Manual for Mixture Proportioning of Self-compacting Concrete

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Manual for Mixture Proportioming of Self-Compacting Concrete

Chapter 1

1.1 Scope

(1) This Manual summarizes the methods of proportioning self-compacting concrete that satisfies the established requirements for self-compactability.
(2) The proportioning methods described herein are valid only when the specified materials are used.

1.2 Classification by materials for self-compacting concrete

According to the methods of material selection and proportioning, self-compacting concrete covered by this Manual for mixture proportioning should be investigated by classifying into three types, i.e., the powder type, viscosity agent type and combination
type.

1.3 Classification by self-compactability of self-compacting concrete

According to the geometry and reinforcement conditions of the structure to which the concrete is to be applied, the self-compactability required of self-compacting concrete covered by this Manual for mixture proportioning should be classified into three levels, i.e., Rank 1, Rank2 and Rank3.

Chapter 2 Characteristics of self-compacting concrete

2.1 Properties of self-compacting Concrete

Self-compacting concrete has excellent self-compactability and can be filled in all comers of forms without vibratory compaction, which is essential for conventional concrete. In addition, it has the following characteristics:
(1) Self-compacting concrete contains a lower coarse aggregate content and higher dosage of air-entraining and high-range water-reducing admixture or superplasticizer than conventional concrete.
(2) Self-compacting concrete causes smaller amount of bleeding water and laitance than conventional concrete.
(3) Setting and hardening of self-compacing concrete tend to delay when compared with conventional concrete.
(4) Being more susceptible to quality fluctuation and hatching errors of materials, self-compacting concrete requires stricter quality control, production control and construction control than conventional concrete.
(5) The pumping resistance of self-compacting concrete is higher than conventional concrete.
(6) Since no vibratory compaction is carried out, greater care is required for the retention time of such qualities as deformability than conventional concrete.

2.2 Characteristics of each type of self-compacting Concrete

2.2.1 Powder-type self-compacting concrete

The characteristics of powder-type self-compacting concrete covered by this Manual for mixture proportioning are as follows :
(1) Proportioning characteristics
Selectable water-powder ratios are limited to a narrow range.
The unit absolute volume of powder should be not less than 0.l6 m^3/m^3.
A wide variety of powders are available to select from.
(2) Characteristics of physical properties
Powder-type self-compacting concrete can be made into high strength concrete, due to the low water-binder ratio.
Certain types of powder can lead to high autogenous shrinkage.
(3) Construction characteristics

The fluctuation of the surface moisture and fineness modulus of fine aggregate significantly affect the qualities of concrete while fresh.
The wide variety of powder may require a larger number of silos than conventional concrete.

2.2.2 Viscosity agent-type self-compacting concrete

The characteristics of viscosity agent-type self-compacting concrete covered by this Manual are as follows:
(1) Proportioning characteristics
The powder content is lower than other types at 300. to 500 kg/m^3. A single binder is used in most instances.
Certain types of viscosity agents lead to a unit water content of over l80 kg/m^3.
Each type of viscosity agent may or may not be compatible with each type of air-entraining and high-range water-reducing admixture or superplasticizer. Such compatibility differences also exist with binders. The types of these materials should therefore be selected in consideration of the compatibility between them.
(2) Characteristics of physical properties
The plastic viscosity can be easily adjusted by changing the viscosity agent content.
Certain types of viscosity agents increase the slump-retaining capability as the viscosity agent content increases, but can delay the setting.
(3) Construction characteristics
A small amount of a powder viscosity agent may be required to be added to the concrete at the time of production in most instances.
Only a single type of powder (binder) is used in most instances. Therefore additional silos for mineral admixtures are rarely required.

