR-ENTRAINING AND HIGH-RANGE WATER-REDUCING AGENTS

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PREFACE

An air-entraining and high-range Water-reducing agent is a new type of chemical admixture developed and commercialized in Japan. The distinctive feature of the agent is that, along With adequate inbuilt air-entraining properties, it has a water-reducing capability higher than that of ordinary air.-entraining and water-reducing agents, as well as an excellent slump-retaining capability. The agent can thus be used at the time of mixing concrete in the same manner as ordinary air-entraining and water-reducing agents. When concrete containing this agent is to be produced to have the same slump as conventional concrete, it requires a lover amount of water. When the unit water content is the same as that of conventional concrete, the concrete containing the agent provides the quality that matches that of superplasticized concrete, while being manufacturable at a ready-mixed concrete plant.

In recent years, the unit water content of concrete has inevitably tended to increase due to the worsening availability of quality aggregate, the remarkable spread of concrete pumping for rational construction practice, the diversified construction methods and structures, and so forth. Since the use of an air-entraining and high-range water-reducing agent is a quite effective means of producing concrete of high-quality and/or high-performance while overcoming such present conditions, applications of the agent to concrete for public structures are gradually increasing for the purposes of reducing the unit water content and/or improving workability of concrete. However, these purposes can be surely attained without impairing other properties of concrete only when the agent of good quality is used in an appropriate manner. It is therefore essential to formulate guidelines to be followed when using the agent.

Under such circumstances as mentioned above, the Concrete Committee of the Japan Society of Civil Engineers (JSCE) conducted research work for about 3 years to formulate the drafts of both the quality standard and Recommended Practice for the agent at the request of the Japan Concrete Admixture Association The Working Group on Flowable Concrete of- the JSCE Research Subcommittee on High Quality Concrete organized in December 1989 assumed a leading role in the activity.

JSCE CONCRETELIBRARYNo.74 issued in July l993 summarizes all the achievements of the research activities by the Working Group on Flowable Concrete, and contains "Recommended Practice for Concrete Containing an Air-Entraining and High-Range Water-Reducing Agent (Draft) ", JSCE Standard "Air-Entraining and High-Range Water-Reducing Agents for Concrete", other references pertaining to concrete containing the agent, and "Recommended Practice for. Superplasticized Concrete (Revised Version)".

The present paper is the translation of the essential parts of the "Recommended Practice for Concrete Containing an Air-Entraining and High-Range Water-Reducing Agent (Draft) ". All of its articles and some of their important commentaries were translated into English. It is hoped that this Recommended Practice will contribute to the sound spread of concrete made using

the agent and help to produce concrete of high quality and high placeability.

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RECOMMENDED PRACTICE FOR CONCRETE CONTAINING AIR-ENTRAINING AND HIGH-RANGE WATER-REDUCINGAGENTS (AEHWRACONCRETE)

CHAPTER 1 GENERAL

1.1 Scope

(l) This recommendation provides the general requirements specially needed for the construction of-concrete structures to which concrete containing an air- entraining and high-range water-reducing agent, abbreviated hereafter to AEHWRA, is applied. Matters not provided in this recommendation shall be in accordance with the JSCE Standard Specification for Design and Construction of Concrete structures [construction].

(2) This recommendation covers concretes with the characteristic compressive strength of 400 kgf/cm^2 (40 N/cm^2) or less.

(3) This recommendation covers concretes containing AEHWRA sufficient for reducing 16% or more water when tested in accordance with the JSCE Standard "Air-Entraining and High-Range Water-Reducing Agents for Concrete", in case the dosage of AEHWRA is represented by the ratio to the weight of cement.

[Commentary]

(1) AEHWRA is a type of admixture developed in Japan. Those currently on the market can be classified by main ingredient into four types: naphthalene type, polycarboxylatetype, aminosulfonate type, and melamine type.

AEHWRA is characterized by having air-entraining properties in addition to highly water-reducing capability, as indicated in the definitions in Section 1.2. This agent can therefore be used in place of a conventional air-entraining and water-reducing agent, being charged into the mixer with other materials at the time of mixing concrete. Also, by utilizing the above-mentioned characteristics of this agent, it becomes possible not only to produce a concrete with a water content less than that of concrete containing an ordinary air-entraining and water-reducing agent (hereafter, this type of concrete will be simply referred to as "ordinary concrete"), but also to produce at a ready-mixed concrete plant a concrete with a quality that matches superplasticized concrete.

(2) AEHWRA can also be used for the production of high-strength concrete, with many instances of its use for that purpose being reported. However, high-strength concrete containing AEHWRA can not be treated in the same manner as ordinary concrete, because the properties in the fresh stage of high-strength concrete are considerably different from those of ordinary concrete. In addition, since concrete with a characteristic compressive strength higher than 400 kgf/cm^2 (40 N/cm^2) generally requires a considerably high unit cement content, in many cases the slump has to be increased over the value specified in this recommendation, in order to ensure good workability. These are the reasons why this recommendation limits its application to the strength range covered by JIS A 5308 (Ready-Mixed Concrete), i.e. a characteristic or nominal strength of 400 kgf/cm^2 (40 N/cm^2) or less.

(3) One of the major advantages of adding AEHWRA in concrete is the improvement of workability of concrete without increasing the unit water content. In order to exploit this advantage,

a slump greater than conventionally permitted was allowed, within the limits of not impairing the quality of' the concrete. That is, as with superplasticized concrete, a slump of up to l8 cm is permitted on the condition that the extra slump over the value permitted for ordinary concrete is obtained by the water-reducing capability of AEHWRA. The provisions of this section were set forth to ensure such condition that the unit water content of AEHWRA concrete is scarcely more than that of ordinary concrete whose slump is near the upper limit generally permitted.

1.2 Definitions

The definitions of certain terms used in this recommendation are as follows:

Air-entraining and high-range water-reducing agent (AEHWRA): a chemical admixture which can be charged into the mixer with other materials at the time of mixing and which has air-entraining properties, higher water-reducing capability than ordinary air-entraining and water-reducing agents, and good slump-retaining capability.

Slump-retaining capability: The properties of an admixture to restrain the slump loss of concrete with time after mixing.

Water-reducing capability: The properties of an admixture to reduce the unit water content required for obtaining the same slump as plain concrete.

