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Approval & Reception Procedure

DMC – Departamento de Materiais de Construção		
Ready Mixed Concrete	Document no.	**ARP/DMC/014**
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1 REFERENCE STANDARDS

Macau Standard for Concrete (N.B. - “Norma de Betões de Macau”)

Macau Standard for Cement (N.C. - “Norma de Cimentos de Macau”)

ASTM C 1202 Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

ASTM C 1260 Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

EN 206-1 Concrete – Part 1 : Specification, performance, production and conformity

BS EN 12620 Aggregates for concrete

EN 13263-1 Silica fume for concrete – Part 1 : Definitions, requirements and conformity criteria

DB44/T 566 抗海水腐蝕混凝土應用技術導則 Technical directives for anti-seawater concrete

GB/T 18046 用於水泥和混凝土中的粒化高爐礦渣粉 Ground granulated blast furnace slag used for cement and concrete

GB/T 50082 混凝土長期性能和耐久性能試驗方法 Standard for test methods of long-term performance and durability of ordinary concrete

GB 50204 混凝土結構工程施工質量驗收規範 Code for acceptance of constructional quality

GB/T 50476 混凝土結構耐久性設計規範 Code for durability design of concrete structures

ISO 1920 Part 1 to Part 5, Test of concrete

2 APPROVAL PROCEDURE

2.1 Submissions

2.1.1 Certified batching plant

2.1.1.1 Ready-mixed concrete certificate and certificate appendix issued by LECM.

2.1.1.2 Concrete mix composition (including mix code, concrete grade, maximum size of aggregates, consistency class, dosage and origin of constituent materials).

2.1.1.3 Type of concrete (structural or non-structural, usage, plain, reinforced or pre-stressed), environmental condition, method of placing and curing.

2.1.1.4 Test report about the ability of concrete to resist chloride ion penetration (only apply to marine structures and structures exposed to chloride ion).

2.1.1.5 Test reports of aggregates:

Table 1

Tests	Coarse aggregates	Fine aggregates	Validation period (inspection frequency)
Alkalis-aggregate reactivity (ASTM C1260) (A)	✔	✔	Recent 6 months
Chloride contents (B)	---	✔	Recent 1 month

Remarks:

(A) In case of same source for coarse and fine aggregates, either one should be tested.

(B) Only for river sand.

2.1.1.6 Copy of conformity certificate of cement issued by LECM, or plan for reception of cement in accordance with Art. 9 of N.C. - “Norma de Cimentos de Macau”. Test certificate according to Tables 3 and 4 of N.C. (not older than 3 months), and including information of alkali content of cement (expressed as Na_2O_{equ}).

2.1.2 Non-certified batching plant

2.1.2.1 Quality management system documents of the batching plant (detail listed in appendix).

2.1.2.2 Concrete mix composition (including mix code, concrete grade, maximum size of aggregates, consistency class, dosage and origin of constituent materials).

2.1.2.3 Type of concrete (structural or non-structural, usage, plain, reinforced or pre-stressed), environmental condition, method of placing and curing.

2.1.2.4 Test report about the ability of concrete to resist chloride ion penetration (only apply to marine structures and structures exposed to chloride ion).

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2.1.2.5 Test reports of aggregates:

Table 2

Tests	**Coarse aggregates**	**Fine aggregates**	**Validation period (inspection frequency)**
Sieve analysis	✔	✔	Recent 6 months
Relative density (specific gravity)	✔	✔	
Water absorption	✔	✔	
Very fine particles and soluble materials	✔	✔	
Elongation index and flakiness index	✔	---	
Volumetric index	✔	---	
LA tests or compressive strength or crushing Strength	✔	---	
Organic materials (B)	---	✔	
Alkalis-aggregate reactivity (ASTM C1260) (A)	✔	✔	Coarse aggregate and crushed stone fine: recent 6 months River sand: recent 3 months
Chloride contents (B)	---	✔	Recent 1 month

Remarks:

(A) In case of same source for coarse and fine aggregates, either one should be tested.