2.2.3 Combination-type self-compacting concrete

The characteristics of combination-type self-compacting concrete covered by this Manual for mixture proportioning are as follows:
(1) Proportioning characteristics
Selectable water-powder ratios are limited to a narrow range.
The unit absolute volume of powder should be not less than 0.13 m^3/m^3.
A wide variety of powders are available to select from.
(2) Characteristics of physical properties
Combination-type self-compacting concrete can be made into high strength concrete, due to the low water-binder ratio.
Certain types of powder can lead to high autogenous shrinkage.
(3) Construction characteristics
The wide variety of powder may require a larger number of silos than conventional concrete.
(4) Characteristics resulting from a viscosity agent addition
The addition of a viscosity agent increases the deformability and minimizes segregation, imparting a high self-compactability to the concrete.
The viscosity agent reduces the otherwise wide fluctuation of the properties of fresh concrete resulting from small differences in the qualities of materials.

Chapter 3 Basics of proportioning

3.1 General

(1) When proportioning self-compacting concrete, the performance requirements should be adequately established according to the structural, constructional and environmental conditions of the structure to which the concrete is to be applied.
(2) The test methods for passability through spaces using a filling tester should be used as the method of verifying self-compactability.

3.2 Selection of the type of self-compacting concrete

When proportioning self-compacting concrete, it is recommended that a suitable type should be selected from the powder type, viscosity agent type and combination type in consideration of the

type of the structure, structural conditions, construction conditions, types of materials available and limitations at concrete production plants.

Chapter 4 Proportioning of Powder-type Self-compacting Concrete

4.1 General

4.1.1 Scope

(1) This chapter describes the methods of proportioning powder-type self-compacting concrete that satisfies the self-compactability requirement corresponding to the rank for the structure as specified in Chapter 1 as well as other performance requirements.
(2) When concreting with powder-type self-compacting concrete covered by this chapter, the methods of concreting, including the methods of transportation, pumping and placing should be established adequately according to the rank of self-compactability.
(3) As to matters not specified in this chapter, the JSCE Standard Specification for Design and Construction of Concrete Structures or other sections of this recommendation should apply.

4.1.2 Proportioning procedure

(1) Powder-type self-compacting concrete should be proportioned to provide the deformability, segregation resistance and self-compactability required according to the structural, construction and environmental conditions of the structure, as well as the strength, durability and other necessary performance items.
(2) The specified mixture proportions of concrete should be established by confirming that the trial mixtures of the initial proportions selected on the basis of this Manual satisfy the established performance described in (1) and by confirming their pumpability where required.

4.2 Selection of materials

(1) Selection of powders
The powders to be used should be selected in consideration of the performance of fresh, hardening and hardened concrete required from the structural, constructional and environmental conditions of the structure.
(2) Selection of aggregates
The aggregates to be used should be selected in consideration of the performance required of fresh, hardening and hardened concrete.
(3) Selection of chemical admixtures
Chemical admixtures to be selected should be those that provide the required performance of fresh concrete and do not adversely affect the properties of hardening and hardened concrete when they are used at an adequate dosage.

4.3 Establishment of initial mixture proportions

4.3.1 Maximum size of coarse aggregate and coarse aggregate content

(1) The standard maximum size of coarse aggregate should be 20 mm or 25 rm.
(2) The coarse aggregate content should be selected to provide the required self-compactability while maintaining the qualities of hardened concrete in the required range. The standard values (unit absolute volume of coarse aggregate) for the self-compactability ranks are as follows:

Self- compactability	Unit absolute volume of coarse aggregate
Rank 1	0.28-0.30 m^3/m^3
Rank 2	0.30-0.33 m^3/m^3
Rank 3	0.32-0.35 m^3/m^3

4.3.2 Unit water content, Water-powder ratio and powder content

(1) The unit water content, water-powder ratio and powder content should be selected to ensure the required performance of the self-compacting concrete while fresh in consideration of the type and properties of powders and qualities of aggregate.
(2) It is desirable that the unit water content be minimized, as it affects the qualities of hardened concrete. It should normally be in the range of 155 to 175 kg/m^3.
(3) The water-powder ratio should normally be in the range of 28% to 37% by mass of cement or

o.85 to 1.15 by volumetric ratio to cement, though dependent on the type and composition of powders.
(4) The powder content should normally be in the range of 0.16 to 0.19 m^3/m^3, though dependent on the type and composition of powders.