[Commentary]

The term "rate of water reduction1" is also used in this recommendation. This is the same term as used in the tests in the JSCE Standard "Air-Entraining and
High-Range Water-Reducing Agents for Concrete", and is expressed as:

$$\text{Rate of Water reduction (\%)} = \frac{W_c - W_t}{W_c} \times 100$$

where W_c= unit water- content of control concrete (kg/m^3)
W_t= unit water content of test concrete (kg/m^3)

"Control concrete" is defined as a concrete which contains no chemical admixtures and is used as the reference in the quality test of AEHWRA "Test concrete" is defined as a concrete under test, containing AEHWRA in the quality test of the agent.

CHAPTER2 QUALITY OF AEHWRACONCRETE

2.l General

AEHWRA concrete shall have adequate workability for concreting work, the required strength, durability, and watertightness, with minimum variation in quality. It shall have suitable quality to protect the steel as well.

[Commentary]

The general properties of AEHWRA concrete covered by this recommendation are as follows:

Fresh concrete

Workability: The slump of concrete properly made using AEHWRA is generally 4 to 7 cm higher than that of ordinary concrete with the same unit water content. In addition, its slump loss with time tends to be less than that of ordinary concrete with the same slump. The degree of segregation is less than that of ordinary concrete with the same slump, and is similar to that of superplasticized concrete with the same slump. These distinct properties of AEHWRA concrete generally tend to be magnified in rich mixtures.

Among the abovementioned properties, the small slump loss generally lasts for about 60 min. after mixing, but then the slump loss tends to gradually become large. When the unit cement content is less than 270 kg/m^3, the slump loss may conversely turn out to be larger than that of ordinary concrete.

Change in air content with time: The change in air content with time of AEHWRA concrete may be regarded as being similar to that of ordinary concrete.

Bleeding: The amount of bleeding water of AEHWRA concrete is similar to that of ordinary concrete with the same unit water content.

Setting time: When normal portland cement is used, the setting time of AEHWRA concrete tends to be delayed by 30 to 60 min. from that of ordinary concrete.

Mechanical properties

Compressive strength: AEHWRA concrete develops compressive strength equivalent to ordinary concrete, if the water-cement ratio is the same. However, when the concrete temperature is low and the dosage of AEHWRA is increased, the delay in setting time may increase, resulting in slightly less strength at early ages such as 1 day.

Modulus of rupture, tensile strength, and modulus of elasticity: The modulus of rupture, tensile strength, and modulus of elasticity of AEHWRA concrete are similar to those of ordinary concrete, if the compressive strength is the same.

Durability

Freeze-thaw resistance: The resistance of AEHWRA concrete against repeated freezing and thawing action is similar to that of ordinary concrete, if the air content is the same.

Water-tightness
The water-tightness of AEHWRA concrete is higher than that of ordinary concrete with the same water-cement ratio. There are reports of instances in which the depth of water permeation was reduced to about 70% and the diffusion coefficient to about 50% by the use of AEHWRA.

Quality of protecting steel
Such properties as watertightness, permeability to chlorides and oxygen, and resistance to carbonation relate to the quality of protecting reinforcing steel within concrete. These properties of AEHWRA concrete can be generally regarded to be the same as or higher than those of ordinary concrete.

2.2 Strength

The strength of AEHWRA concrete shall generally be expressed by the strength tested at the age of 28 days.

2.3 Limit of total chloride content in concrete

The maximum total chloride content in AEHWRA concrete at the time of mixing shall be, as a rule, not more than 0.30 kg/m^3.

[Commentary]

The total chloride content in concrete at the time of mixing is the sum of the chlorides supplied from each material, when calculated according to the field mix proportions. As of August 1992, the chloride content in AEHWRA manufactured and supplied in Japan is 0.1rb at the most and 0,02ro on average; practically negligible amount of chloride being supplied from the agent to concrete.

CHAPTER 3 MATERIALS

3.1 General

Materials to be used for AEHWRA concrete shall be of confirmed quality.

3.2 Cement

(l) Ordinary, high-early-strength, and moderate-heat portland cements shall conform to the requirements of JIS R 5210. Portland blast-furnace slag cement and portland fly ash cement shall conform to the requirements of JIS R 521l and JIS R 5213, respectively.

(2) For cement types other than those listed in (1), it is necessary to test their quality and thoroughly investigate proper methods of their use.

[Commentary]

(l) In the case of portland fly ash cement, unburnt carbon contained in the cement may adsorb the air-entraining ingredient of AEHWRA, often weakening its air-entraining effect. In such a case, the addition of a supplementary air-entraining agent to obtain the required air content may have to be considered.

3.3 AEHWRA

AEHWRA shall conform to the requirements of the JSCE Standard "Air-Entraining and High-Range Water-Reducing Agents for Concrete".

[Commentary]

JSCE enacted the JSCE Standard "Air-Entraining and High-Range Water-Reducing Agents for Concrete". The AEHWRA conforming to this standard can generally be regarded as having adequate performance. The JSCE Standard classifies AEHWRA into 2 types: standard and retarding.

In the JSCE Standard, the quality of AEHWRA is evaluated by testing the prescribed properties of AEHWRA concrete and comparing the results with those of the respective test values of control concrete containing no admixture. In this test, cement content of concrete is fixed at 320 kg/m^3 and slump at 8 and 18 cm. Air content of AEHWRA concrete is adjusted to 4.5%.

Table C3.1 shows the specified values. The values for the durability factor and the losses of slump and air are applicable only to concrete whose slump is set at 18 cm.

Table C3.1 Required performance of AEHWRA

Items		Types	
		Standard	Retarding
Rate of water reduction, % from control		18 min.	18 min.
Bleeding, % of control		60 max.	70 max.
Setting time, test minus control in min.	Initial	-30～+120	-90～+240
	Final	-30～+120	+240 max.
Compressive strength, % of control	3 days	135 min.	135 min.
	7 days	125 min.	125 min.
	28 days	115 min.	115 min.
Length change, % of control		110 max.	110 max.
Durability factor, %		80 min.	80 min.
Quality changes at 60 min. after mixing, Q_{60} minus Q_0	Slump, cm	6.0 max.	6.0 max.
	Air content, %	-1.5～+1.5	-1.5～+1.5

3.4 storage of AEHWRA

(l) AEHWRA shall be stored in such a manner as to prevent inclusion of' dirt or other foreign matter, freezing, or evaporation.