(B) Only for river sand.

2.1.2.6 Manufacturer technical specifications of admixtures, and test certificates of relative density and chloride content (not older than 6 months).

2.1.2.7 Copy of conformity certificate of cement issued by LECM, or plan for reception of cement in accordance with Art. 9 of N.C. - “Norma de Cimentos de Macau”. Test certificate according to Tables 3 and 4 of N.C. (not older than 3 months), and including information of alkali content of cement (expressed as Na_2O_{equ}).

2.1.2.8 Test certificates of PFA on the relevant properties specified in Table 5 of N.B, if used as an addition to concrete (not older than 6 months).

2.1.2.9 Test certificates of other additions (if any) on the relevant properties specified in reference standards, if used as an addition to concrete (not older than 6 months).

2.1.2.10 Relevant concrete mix design, job references and statistic of recent 3 month test results of concrete compressive strength with the same grade, production procedure and concrete mix composition, in accordance with the sampling frequency stated in N.B. The minimum test result records of samples should not be less than 30 sets.

2.1.2.11 Calibration certificate of dosage measuring equipment (not older than 6 months).

2.2 Inspection of batching plant

2.2.1 Certified batching plant

2.2.1.1 Can be exempted.

2.2.2 Non-certified batching plant

2.2.2.1 After the above documentation review, inspection on batching plant will be carried out, include verification of calibration certificate of dosage measuring equipment and testing equipment, stack of constituents, curing facility, and proficiency of the batching plant to produce concrete conforming to the technical specifications.

2.3 Verification of trial mix

2.3.1 Plant trial mixes are required for structural concretes at the related approved batching plant.

2.3.2 Certified batching plant

2.3.2.1 For mix design belonging to the certified family, the verification of trial mix could be exempted. For other mix design produced by the batching plant, after documentation approval of the concrete mix design, 1 trial mix shall be performed, at least 35 days in advance of production, LECM shall witness and verify the performance of the fresh and harden concrete.

2.3.3 Non-certified batching plant

2.3.3.1 After documentation approval of the concrete mix design, 3 times of trial mix will be performed in 3 different dates respectively, at least 35 days in advance of production. LECM shall witness and verify the performance of the fresh and hardened concrete.

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Sample of aggregates shall be taken for sieve analysis. Samples of river sand shall be taken for testing of ASR and chloride content.

2.3.4 Verification of trial mix could be exempted when trial mix verification is taken place within 3 months from the submission date and sufficient quality control information is provided (for concrete with the same grade, production procedure and concrete mix composition).

2.3.5 If there is any change of the source or type of constituents, trial mix should be re-done.

2.3.6 If there is any significant change in the batching environmental condition, trial mix should be re-done.

2.3.7 If there is any significant change in the performance of concrete, trial mix should be re-done.

2.3.8 Any change in the mix design shall be approved in advance and trial mix should be re-done.

2.3.9 Waterproofing, setting time, bleeding, air content or other performance shall be verified on trial mix, if applicable.

2.3.10 For the marine structures or structures exposed to chloride ions, the ability of concrete to resist chloride ion penetration shall be verified on trial mix.

3 Intermediate check of concrete production

3.1 Certified batching plant

3.1.1 Maintain the validation of certificate of batching plant.

3.2 Non-certified batching plant

3.2.1 At least 1 visit every 3 months shall be made to the batching plant, to verify the calibration of dosage measuring equipment and testing equipment, stack of constituents, curing facility, and batching records.

3.2.2 Submissions of test certificates, the 3rd party test reports and documents about the source of constituents shall be according to table 3.