4.3.3 Water-binder ratio

The water-binder ratio to be selected should be smaller than the minimum value of the range determined from the performance requirements for hardened concrete.

4.3.4 Binder content and mineral admixture content

(1) The binder content should be determined from the unit water content and water-binder ratio.
(2) The mineral admixture content should be determined by subtracting the cement content from the powder content.

4.3.5 Air content

The air content of powder-type self-compacting concrete should be determined in consideration of such factors as the maximum size of coarse aggregate, strength and environmental conditions of the concrete structure. The standard air content of fresh concrete requiring high resistance to frost damage should normally be 4.5%.

4.3.6 Unit fine aggregate content

Unit fine aggregate content should be determined from the unit coarse aggregate content, unit water content, umit powder content and air content.

4.3.7 Dosage of chemical admixture

Dosage of chemical admixture should be determined from trial mixes in consideration of performance of concrete.

4.4 Establishment of specified mixture proportions

4.4.1 Confirmation of qualities of fresh concrete

(1) When the –initial mixture proportions have been selected, trial mixture should be made, by which it should be confirmed that their qualities satisfy the performance requirements for fresh concrete.
(2) The qualities of fresh concrete to be confirmed should generally be as follows:
1) Deformability
2) Resistance to segregation
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3) Self-compactability

4.4.2 Modification of mixture proportions by fresh concrete qualities

(1) When the trial mixtures do not attain the required properties of fresh concrete, the dosages of chemical admixtures, unit water content, powder content (water-powder ratio by volume) and coarse aggregate content should be modified accordingly. The air content should also be modified accordingly where the air content should be considered as a performance requirement.
(2) When the target values for fresh concrete cannot be attained by such modification, the concrete should be reproportioned using different materials. Where the materials cannot be changed easily, the proportioning should be totally reviewed including the target values.
(3) When the deformability and/or segregation resistance do not attain the target values and yet the state of concrete is satisfactory and the self-compactability attains the target value, the target values established for the initial proportions may not be adequate. In that case, the target Values should be reviewed.

4.4.3 Confirmation of the qualities of hardened concrete

It should be confirmed that the mixture proportions satisfying the performance requirements for fresh concrete also satisfy the performance requirements for hardened concrete initially established. The standard method should be the direct measurement of trial mixtures.

4.4.4 Modification of mixture proportions according to the results of quality confirmation of hardened concrete

When the qualities of hardened concrete do not satisfy the performance requirements initially established, adequate measures should be taken, such as modification of the materials and mixture proportions, and trial mixtures should be made with the new proportions for confirmation that they satisfy the performance requirements.

4.4.5 Form for expressing the specified mixture proportions

The form for expressing the specified mixture proportions should be described as follows.

Notes: 1) When more than one material of the same kind is used, each should be indicated in a separate box.

2) The dosage of an air-entraining and high-range water-reducing admixture Should be indicated in kg/m^3 and should be included in the unit water content.

3) The dosages of other chemical admixtures should be indicated in ml/m^3 or g/m^3, and should be indicated undiluted and undissolved.

4.5 Proportioning examples.

Examples of proportioning the initial mixtures and specified mixtures according to the procedure described from 4.1 to 4.4.

Chapter 5 Proportioning of Viscosity agent-type Self-compacting Concrete

5.1 General

5.1.1 Scope

(1) This chapter describes general methods of proportioning viscosity agent-type self-compacting concrete that satisfies the self-compactability requirement corresponding to the rank for the structure as specified in Chapter 1 as well as other performance requirements.

(2) When concreting with viscosity agent-type self-compacting concrete covered by this chapter, the methods of concreting, including the methods of transportation, pumping and placing should be established adequately according to the self-compactability rank.