(2) AEHWRA which has been stored for a long time or is found to be unusual shall be tested before use. When the test results showed poor performance, the agent shall be discarded.

3.5 Fine aggregates

Fine aggregates shall conform to the requirements of Section 3.4 of the JSCE Standard Specification for Design and Construction of Concrete Structures [Construction].

[Commentary]

(1) Fine particles less than 0.l5 mm in diameter are necessary for AEHWRA concrete in order to ensure good workability. Therefore, it is recommended to use fine aggregates which contain as many fine particles allowable within the limits of the standard grading.

3.6 Coarse aggregates

Coarse aggregates shall conform to the requirements of Section 3-5 of the JSCE Standard Specifications for Design and Construction of Concrete Structures.

[Construction]

[Commentary]

When cement content is around 270 kg/m^3, crushed stone poT7der is effective in obtaining good workability in many cases. However, the content of crushed stone powder must not exceed the value specified in the Standard Specifications, because there are reports that it can cause increases in drying shrinkage.

3.7 Admixtures

(1) Air-entraining agents to be used as supplementary chemical admixtures shall conform to the requirements of JIS A 6204, and corrosion inhibitors for reinforcing steel shall conform to the requirements of JIS A 6205.

(2) Fly ash to be used as a mineral admixture shall conform to the requirements of JIS A 620l.

(3) Expansive admixtures to be used as mineral admixtures shall conform to the requirements of-JIS A 6202.

(4) Ground granulated blast-furnace slag to be used as a mineral admixture shall conform to the requirements of the JSCE Standard Ground Granulated Blast-Furnace Slag for Concrete (draft).

(5) Admixtures other than (1), (2), (3), and (4) above shall be used upon confirming that they do not produce any deleterious effects on the quality of concrete.

[Commentary]

(1) When an air-entraining agent is used as a supplementary admixture, it is important to ensure before use that both the air-entraining agent and AEHWRA have no deleterious effect on each other's performance.

CHAPTER 4 MIX PROPORTIONS

4.1 General

Mix proportions of AEHWRA concrete shall be determined to provide the adequate workability, required strength, durability, watertightness, and quality to protect steel, with minimal variation in quality.

[Commentary]

AEHWRA is characterized by excellent water-reducing capability, and allow a relatively wide selection of dosages When compared with conventional air-entraining and water-reducing agents. However, certain dosages will lead to wide variations in concrete quality, such as slump-retaining capability and workability. Also, the quality of AEHWRA concrete is more sensitive to such conditions as materials used and temperature compared with that of ordinary concrete. Therefore, AEHWRA concrete should be proportioned in accordance with this recommendation and by tests so as to obtain concrete of the required quality.

4.2 Water-cement ratio

The water-cement ratio shall be determined so that AEHWRA concrete satisfies the required strength and durability. For structures required to be watertight, the water-cement ratio shall be determined so that the resulting concrete satisfies the requirements for water-tightness.

4.3 Slump

The slump of AEHWRA concrete at the time of placing shall be in the range suitable for its transportation, placement and consolidation, and shall be, as a rule, not more than l8 cm.

[Commentary]

Use of AEHWRA enables concrete to have a slump of 18 cm with a unit water content which would produce a slump of l2 cm in ordinary concrete. The slump as high as l8 cm thus obtained scarcely impairs the quality of concrete because of the high viscosity and small bleeding compared with ordinary concrete. With a slump above l8 cm, however, the mortar or paste tends to segregate, gradually impairing the quality of concrete. Therefore, in this recommendation the upper limit of the slump Was set at l8 cm- This limit, however, may be exceeded if it is confirmed by tests that the

increase in slump has no deleterious effects, such as increased segregation, on the concrete quality.

Table C4.1 presents the standard slump ranges of AEHWRA concrete to be the purpose of improving workability.

Table C4.1 Standard slump ranges of AEHWRA concrete

Type of structures			Slump (cm)
Massive concrete(e.g. large bridge piers, large foundations)			8 - 12
Relatively massive concrete (e.g. bridge piers, thick walls, foundations, large arches)			10 - 15
Thick slabs			8 - 12
General reinforced concrete			12 - 18
Reinforced concrete with large cross-sectional areas			8 - 15
Prestressed concrete beams			10 - 15
Watertight concrete			8 - 15
Tunnel lining concrete			15 - 18
Lightweight aggregate concrete	Reinforced concrete	Slabs	12 - 18
		Beams	12 - 18
		Walls and columns	10 - 15
	Prestressed concrete beams		10 - 15

4.4 Air content

The air content of AEHWRA concrete shall normally be 4 to 7ro of concrete volume, depending on the maximum size of coarse aggregate, environmental conditions of the concrete structure, and other factors.

4.5 Unit water content

(l) The unit water content of AEHWRA concrete shall be determined by tests so as to be the least needed as the required quality of concrete is obtained.

(2) The unit water content of AEHWRA concrete shall be, as a rule, not more than 175 kg/m^3

[Commentary]

(2) As set forth in Section 4.3, the slump is allowed to be l8 cm at the maximum for AEHWRA concrete. However, the additional slump increase above the maximum value allowed for Ordinary concrete must be attained utilizing the high water-reducing capability of AEHWRA.

According to a survey of execution records, the unit water content of concrete with a slump of 20 cm or less is generally less than 170 kg/m^3 and seldom exceeds l75 kg/m^3. Even in areas where good aggregates are not available, the unit water content of concrete with a slump of 8 cm never greatly exceeds l75 kg/m^3, if an ordinary air-entraining and water-reducing agent is used. The upper limit value for the unit water content in this section was established in consideration of these results. In areas where the availability of good aggregates is exceptionally poor, the unit water content may exceed l75 kg/m^3, if it is confirmed by tests that the concrete quality is not impaired.

4.6 unit cement content

(l) The unit cement content of AEHWRA concrete shall be determined from the unit water content and Water-cement ratio.

(2) The unit cement content of AEHWRA concrete shall be, as a rule, more than 270kg/m^3.