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Table 3		
Constituents	**Test certificate & the 3rd party test report**	**Source control**
Cement	Submit test certificate each month	Submit origin certificate and delivery notes monthly
Coarse aggregate	Submit report of test listed in Table 2	
Crushed stone fine		
River sand		
Additions	Submit test reports each 6 months	
Admixture		

4 RECEPTION PROCEDURE

4.1 The contractor should submit a weekly concrete casting plan in advance, including the following information:

4.1.1 Date of casting;

4.1.2 Casting locations;

4.1.3 Mix code, concrete grade, consistency class and corresponding volumes;

4.1.4 Number of cubes to be fabricated for compressive strength tests.

4.2 The contractor is responsible for all operations involved in the reception of concrete, such as:

4.2.1 Verifying the arrival of concrete on the site, i.e. mix code and concrete grade;

4.2.2 Collecting samples and performing all required tests, such as consistency test, temperature measurements, fabrication and marking of cubes, and delivery of cubes to the approval 3rd laboratory for testing. The contractor must have all the equipment necessary.

4.2.3 Maintaining a register of the concrete reception, including:

A. Delivery notes of concrete
B. Location of placing
C. Time of batching, delivery, and placing
D. Volume of concrete placed

E. Tests made

F. Number of cubes fabricated for compressive tests and their ID

G. Results of consistency tests and temperature

4.3 Sampling frequency

4.3.1 Consistency tests

4.3.1.1 Sampling frequency for consistency tests should be 1 test per each 15 m^3 of concrete.

4.3.2 Compression tests

4.3.2.1 For each sample, 6 cubes should be taken (3 cubes for 7 days and 3 cubes for 28 days), unless otherwise specified. Cubes shall be marked with a unique, consecutive, sequential number; and shall be marked with project name, casting date and concrete grade.

4.3.2.2 Certified concrete

4.3.2.2.1 A sampling frequency of not less than the bigger of the following values: one sample for each 75 m^3 of concrete, or one sample for one-day of site concrete casting.

4.3.2.3 Non-certified concrete

4.3.2.3.1 A sampling frequency of not less than the bigger of the following values: one sample for each 30 m^3 of concrete, or one sample for one-day of site concrete casting. In the case of continuous casting of one type of structural element (e.g. slabs, column, walls or foundations), with the same concrete and a volume of more than 200 m^3, a sampling frequency of no less than one sample for each 50 m^3 of concrete can be adopted.

4.3.2.4 If compressive strength test of cores are required, a set of samples should include three cores. Sampling and testing frequency should be agreed in advance.

4.3.3 Temperature tests

4.3.3.1 Whenever required.

4.3.3.2 Temperature tests should be done during sampling of fresh concrete for cube fabrication.

4.3.4 Water permeability

4.3.4.1 Sample for water penetration tests shall be taken. The frequency of sampling and tests shall be agreed in advance; each sample comprises of at least 3 specimens.

4.3.5 Chloride content

4.3.5.1 Certified batching plant

4.3.5.1.1 Once every 3 months for concrete work, by sample taken from structures.

4.3.5.2 Non-certified batching plant

4.3.5.2.1 Once a month, by sample taken from structures, or per 5000 m^3 of concrete cast on the site, whichever is less.

4.3.6 Other properties

4.3.6.1 If the test of setting time, bleeding, air content, chloride resistance or other performance is required, the sampling frequency shall be agreed in advance.

5 ACCEPTANCE CRITERIA

5.1 Constituent materials

5.1.1 Cement quality shall comply with N.C.

5.1.2 The quality of additions and admixtures shall comply with N.B, EN 13263-1 and GB/T 18046.

5.1.3 The quality of aggregates shall comply with N.B and BS EN 12620.

5.1.4 The elongation index shall be ≤ 35% and the flakiness index shall be ≤ 30%.

5.1.5 Alkalis-aggregate reactivity tested in accordance with ASTM C 1260, acceptance criteria for mortar bar expansion (ε) at the 16th day shall be:

5.1.5.1 $\varepsilon < 0.10$ %, can be used for all structures;

5.1.5.2 $0.10\% \leq \varepsilon \leq 0.20\%$ cannot be used for marine structures and structures exposed to water or soil containing alkaline salt or marine atmosphere. When it is used for structure other than the above, the following conditions shall be fulfilled:

- The alkali content (Na_2O_{equ}) of cementitious material is less or equal to 0.6%, and
- The alkali content (Na_2O_{equ}) of concrete is less or equal to 3.0 kg/m^3.