(3) As to matters not specified in this Chapter, the JSCE Standard Specification or other sections of this recommendation should apply.

5.1.2 Proportioning procedure

(1) Viscosity agent-type self-compacting concrete should be proportioned to provide the deformability, segregation resistance and self-compactability required according to the structural, constructional and environmental conditions of the structure, as well as the strength, durability and other necessary performance items.

(2) The specified mixture proportions of concrete should be established by confirming that the trial mixtures of the initial proportions Selected on the basis of this Manual satisfy the established performance described in (1) and by confirmig their deformability retaining capability, pumpability and other performance items.

5.2 Selection of materials

(1) Selection of powders

The powders to be used should be selected in consideration of the performance of fresh, hardening and hardened concrete required from the structural, constructional and environmental conditions of the structure.

(2) Selection of aggregates

The aggregates to be used should be selected in consideration of the performance required of fresh, hardening and hardened concrete.

(3) Selection of chemical admixtures

Chemical admixtures to be selected should be those that provide the required performance of fresh concrete and do not adversely affect the properties of hardening and hardened concrete when they are used at an adequate dosage.

5.3 Establishment of initial mixture proportions

5.3.1 Maximum size of coarse aggregate and coarse aggregate content

(l) The standard maximum size of coarse aggregate should be 20 mm or 25 mm.

(2) The unit absolute volume of coarse aggregate should be selected to provide the required self-compactability while maintaining the qualities of hardened concrete in the required range. The standard values for the self-compactability ranks are as follows:

Self- compactability	Unit absolute volume of coarse aggregate (m^3/m^3)

Rank 1	0.28-0.3 1
Rank 2	0.30-0.33
Rank 3	0.30-0.36

5.3.2 Water-binder ratio and water-powder ratio

(1) It is recommended that the minimum water-binder ratio be selected from among those determined by the performance items required of the concrete, such as strength, durability, water-tightness and steel-protecting capability.

(2) When the required self-compactability cannot be obtained by the water-binder ratio determined by the method mentioned in (1) above, it is recommended that the water-binder ratio be reduced by increasing the binder content or that the water-powder ratio be reduced by using a non-binder powder.

5.3.3 Unit water content

The unit water content should be the minimum required to attain the specified self-compactability, as it produces strong effects on the qualities of hardened concrete.

5.3.4 Binder content and powder content

(1) The binder content should as a rule be determined from the unit water content and water-binder ratio.

(2) The powder content should be determined so that the self-compactability can be attained.

5.3.5 Air content

The standard air content of fresh concrete should generally be 4.5% of the volume of concrete. However, a value higher by approximately 1 percentage point may be recommended for certain proportioning conditions.

5.3.6 Chemical admixture dosage

(1) It is recommended that the dosages of a viscosity agent and air-entraining and high-range water-reducing admixture or superplasticizer be determined by testing so that the specified segregation resistance, deformability and self-compactability can be attained. The dosages must be determined in the ranges of not adversely affecting the qualities, such as the specified time-related quality changes of fresh concrete, setting time and strength development.

(2) When using chemical admixtures other than those mentioned above, it is recommended that they should be used subject to confirmation by testing that the specified qualities are obtained.

5.3.7 Fine aggregate content

The fine aggregate content should be determined from the coarse aggregate content, unit water content, powder content and air content.

5.4 Establishment of specified mixture proportions

5.4.1 Confirmation of qualities of fresh concrete

(1) Trial mixtures should be made according to the initial mixture proportions to confirm that their qualities satisfy the performance requirements for flesh concrete.

(2) The qualities of fresh concrete to be confirmed should generally be as follows:

1) Deformability
2) Resistance to segregation
3) Self-compactability

5.4.2 Modification of mixture proportions based on fresh concrete test results

(1) When the trial mixtures do not attain the required properties of fresh concrete, the dosages of the air-entraining and high-range water-reducing admixture or superplasticizer and viscosity agent, unit water content, powder content and coarse aggregate content should be modified accordingly. Such modifications should also ensure the specified time
of self-compactability retention.