[Commentary]

(2) According to the results of tests on AEHWRA concrete using coarse aggregate 25 mm in maximum size, good quality concrete was obtained when the unit cement content was 275 kg/m^3, whereas the unit cement content as low as 250 kg/m^3 resulted in not only poor workability, but also large slump loss with time. In consideration of these points, the unit cement content of AEHWRA concrete was established to be, as a rule, more than 270 kg/m^3, for the cases where coarse aggregate of maximum size of 20 or 25 mm is used. When coarse aggregate of maximum Size of 4o mm or more is used and the unit cement content calculated from the unit water content and water-cement ratio is less than 270 kg/m^3, it is recommended to adopt a unit cement content confirmed by tests.

4.7 sand-aggregate ratio

The sand-aggregate ratio of AEHWRA concrete shall be determined by tests so that the unit water content is minimum while adequate workability is maintained.

[Commentary]

In general, AEHWRA concrete tends to show a rougher appearance than ordinary concrete if the water-cement ratio and slump are kept constant, because of its reduced unit cement content. In most cases this can be improved by increasing the sand-aggregate ratio by l to 2%.

When unit cement content is small and fine particles are extraordinarily deficient, the workability will not be improved by simply increasing the sand-aggregate ratio. In such a case it is recommended to consider the addition of fly ash, ground granulated blast-furnace slag, or stone powder.

4 .8 Dosage of AEHWRA

The dosage of AEHWRA shall be determined by tests so as to produce concrete of the required quality, within the range at which a rate of water reduction of l6 to 20%, as a rule, is obtainable.

[Commentary]

In general, the addition of AEHWRA scarcely impair the workability and setting of concrete, if its dosage is limited to the range of water reduction not above 20%. Also, it is confirmed that good slump retaining capability is assured when the dosage is selected so as to obtain a rate of water reduction higher than l6%. Consequently, the dosage at which the performance of AEHWRA is effectively exhibited was established to be in the range at which a water reduction of l6 to 20ro is obtainable. However, the water reduction may exceed 20%, if no adverse effects on concrete quality are confirmed by tests.

4.9 Unit content of admixtures

The unit content of admixtures other than AEHWRA shall be established to provide the required effects.

4 .10 Form for expressing mix proportions

(1) Mix proportions of AEHWRA concrete shall be indicated generally using the form as shown in Table 4.l.

Table 4.1 Form for expressing mix propotions

Maximum size of coarse aggregate (mm)	Range of slump (cm)	Range of air content (%)	Water-cement ratio 1) W/C (%)	Unit content (kg/m³)							
				Water W	Cement C	Mineral admixiture F	Fine aggregate S	Coarse aggregate, G mm ∫ mm	Coarse aggregate, G mm ∫ mm	AEHWRA	Other chemical admixtures 2)

Notes: 1) When using mineral admixtures having pozzolanic reactivity or latent hydraulic properties, the water-cement ratio shall be the water-cementitious material ratio.
2) The dosages of other chemical admixtures shall be indicated as the undiluted or undissolved amount in $m1/m^3$ or g/m^3.

(2) In the specified mixes, fine aggregate shall be defined as that entirely passing through a 5 mm sieve and coarse aggregate retained as a whole on a 5 mm sieve. Both aggregates shall be in a saturated surface-dry state.

(3) When converting the specified mixes into field mixes, the following points shall be taken into account: the moisture content of aggregate, the quantity of fine aggregate retained on the 5 mm sieve, the quantity of coarse aggregate

Passing through the 5 mm sieve, the quantity of water used to dilute chemical admixtures, and so on.

CHAPTER 5 BATCHING AND MIXING

5.1 Batching

5.1.1 General

Each material for AEHWRA concrete shall be weighed accurately so as to obtain the concrete of designated quality.

5.1.2 equipment

(1) The hatching method and equipment shall be suitable for the work, and shall be capable of accurately weighing the quantity of each material within the prescribed limit permissible f-or hatching errors.

(2) Batching equipment for each material shall be checked and adjusted both before the start and periodically during the execution of the work.

[Commentary]

(l) and (2) It is necessary to select equipment with sufficient capacity for batching AEHWRA, because its dosages are generally larger than those of air-entraining agents or air-entraining and water-reducing agents.

5.1.3 Batching of materials

(1) The materials for concrete shall be weighed based on the field mix. The test of the surface moisture content of aggregates shall be made in accordance with JIS A 1111 or JIS A ll25, or by another appropriate method, If the aggregate is dry, the measuring of the effective absorption of aggregate shall be performed after wetting it for a proper period of time.

(2) The size of batch shall be determined taking into account the kind of construction, amount of concrete to be placed, mixing equipment, and transportation methods.

(3) Each material shall be weighed for each batch of concrete. Water and diluted solutions of chemical admixtures may be measured by volume.

(4) Batching errors shall not be greater than the allowances given in Table 5.1.

[Commentary]

(3) and (4) When measuring AEHWRA by volume, the amount adhering to the dispenser should be taken into account, because the agents are general1y measured undiluted.

Table 5.1 Permissible errors in batching

Material	Tolerances (%)
Water	1
Cement	1
Aggregates	3
Mineral admixtures	2
Chemical admixtures	3

5.2 Mixing

5.2.1 General

The materials of AEHWRA concrete shall be thoroughly mixed to yield a uniform concrete.

5.2.2 Mixers

(1) As a rule, batch mixers shall be used for mixing AEHWRA concrete.

(2) Both tilting batch mixers and forced mixing type batch mixers shall, as a rule, conform to the requirements of JIS A 86o2 and JIS A 8603, respectively.

(3) Concrete mixers shall be so designed that the concrete segregates little on its discharging.

[Commentary]

(l) Since there are no records of mixing AEHWRA concrete in a continuous mixer, mixing with continuous mixers was excluded from the scope of this recommendation.

5.2.3 Mixing

(1) The proper order of charging materials into mixer shall be decided in advance.

(2) The mixing time shall be determined by testing in principle.

(3) Mixing shall not be continued for. more than three times the predetermined mixing time.

(4) The inner surface of the mixer shall be covered with mortar, before commencing concrete mixing.

(5) Materials for the next batch shall not be introduced into the mixer before the previous mixture has been completely discharged.