5.1.5.3 $\varepsilon > 0.20$ %, the aggregate cannot be used.

5.1.6 Chloride content of aggregate shall be less or equal to 0.01% (EN 12620).

5.2 Trial mix

5.2.1 The strength of cubes shall comply with the following criteria:

$f_{cum} \geq f_{ck}+1.645S_n$

$f_{cu,min} \geq f_{ck} + 5MPa$

where:,

f_{cum} – average strength of cubes;

$f_{cu,min}$ – lowest individual value of cube strength;

f_{ck} – specified characteristic strength of concrete;

S_n – standard deviation strength of cubes (either equal to the statistical value of the same type of concrete with not less than 30 sets of samples and the minimum value not less than 3.0 MPa, or the value of 5.0 MPa if there is not any statistics information);

5.3 Consistency tests

5.3.1 The acceptance criteria for consistency tests should follow the requirements specified in N.B.

5.4 Temperature tests

5.4.1 The maximum temperature of the concrete delivered to site shall not be greater than 35°C.

5.4.2 For mass concrete, measures should be taken to enable the temperature difference will not greater than 20°C within the casted concrete structure and the maximum temperature shall not be higher than 70°C.

5.5 Acceptance criteria for compression tests

5.5.1 A sample's strength value shall be equal to the average value of the test results of 3 test specimens, expressed in MPa. If the difference between the highest and lowest specimen result exceeds 15% of the sample's strength, this sample shall be rejected. Except there is sufficient reason to eliminate the test result of one specimen, then the sample's strength value could be equal to the average value of the test results of the rest 2 test specimens.

5.5.2 Certified concrete

5.5.2.1 Criterion 1 - This criterion is applied when conformity is verified in 6 or more consecutive samples, with strengths of x_1, x_2 ... x_n.

$$f_{cm} \geq f_{ck} + 1.48\, s_n$$

$$f_{c,\,min} \geq f_{ck} - k$$

where:

f_{cm} – average strength for a set of samples;

$f_{c,\,min}$ – lowest individual value in a set of samples;

s_n – standard deviation for strength in a set of samples;

f_{ck} – characteristic strength specified for concrete;

k - constants that depend on the number (n) of samples (Table 4).

If more than 15 sample results are available, criterion 1 should be used in all consecutive 15 sample results.

Table 4. Values of λ and k

n	λ	k
6	1.87	3
7	1.77	3
8	1.72	3
9	1.67	3
10	1.62	4
11	1.58	4
12	1.55	4
13	1.52	4
14	1.50	4
15	1.48	4

5.5.2.2 Criterion 2 - This criterion is applied when conformity is verified in 2, 3, 4 or 5 consecutive samples whose strength values are $x_1 \ldots x_n$ (n=2, 3, 4 and 5).

$$f_{cm} \geq f_{ck} + 3$$

$$f_{c,min} \geq f_{ck} - 1$$

where:

f_{cm} - average strength for a set of samples;

$f_{c,min}$ - lowest individual value in a set of samples;

f_{ck} – characteristic strength specified for concrete.

5.5.2.3 Criterion 3 - This criterion is applied when conformity is verified considering only 1 sample whose strength values are x_1.

$$x_1 \geq f_{ck}$$

where:

f_{ck} – characteristic strength specified for concrete.

5.5.3 Non-certified concrete

5.5.3.1 Criterion 1 - This criterion is applied when conformity is verified in 6 or more consecutive samples, with strengths of x_1, x_2 ... x_n.

$$f_{cm} \geq f_{ck} + \lambda s_n$$

$$f_{c,\,min} \geq f_{ck} - k$$

where:

f_{cm} – average strength for a set of samples;

$f_{c,\,min}$ – lowest individual value in a set of samples;

s_n – standard deviation for strength in a set of samples;

f_{ck} – characteristic strength specified for concrete;

λ and k - constants that depend on the number (n) of samples (Table 4).