(2) When the required qualities still cannot be attained by such modification, a review of the target qualities is recommended, as well as a review of the mixture proportions involving substitutions of materials.

(3) When the deformability and/or segregation resistance of concrete do not attain the target values and yet the self-compactability attains the target value, the established target values may not be adequate. h that case, the target values should be reviewed.

5.4.3 Confirmation of the qualities of hardened concrete

It should be confirmed that the mixture proportions satisfying the performance requirements for fresh concrete also satisfy the initially established performance requirements for hardened concrete. This should be confirmed by the direct measurement of trial mixtures or other methods.

5.4.4 Modification of mixture proportions based on hardened concrete test results

When the qualities of hardened concrete do not satisfy the initially established performance requirements, the materials and mixture proportions should be modified, and trial mixtures should be made again for confirmation that the hardened concrete satisfy the performance requirements. The specified mixture proportions should then be established.

5.4.5 Form for expressing the specified mixture proportions

The form for expressing the specified mixture proportions should be described as follows.

Notes: 1) When more than one material of the same kind is used, each should be indicated in a separate box.

2) The dosage of an air-entraining and high-range water-reducing admixture or superplasticizer should be indicated in kg/m^3 and the water included in the admixture should be regarded as part of the unit water content.

3) The viscosity agent dosage should be indicated in kg/m^3 and should be indicated undiluted and undissolved.

4) The dosage of other chemical admixtures should be indicated in ml/m^3 or g/m^3, and should be indicated undiluted and undissolved.

Chapter 6 Proportioning of Combination-type Self-compacting Concrete

6.1 General

6.1.1 Scope

(1) This chapter describes the methods of proportioning combination-type self-compacting concrete that satisfies the self-compactability requirement corresponding to the rank for the structure as specified in Chapter 1 as well as other performance requirements.

(2) When concreting with combination-type self-compacting concrete covered by this chapter, the methods of concreting, including the methods of transportation, pumping and placing should be established adequately according to the rank of self-compactability.

(3) As to matters not specified in this chapter, the JSCE Standard Specification or other sections of this recommendation should apply.

6.1.2 Proportioning procedure

(1) Combination-type self-compacting concrete should be proportioned to provide the deformability, segregation resistance and self- compactability required according to the structural, constructional and environmental conditions of the structure, as well as the strength, durability and other necessary performance items.

(2) The specified mixture proportions of concrete should be established by confirming that the trial mixtures of the initial proportions selected on the basis of this Manual satisfy die established performance described in (1) and by confirming their deformability retention, pumpability and other performance items.

6.2 Selection of materials

(l) Selection of powders

The powders to be used should be selected in consideration of the performance of fresh, hardening and hardened concrete required from the structural, construction and environmental conditions of the structure.

(2) Selection of aggregates

The aggregates to be used should be selected in consideration of the performance required of fresh, hardening and hardened concrete.

(3) Selection of chemical admixtures

Chemical admixtures to be selected should be those that provide the required performance of fresh concrete and do not adversely affect the properties of hardening and hardened concrete when they

are used at an adequate dosage.

6.3 Establishment of initial mixture proportions

6.3.1 Maximum size of coarse aggregate and coarse aggregate content

(1) The standard maximum size of coarse aggregate should be 20 mm or 25 mm.

(2) The coarse aggregate content (unit absolute volume of coarse aggregate) should be selected to provide the required self-compactability while maintaining the qualities of hardened concrete in the required range. The standard values for the self-compactability ranks are as follows:

Self- compactability	Unit absolute volume of coarse aggregate (m^3/m^3)
Rank 1	0.28-0.30
Rank 2	0.30-0.33
Rank 3	0.30-0.35

6.3.2 Unit water content and water-powder ratio by volume

The unit water content and water-powder ratio by volume should be selected to ensure the specified deformability and segregation resistance of the self-compacting concrete.