(6) Concrete mixers shall be thoroughly cleaned before and after use.

[Commentary]

(1) AEHWRA shall, as a rule, be dispersed in the mixing water before mixing.

CHAPTER 6 READY-MIXED CONCRETE

6.1 General

When AEHWRA concrete is produced as ready-mixed concrete, this recommendation as well as JIS A 5308 shall be observed.

[Commentary]

In addition to general cautions applicable to ordinary concrete, special care should be taken for AEHWRA concrete. This recommendation is thus intended to cover matters specially needed for AEHWRA concrete used as ready-mixed concrete, whereas other general matters are to be covered by the requirements of JIS A 5308 "Ready-Mixed Concrete".

6.2 Choice of concrete plants

(1) In principle, the supplier's plant of ready-mixed concrete shall be chosen from among the plants which are not only JIS-mark licensed but also operated or controlled by persons who are authorized by JCI as Concrete Engineer or Chief Concrete Engineer, or by other persons of equal or higher knowledge and experience compared with the authorized Engineers by JCI.

(2) In choosing plant, the following matters shall be taken into account: transporting time to sites, unloading time, concrete production capacity, number of transporting vehicles, manufacturing equipment, condition of quality control, and so on.

[Commentary]

(2) AEHWRA concrete is generally characterized by small slump loss for about 60 min. after mixing. However, as more time elapses, the good slump-retaining capability of the agent gradually become indistinct, approaching the level of those of ordinary concrete with the same initial slump- Therefore, it is desirable to choose a plant from Which the transporting time is not greater than 60 min., in order to effectively utilize the characteristics of the agent.

The slump of AEHWRA concrete is quite sensitive to the changes in aggregate grading and surface moisture, because of its small unit water content. Thus it is important to choose a reliable plant at which mix proportioning and quality control of- materials are precisely carried out.

6.3 Designation of quality

The designation of ready-mixed concrete shall be made correctly with regard to the following items,

principally in accordance with JIS A 5308.

(1) The purchaser shall choose a suitable combination of nominal strength and slump from among the various combinations shown in Tables l and 2 of JIS A 530B.

(2) The purchaser shall specify the following items, depending on the purposes of using AEHWRA concrete by consulting with the relevant suppliers:

l) type of cement
2) type of aggregate
3) maximum size of coarse aggregate
4) alkali-silica reactivity class of aggregate; when using a class B aggregate, method of suppressing alkali-aggregate reaction
5) type of admixtures
6) limit of chloride content, if it is different from the value specified in section 3.2 of JIS A 5308
7) age of concrete guaranteeing nominal compressive strength
8) air content
9) mass per unit volume of concrete, in the case of lightweight concrete
l0) maximum or minimum temperature of concrete
11) upper limit of water-cement ratio
12) upper limit of unit water content
13) lower or upper limit of unit cement content
14) other necessary items, if any

[Commentary]

(1) Tables C6.l and C6.2 are tabulated by selecting the combinations of nominal strength and slump conforming to this recommendation from the tables of JIS A 5308 "Ready-Mixed Concrete".

Table C6.1 Types of ready-mixed concrete (applicable until March 31, 1995)

Type of concrete	Maximum size of coarse aggregate (mm)	Slump (cm)	Nominal strength						
			210	240	270	300	350	400	Modulus of rupture 45
ordinary concrete	20, 25	8,10,12,15,18	○	○	○	○	○	○	—
	40	5,8,12,15	○	○	○	○	—	—	—
		18	—	—	—	○	—	—	—
Lightweight concrete	15, 20	8,12,15,18	○	○	○	○	—	—	—
Pavement concrete	40	2.5, 6.5	—	—	—	—	—	—	○

Table C6.2 Types of ready-mixed concrete (applicable from April 1, 1995)

Type of concrete	Maximum size of coarse aggregate (mm)	Slump (cm)	Nominal strength						
			21	24	27	30	35	40	Modulus of rupture 45
ordinary concrete	20, 25	8,12,15,18	○	○	○	○	○	○	—
	40	5,8,12,15	○	○	○	○	—	—	—
Lightweight concrete	15, 20	8,12,15,18	○	○	○	○	—	—	—
Pavement concrete	40	2.5, 6.5	—	—	—	—	—	—	○

Note: Values of nominal strength are expressed in an SI unit (nondimensional).

(2) Matters to be specially specified when placing an order for ready-mixed concrete containing AEHWRA are as follows:
The lower limit of unit cement content should, as a rule, be 270 kg/m^3. AEHWRA to be used should conform to the requirements of the JSCE Standard "Air-Entraining and High-Range Water-Reducing Agents for Concrete"
The upper limit of unit water content should, as a rule, be l75 kg/m^3
The rate of water reduction should, as a rule, be 16 to 20%.

6.4 Acceptance of supplied concrete

(1) The delivery time schedule, type and quantity of the ready-mixed concrete, unloading location, rate of delivery, and other items shall be sufficiently discussed and confirmed with the relevant suppliers in advance to ensure smooth concrete placement.

(2) Close communication with the relevant suppliers shall always be maintained during placing concrete to ensure a stable supply of concrete .

(3) The concrete unloading location shall be an appropriate one to which vehicles can gain access safely and easily. Also so the concrete unloading operation can easily be carried out.

(4) Unloading of concrete shall be done so as to bring about little segregation of concrete.

(5) Acceptance inspections of ready-mixed concrete shall be conducted in accordance with Section 9 of JIS A 5308.

CHAPTER7 TRANSPORTATION ANDPLACING

7.1 General

Prior to commencing Work, adequate plans for the transportation and placing of AEHWRA concrete shall be made.

7.2 General requirements

(l) AEHWRA-concrete shall be transported quickly, placed immediately, and compacted fully. The time from the start of mixing to the completion of the placing shall, as a rule, not exceed one and a half hours when the outdoor temperature is above 25 ^{o}C ,and two hours When it is 25 ^{o}C or below.

(2) AEHWRA concrete shall be transported and placed in such a manner as to ensure the least possible segregation of concrete.