If more than 15 sample results are available, criterion 1 should be used in all consecutive 15 sample results.

5.5.3.2 Criterion 2 - This criterion is applied when conformity is verified in 2, 3, 4 or 5 consecutive samples whose strength values are $x_1 \ldots x_n$ (n=2, 3, 4 and 5).

$$f_{cm} \geq f_{ck} + 5$$

$$f_{c,min} \geq f_{ck} - 1$$

where:

f_{cm} - average strength for a set of samples;

$f_{c,min}$ - lowest individual value in a set of samples;

f_{ck} – characteristic strength specified for concrete.

5.5.3.3 Criterion 3 - This criterion is applied when conformity is verified considering only 1 sample whose strength values are x_1.

$$x_1 \geq f_{ck}$$

where:

f_{ck} – characteristic strength specified for concrete.

5.5.4 The average value of estimated cube strength for cores should not be less than 100% of the characteristic strength and the minimum value should be at least 85%.

5.6 Water permeability

5.6.1 The maximum water permeable depth of each individual specimen shall be not greater than 50 mm and the average of water permeable depth of the specimens shall be not greater than 20 mm.

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5.7 Chloride contents of concrete

5.7.1 The chloride content of concrete shall comply with Table 5 (or Table 6) and the design requirements (see DB44/T 566, GB/T 50476).

Table 5. Maximum chloride content of concrete mix	
End use of concrete	**Maximum chloride content (in relation to the mass of cementitious material)**
Plain concrete	1.00%
Reinforced concrete (or containing other embedded metal devices)	0.20% (exposure class 1 & 2) 0.10% (exposure class 3)
Pre-stressed concrete	0.06% (exposure class1, 2 & 3)

Table 6 Maximum chloride content in harden concrete	
End use of concrete	**Maximum chloride content (in relation to the mass of concrete)**
Plain concrete	0.15%
Reinforced concrete (or containing other embedded metal devices)	0.03%（exposure class 1 & 2） 0.015 % (exposure class 3)
Pre-stressed concrete	0.009%（exposure class1, 2 & 3）

5.8 Ability to resist chloride ion penetration

5.8.1 The ability to resist chloride ion penetration of concrete shall comply with Table 7 (or Table 8) and the design requirements (see DB44/T 566, GB/T 50476).

Table 7 Chloride ion penetrability in concrete based on charge passed (at the age of 56d, C)						
Design service period	**100 years**		**70 years**		**50 years**	
Exposure Class	Moderate, severe	very severe, extreme	Moderate, severe	very severe, extreme	Moderate, severe	very severe, extreme
Charge passed for 6 hours	<950	<800	<1100	<800	<1350	<950

Table 8 Concrete resistance to chloride ion migration index , D_{RCM}(at the age of 28d,$10^{-12}m^2/s$)						
Service period of Design	**100 years**		**70 years**		**50 years**	
Exposure Class	Moderate, severe	very severe, extreme	Moderate, severe	very severe, extreme	Moderate, severe	very severe, extreme
chloride ion migration index	≤6	≤4	≤7	≤4	≤10	≤6

5.9 Acceptance criteria for other properties

5.9.1 Other properties shall conform to N.B and designed requirements.

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Appendix

Quality management system documentation of batching plant

- Most updated product catalogue；
- Most updated quality manual；
- Most updated operational procedure；
- Most updated work instruction including：
  - test item, method and its frequency on the raw materials related with concrete production；
  - test item, method and its frequency on concrete production process；
  - test item, method and its frequency on concrete；
  - details about product identification and its traceability。
- Valid certificate about quality management；
- Most Updated organization structure, including management representative；
- Factory layout；
- Recent management review report；
- Recent internal and external audit report；
- Recent customer survey report。