6.3.3 Powder content

The powder content should as a rule be determined from the unit water content and water-powder ratio by volume. However, a powder content of at least 0.13 m^3/m^3 is necessary to attain good self-compactability.

6.3.4 Water-binder ratio

The water-binder ratio must be selected to ensure all necessary performance items in consideration of the strength, durability, watertightness, resistance to cracking and steel-protecting capability required of the self-compacting concrete.

6.3.5 Binder content and mineral admixture content

(1) The binder content should as a rule be determined from the unit water content and water-binder ratio.

(2) The content of powders not included in the binders should be determined by subtracting the unit binder volume from the unit powder volume.

6.3.6 Viscosity agent content

The dosage of a viscosity agent should be determined to attain stable fresh concrete properties and the specified segregation resistance.

6.3.7 Air content

The standard air content of fresh concrete requiring high resistance to frost damage should be 4.5%.

6.3.8 Dosage of air-entraining and high-range water-reducing admixture

The dosage of an air-entraining and high-range water-reducing admixture should as a rule be determined by testing to attain the specified slump flow.

6.3.9 Fine aggregate content

The fine aggregate content should be determined by subtracting the volume of all the other materials including the air content from a volume of 1 m^3.

6.4 Establishment of specified mixture Proportions

6.4.1 Confirmation of qualities of fresh concrete

(1) Trial mixture should be made according to the initial mixture proportions, with which it should be confirmed that their qualities satisfy the performance requirements for fresh concrete.

(2) The qualities of fresh concrete to be confirmed should generally be as follows:

1) Deformability
2) Resistance to segregation
3) Self-compactability

6.4.2 Modification of mixture proportions based on fresh concrete test results

(1) When the trial mixtures do not attain the required properties of fresh concrete, the dosages of chemical admixtures, unit water content, powder content (water-powder ratio by volume) and coarse aggregate content should be modified accordingly. The time of self-compactability retention and air content should also be modified accordingly where these should be considered as performance requirements.

(2) When the target values for fresh concrete still cannot be attained by such modification, the concrete should be reproportioned using different materials. Where the materials cannot be changed easily, the proportioning should be totally reviewed including the target values.
(3) When the deformability and/or segregation resistance of concrete do not attain the target values and yet the state of concrete is satisfactory with the self-compactability attaining the target value, the target values established for the initial proportions may not be adequate. In that case, the target values should be reviewed.

6.4.3 Confirmation of the qualities of hardened concrete

It should be confirmed that the mixture proportions satisfying the performance requirements for fresh concrete also satisfy the initial1y established performance requirements for hardened concrete. This should be confirmed by the direct measurement of trial mixtures or other methods.

6.4.4 Modification of mixture proportions based on hardened concrete test results

When the qualities of hardened concrete do not satisfy the initially established performance requirements, the materials and mixture proportions should be modified, and trial mixtures should be made again for confirmation that the hardened concrete satisfy the performance requirements. The specified mixture proportions should then be established.

6.4.5 Form for expressing the specified mixture proportions

The form for expressing the specified mixture proportions should be described as follows.
Notes: 1) More than one powder with different specific gravities may be used for combination-type self-compacting concrete. In that case, it may be more appropriate to measure the powder quantities by volume. Therefore, the water-powder ratio is required to be indicated in terms of volumetric ratios.
2) When more than one material of the same kind is used, each should be indicated in a separate box.
3) The dosage of an air-entraining and high-range water-reducing admixture or superplasticizer should be indicated in kg/m^3 and should be included in the unit water content.
4) The dosage of a viscosity agent should be indicated in kg/m^3.
5) The dosages of other chemical admixtures should be indicated in ml/m^3 or g/m^3, and should be indicated undiluted and. undissolved.