[Commentary]

(1) The slump loss of AEHWRA concrete shows the tendency as described in the commentary f-or Section 6.2. Therefore, the time limits from the start of mixing to the completion of placing are specified here to be the same as those for ordinary concrete shown in Section 7.2 of the JSCE Standard Specification for Design and Construction of Concrete Structures [Construction]. When the time before placing is expected to be long, or When the outdoor temperature is above 25 ^{o}C , a retarding type of AEHWRA is recommended.

7.3 Transportation to site

(1) Vehicles for transporting AEHWRA concrete shall allow easy unloading of concrete. When the concrete is to be transported a long distance, an agitator or other alternative equipments shall be provided.

(2) When AEHWRA concrete is used as ready-mixed concrete, its transportation shall, as a rule, conform to the requirements of JIS A 5308.

7.4 Conveying within site

7.4.1 General

The conveying of AEHWRA concrete within the construction site shall be made by suitable methods in consideration of the type and quality of the concrete, type and shapes of the structure, conditions of the portions to be placed, amount and rate of placement, safety of the work, and so on.

7.4.2 Concrete pumping

(l) When pumping AEHWRA concrete, the concrete shall have the adequate workability, and have the specified quality during concreting work and after hardening.

(2) When pumping AEHWRA concrete, the slump shall be the least in the range suitable for the work depending on the type of structure.
(3) The pipe diameters and line layout shall be determined in consideration of the type and quality of concrete, maximum size of coarse aggregate, type of pumps, and pumping conditions, as well as

the ease and safety of the pumping work.

(4) The type and number of pumps shall be selected in consideration of- the type and quality of concrete, pipe diameters, equivalent horizontal length of the pipeline system, pumping load, outputs of pumped concrete, amount of placement per unit time, safety against blocking, and environmental conditions at the site

(5) When pumping is expected to be difficult, as in the case of pumping special concrete or pumping under special conditions, preliminary pumping tests shall be conducted.

(6) Concrete shall be pumped continuously accordingly to the plan, and pump stoppage shall be avoided as much as possible. When any long stoppage is inevitable, appropriate means shall be provided so that the stoppage does not cause any changes in the pump ability and quality of the concrete after pumping is resumed.

[Commentary]

(2) As stated in Section 4.3, When AEHWRA concrete is used for the purpose of improving workability, the slump may be increased to l8 cm. The concrete may be proportioned to have a slump higher than l8 cm, if it is proved by reliable data or records that there will be no deleterious effects such as segregation to the concrete.

(4) When AEHWRA concrete is proportioned to have a water-cement ratio of 40% or less, 1ar-ge losses of pipe pressure during pumping have been reported. When formulating a pumping plan for such concrete, it is recommended to study the records of pumping concrete of similar mix proportions and conduct pumping tests if necessary.

7.5 Preparation before placement

Before placing AEHWRA concrete, the following preparations shall be made:
(1) It shall be confirmed that the layout of the reinforcing bars, forms, and other devices are positioned as specified in the design.

(2) The facilities for conveyance and placement of concrete shall be confirmed as conforming with the construction plan provided in Section 7.l.

(3) The conveyance facilities, placing equipment and interior of forms shall be cleaned to prevent the inclusion of foreign materials into the concrete. Positions which are likely to absorb moisture upon contact with the concrete shall be moistened beforehand.

(4) Remaining water in any excavated pits shall be removed prior to concrete placement. Adequate measures shall be taken to prevent water from flowing into the pits and scouring the newly placed concrete.

7.6 Placing

(1) Concrete containing AEHWRA shall be placed in accordance with the plans provided in Section

7.1.

(2) AEHWRA concrete shall be placed so as not to move the locations of reinforcing bars and forms.

(3) The placed fresh concrete shall not be shifted horizontally within the forms.

(4) When severe segregation is observed during placement, measures shall be taken to prevent segregation.

(5) Concrete shall be placed continuously until placement for a given block is completed.

(6) AEHWRA concrete shall, as a rule, be placed so that its surface is nearly level within a block. The height of a lift shall be determined in consideration of the compaction capacity.

(7) When the placement of AEHWRA concrete is made in layers, the upper layer shall be placed carefully before the concrete in the lower layer starts to harden, so as to construct an integrated structure.

(8) When the height of the forms is relatively high, the placement of concrete shall be made through access holes provided in the form, or by lowering the outlet of the vertical chute or pumping pipe to a position close to the placing surface, in order to prevent the concrete from segregating, as well as to prevent the concrete from adhering and hardening on the surfaces of the upper reinforcing bars or for-ms. In this case, the distance from the outlet of the chute, pipe, bucket, hopper and other devices to the placing surface shall be, as a rule, 1.5 m or less.

(9) If bleeding water is detected while placing concrete, the placement shall be halted until the water is removed by proper means.

(10) When concrete is placed continuously in the forms for high members such as walls or columns, the height of each lift and the rate of placement shall be adjusted during the placement and compaction so as to minimize the adverse effects of bleeding.

[Commentary]

(3) When AEHWRA concrete is used for the purpose of improving workability, it shall not be intentionally shifted into horizontal direction during compaction, because such concrete has high flowability, and is susceptible to segregation if it is intentionally moved horizontally.

7.7 Compaction

(1) As a rule, internal vibrators shall be used for the compaction of AEHWRA concrete. Form vibrators may be used where the use of an internal vibrator is difficult, such as thin walls- Vibrators shall be of a suitable type for the work.
(2) AEHWRA concrete shall be sufficiently compacted soon after placement so as to ensure the full permeation of the concrete around the reinforcing bars and into all the corners of the forms.

(3) During vibratory compaction, the vibrator shall be inserted into the lower concrete layer about l0cm.

(4) The vibration pitch and vibration time per point shall be determined so as to ensure sufficient compaction of concrete. The vibrator shall be pulled up from the concrete gradually so that the holes in concrete created by vibrator insertion are refilled thoroughly with concrete.

(5) When re-vibration is given, appropriate time shall be allotted , so as to avoid adverse effects to the concrete.

[Commentary]

(4) The commentary for Section 7.4.3 of the JSCE Standard Specification for Design and Construction of Concrete Structures [Construction] states that the distance between insertions of an internal vibrator should be less than the diameter of the area visibly affected by the vibrator, and should generally be less than 50 cm. It also states that the vibration time at each insertion should be determined by careful watching of the condition of the concrete surface. AEHWRA concrete has higher viscosity than ordinary concrete with the same slump, and thus the radius of action of vibrators tends to be small. On the other hand, excessive vibration of high-slump concrete can cause undesirable settlement of aggregates. Therefore, it is recommended that vibrators be inserted at a shorter distance and the vibration time at each insertion be limited to the minimum required.

7.8 Treatment of settlement cracks

(l) If a concrete slab or beam is connected to a wall or column, in order to prevent cracks due to settlement, the concrete of the slab or beam shall be placed after- the settlement of' AEHWRA concrete placed in the wall or column is nearly completed. The same rule shall be applied to structures with an overhang.

(2) If settlement cracks have occurred, tamping shall be performed without delay to eliminate the cracks.

[Commentary]

(2) Some types of AEHWRA may cause delayed setting of concrete at low temperatures, resulting in extended bleeding time. It should be noted that the occurrence of settlement cracks may be delayed in this case.

CHAPTER 8 SURFACEFINISHING ANDCURINGOF CONCRETE

8 .1 General

(1) AEHWRA concrete shall be finished to the specified level and configuration, and shall be cured for a certain period after placing, by not only maintaining the necessary temperature and humidity conditions for its hardening but also protecting its from harmful effects.

(2) Surface finishing and curing of AEHWRA concrete shall be properly timed.

[Commentary]

(l) and (2) AEHWRA concrete has a smaller amount of bleeding water than ordinary concrete, but the duration of bleeding may last longer. Therefore, it is important to formulate an appropriate execution plan for staffing and methods of surface finishing, in order that started at the right time.

8.2 Surface finishing

The surface of AEHWRA concrete shall be finished after consolidating and screeding the surface to the required level and configuration, but the finishing shall not be done unless the bleeding water accumulated on the top surface has vanished or has been removed.

8.3 Curing of concrete

Beginning immediately after placement, AEHWRA concrete shall be protected from surface drying, and shall be moist-cured with care, especially at early ages, so as to ensure the required qualities of concrete, such as strength, durability, watertightness, and quality to protect the steel.

[Commentary]

AEHWRA concrete has less bleeding than ordinary concrete, and thus its surface tends to become dry. Therefore, it should be protected from surface drying especially at early ages. Shading or windbreaks should be provided until the concrete is hardened enough to receive curing sheets or mats without damage to the surface.

CHAPTER 9 FORMWORK AND SHORING

9 .l General

Formwork and shoring shall be designed and constructed to possess the specified strength and rigidity, and to ensure accuracy of locations, configuration and dimensions of permanent structures, as well as to achieve the required quality of concrete.

9.2 Formwork

(1) Formwork shall be designed for the adequately assumed lateral pressure of AEHWRA concrete during placing and consolidating.

(2) Formwork shall be sufficiently tight to prevent leakage of mortar or cement paste.

(3) When AEHWRA concrete is placed in a structure with inclined surfaces, top forms shall be provided as required.

[Commentary]

(1) When the slump exceeds l0 cm, it is recommended for safe design of the formwork to assume the lateral pressure in terms of' hydrostatic pressure. When the slump is less than l0 cm, Fig. C11.2.1 in Section 11.2 of the JSCE Standard Specification for Design and Construction of Concrete [Construction] may be used.

9.3 Shoring

(l) Shoring of a suitable type shall be selected to ensure that all loads are transmitted to the foundations by proper means.

(2) Shoring shall be designed and constructed to possess sufficient strength and to be safe against buckling.

CHAPTER l0 CONCRETES REQUIRING SPECIAL CONSIDERATION

10.l General

When AEHWRA is used in the concrete requiring special consideration, the construction shall be properly conducted, exercising special care with respect to the materials, mix proportion, and methods of mixing, transportation, placing, and curing, in consideration of the special characteristics of the concretes.

[Commentary]

The provisions of Chapters 1 to 9 cannot always be applied as such, when AEHWRA is used in such concretes or concreting works as mass concrete, cold weather concreting, hot weather concreting, watertight concrete, lightweight aggregate concrete, marine concrete, prestressed concrete, combined steel and reinforced concrete, and pavement concrete. This chapter provides the requirements particularly needed for these cases.

10.2 Mass concrete

In the construction of mass concrete, special care shall be exercised with respect to the materials, mix proportion, and methods of transportation and placing, so that thermal cracking caused by the heat of hydration of cement is the least, ensuring the quality of concrete at a required level.

[Commentary]

Mass concrete is usually made using moderate heat portland cement, portland blast-furnace slag cement containing more than 50YDground granulated bla st-furnace slag, or fly ash cement, in order to minimize thermal cracking. Also, multi-component cements, which have been produced by adding one or more mineral admixtures to normal portland cement or moderate heat portland cement, may be used. Most test results with these cements suggest that the water-reducing capability of AEHWRA in concrete made using these cements is similar to or slightly higher than in the case of normal portland cement- However, instances have been reported in which air content,

setting time, and slump loss with time, as well as water-1educing capability vary depending on the type of cement, type, brand, and dosage of AEHWRA, type of fine aggregates, and other factors. Thus it is important to con firm in advance that the required effects can be obtained using the materials to be used in actual construction, when the mix proportion is determined.

10.3 Cold weather concreting

In cold weather concreting, special care shall be taken with respect to the materials, mix proportion, and curing, so that the concrete is protected from freezing and the required quality can be obtained even in cold weather.

[Commentary]

When the temperature of concrete is low, the dosage of AEHWRA necessary for the required water-reducing capability may increase, depending on the type or brand of the agents. In this case it should be noted that the increase in the dosage leads to a delay in setting time.

10.4 Hot weather concreting

In hot Weather concreting, special care shall be taken with respect to the
Materials, and mix proportions, and methods of transportation, placing and curing, so that the quality of concrete is not impair-ed by high temperature.

[Commentary]

Materials and mix proportion
When applying AEHWRA concrete to hot weather concreting, it is recommended to use a retarding type. When the temperature of concrete is high, the dosage of AEHWRA necessary for the required water-reducing capability may decrease, depending on the type or brand, or some of the agents may exhibit a tendency to provide insufficient air content. Therefore, it is necessary to confirm these properties at high temperatures in advance. When the specified air content is not attained, a supplementary air-entraining agent should be used to adjust the air content.

Curing
Since AEHWRA concrete generally has less unit water content than ordinary concrete, it tends to develop cracks because of plastic shrinkage when it is used for hot weather concreting. Thus care should be taken in curing, especially at early ages, by providing such protection as windbreaks, to protect the concrete surface from drying.

10.5 Watertight concrete

In the construction of watertight concrete, special care shall be taken with respect to the materials, mix proportion, and method of placing, so as to produce no defect that causes leakage.

[Commentary]

Materials and mix proportions

Concrete with an excessively high slump is susceptible to segregation, and in some cases bleeding increases. Therefore, it is desirable to carry out the construction of watertight concrete with great care, maintaining the slump of
AEHWRA concrete at 15 cm or lower.

10.6 Prestressed concrete

In the construction of prestressed concrete, special care shall be taken with respect to the materials, mix proportion, and method of placing, so that rich mixtures of concrete are placed densely in the small sectional area of the member and in portions where the steel bars are embedded at narrow intervals.

[Commentary]

In most cases, prestressed concrete is made using high-early-strength portland cement, because prestress is generally applied at early ages. The water-reducing capability of AEHWRA is more distinct in rich mixtures of concrete than in normal concrete, and is reported to be even more distinct when high-early-strength portland cement is used.

10.7 Other concretes requiring special consideration

When using lightweight aggregate concrete, Or Constructing marine concrete, combined steel and reinforced concrete, or pavement, AEHWRA concrete shall be treated properly in consideration of the special characteristics of each concrete or construction work.

[Commentary]

Lightweight aggregate concrete
Lightweight aggregate concrete is considered to have a lower resistance to freezing and thawing action, and thus the air content is required to be l% greater than that of ordinary concrete. In the case of lightweight aggregate concrete containing AEHWRA as well, the required air content should be ensured by such measures as adding a supplementary air-entraining agent where necessary.

Marine concrete
Marine concrete structures are generally constructed and used in severe climatic and marine conditions. The characteristics of AEHWRA concrete is effectively utilized in such environments. If the same slump as that of ordinary concrete is selected, both the water-cement ratio and unit water content can be reduced, thereby improving the watertightness of the concrete and thus increasing the resistance to chemical attack by salts contained in the seawater as well as to corrosion of steel bars in concrete. The improvement of workability by means of the increase of the slump keeping water-cement ratio, unit cement content, and unit water content being unchanged is also effective in obtaining concrete with less defects.

Combined steel and reinforced concrete
Since AEHWRA can increase the slump and filling capacity by compaction without impairing the quality of concrete, its use in combined steel and rein forced concrete is expected to bring about an

improvement in construction efficiency and quality. However, excessively high slump or excessive compaction with vibrators could cause segregation and result in failure to obtain uniform concrete- Thus it is important to determine the mix proportion properly and to carry out placement and compaction strictly in accordance with the provisions of Chapter7.

Pavement concrete
Steel fiber reinforced concrete is sometimes used for the repair of concrete Pavement Surfaces, for the purpose of preventing cracks and improving flexural ductility. Workability of concrete is generally worsened substantially by the use of steel fibers. Since AEHWRA concrete can ensure the workability required for constructing without increasing the unit water content, such concrete is frequently used for the repair of pavement surfaces. In this case, it is important to grasp the relationship between the workability and the sand aggregate ratio, dosage of AEHWRA, and steel fiber content in order to obtain adequate workability, as well as to select coarse aggregates with high resistance to abrasion.

CHAPTER11 QUALITYCONTROLAND INSPECTION

11.1 General

Concrete materials, machinery, equipment, and workmanship shall be controlled in order to economically make concrete of the required quality using AEHWRA.

[Commentary]

When conducting quality control and inspection, material quality control and inspection are particularly important, because AEHWRA concrete is sensitive to Variations in material quality.

11.2 Testing methods

Testing methods as a rule shall be in accordance With those specified in JIS or other proper standards widely accepted.

11.3 Tests on concrete materials

(1) Concrete materials shall be tested for the required properties to confirm their quality prior to the work.

(2) The tests on the materials shall be performed as required for confirmation of quality and changes in quality during construction.

11.4 Tests on concrete

(1) Tests for determining the mix proportions shall be performed prior to the work. Performance of machinery and equipment shall also be confirmed.

(2) The following tests shall be performed as the circumstances require during construction:

(a) slump test
(b) air content test
(c) bulk density test of concrete
(d) chloride content test of concrete
(e) compressive strength test of concrete
(f) water cement ratio test
(a) concrete temperature
(h) other tests required

(3) The concrete test specimens cured under conditions as close to the field conditions as possible shall be tested for their strength to estimate the adequacy of curing, appropriate time for form removal and prestressing, or to ensure safety in case a load is applied to the structure at an early age.

(4) If necessary, non-destructive tests and tests on core specimens taken from the completed structure shall be performed upon the job completion.

[Commentary]

(1) When determining the mix proportions of concrete containing an AEHWRA, temperature, transportation time, and construction conditions should be taken into consideration, and tests for the slump retaining capability and the change of air content under these conditions should be also conducted, so as to obtain concrete with the specified slump and air content at the time of placing.

(2) Slump test and air content test
It is important to check at the beginning of construction that concrete of desired slump and air content is obtainable. During construction, it is desirable to conduct both slump and air content tests once at every 20 to l50 m^3 of continuously placed concrete, depending on the scale of construction.

Other tests
Besides the tests indicated in the commentary (2) for Section l3.2.3 of the JSCE Standard Specification for Design and Construction of Concrete Structures [Construction], other tests for AEHWRA concrete include the test of unit water content. This test is conducted to confirm that the extra slump over the value permitted for ordinary concrete is not due to the addition of mixing water. Differential salt solution method, alcohol hydrometer method, and radioisotope moisture meter method have been proposed and are available as testing methods of unit water content suitable for the field.

11.5 Quality control of concrete

The quality control of AEHWRA concrete shall be in accordance with Sections 13.3.1 and 13.3.2 of the JSCE Standard Specification for Design and Construction of Concrete [Construction].

11.6 Quality inspection of concrete

The quality inspection of AEHWRA concrete shall be in accordance with Section 13.4 of the JSCE Standard Specification for Design and Construction of Concrete Structures [Construction].