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1. SCOPE

This specification provides definitions and requirements for the production, testing, and storage of concrete armour units (CAUs) intended to be used in the construction of marine rubble mound structures such as breakwaters, revetments, scour protection and groynes.

2. DEFINITIONS

For the purposes of this specification the following definitions apply:

CAU: Concrete Armour Unit.

Dolos: precast concrete armour unit (CAU) forming the outer layer to the seawall.

Seawall/Revetment: A structure consisting of rock rubble and armoured with armourstone or concrete armour units (CAUs) constructed along the shoreline primarily to protect landside infrastructure from waves and storm surges as well as protect the shoreline from erosion

Tonne (abbreviated t): Metric ton, 1000 kg.

3. MATERIALS

Concrete for use in the armour units is covered by specifications SANS 2001-CC1:2012 Construction works, Part CC1: Concrete works (structural) (SANS 2001-CC1), and Variations to SANS 2001-CC1: Constructions works, Part CC1: Concrete works (structural) for marine works (Variations to SANS 2001-CC1).

Concrete for CAUs must have the characteristics shown below:

a) Minimum flexural strength on removal from soffit form (*) : 2 MPa
b) Minimum 28 day compressive crushing strength : 40 MPa
c) Minimum 28 day flexural strength (**) : 4 MPa
d) Maximum stone aggregate size (***) : 40 mm
e) Minimum concrete density : 2400 kg/m^3

*: Note that this strength requirement is directed towards the early age lifting and handling of dolos CAUs. Antifer CAUs may be lifted at a lower flexural strength provided that it can be demonstrated by the Contractor that the units will not be overstressed.

**: Two point loading method to SANS 5864

***: Note that tensile strength is decreased as aggregate size is increased

The minimum binder contents and water/binder ratios specified in Variations to SANS 2001-CC1 must be fulfilled.

4. EQUIPMENT

4.1. General

Suitable equipment must be provided for the safe casting, handling, transport and storage of the CAUs.

Suitable access equipment must be provided for personnel to safely undertake quality inspections of CAUs in the casting yard and storage area.

All equipment must comply with the specified safety and environmental requirements and requirements stipulated by law.

5. CONSTRUCTION

5.1. Preparation of on-site casting yard

The Contractor must design and construct a facility for the casting, handling and storage of the CAUs.

The yard must be so designed as to facilitate all operations associated with the setting up and handling of formwork, casting, stripping, curing, handling and storage of the units. The stacking area must be designed to accommodate the high loading intensities imposed by the stacked units without excessive settlement.

Casting beds must be properly aligned and levelled. The casting and storage area must be provided with even and compacted access roads to enable safe handling and transport of units.

5.2. Manufacture and storage of CAUs

5.2.1. General

Since CAUs are manufactured without steel reinforcement the concrete strength and in particular the consistency of tensile strength is of critical importance. The development of cracks in the concrete which severely weakens the tensile strength of concrete must therefore be prevented. Aspects that need special attention include:

Prevention of cracks in concrete that can develop due to restraint by the formwork on concrete during dry shrinkage after casting.

Prevention of cracks in concrete that can develop as a result of excessive temperature difference between concrete core and surface during curing.

Prevention of cracks in concrete that can develop as a result of inappropriate handling during formwork removal, transport and placing in storage and finally in the seawall armour layer.

5.2.2. Casting

Concrete must be transported and placed within 60 minutes of mixing.

Placing of concrete must conform to the requirements of SANS 2001-CC1 and Variations to SANS 2001-CC1.

Special arrangements must be made when air temperatures exceed 35 °C. In all cases the concrete temperature on placing must be less than 30 °C.

The mould of each unit must be filled in one pour of several batches to form a complete unit. The exposed surfaces must be wood-floated.

If the filling of a mould is stopped for more than half an hour due to a breakdown of plant or any other cause whatsoever, the unit must be rejected, and must not be used in the works.

5.2.3. Curing

Curing of the CAUs after casting must conform to the methods and timing requirements of SANS 2001-CC1 and Variations to SANS 2001-CC1.

Curing must commence as soon as possible after placing of the concrete for un-formed surfaces, and immediately after removal of formwork elsewhere.

Retention of the formwork on formed surfaces after casting may be counted as part of the curing period, provided they are made with non-absorbent facing materials. Care must be taken that the forms do not restrain the unit and cause shrinkage cracks. For unformed surfaces the compound must be applied after finishing and as soon as the free water on the surface has disappeared and no water sheen is visible. When forms are removed, the exposed concrete surface must be wet with water immediately and kept moist until the curing compound is applied. Immediately prior to application, the concrete must be allowed to reach a uniformly damp appearance with no free water on the surface. Application of the compound must then begin at once. The compound must be applied at a uniform rate with two applications at right angles to each other to ensure complete coverage and may be applied by hand or power sprayer. Pigmented compounds must be adequately stirred to assure even distribution of the pigment during application, unless the formulation contains a thixotropic agent which prevents settlement.

The surface must be prepared, and the curing compound must be applied, strictly in accordance with the manufacturer's printed instructions.

In the case of concrete surfaces with run-off problems, it may be necessary to apply more than one coat of membrane forming curing compound to obtain the specified total or cumulative application rate.

When the wind velocity exceeds 5 m/s, or the ambient temperature is above 25 °C, or the relative humidity is below 60 percent, the initial 24 hour curing of concrete surfaces not covered by formwork must be carried out by continuous spraying with fresh water. The *Contractor* must have a handheld weather station during curing, or alternative Equipment accepted by the *Supervisor*, for recording wind, temperature and humidity.

All water for curing must be clean, fresh water and seawater must not be used.

5.2.4. CAU quality acceptance criteria

A high-quality finish is required for the CAUs, and they must be free from honeycombing, cracks, blow holes, surface delamination and cold joints. CAUs must have the specified mass and concrete strength, and must be cured as specified.

However, it is recognised that some surface blemishes will always be present, and that some CAUs with significant blemishes can still be used in the works in locations where the full performance of the unit is not required.

For each type and size of CAU a set of quality criteria is defined, together with the levels of quality that determine its acceptance grade or rejection. Two acceptance grades are defined:

- Acceptance Grade 1: No restrictions on placement location and may be used anywhere in the works where the unit type and size is specified.
- Acceptance Grade 2: A unit of lower than ideal quality but still considered acceptable for use in the works in particular designated zones. The zones, if any, where Acceptance Grade 2 units may be placed is defined in the project particular specification or drawings

The acceptance criteria for the CAUs are given in **Table 5-1**. A CAU falls into an acceptance category if all the listed criteria are met.

CAUs must be left in an "as-cast" condition, and the off-shutter surface must not be finished off or made good in any way. Surface imperfections, cracks, and honeycombing must be left as cast, and not repaired of covered up in any way. CAUs that are not in an "as-cast" condition must not to be used in the *works*.

Table 5-1: Quality acceptance criteria for 3 t dolos.

No	Quality criteria	Acceptance Grade 1	Acceptance Grade 2	Rejection
		Quality levels for unrestricted placement	**Quality levels for placement in designated zones**	**Quality levels for rejection**
1	Mass	> 98 % of 3 t	97-98 % of 3 t	< 97 % of 3 t
2	Leading dimensions tolerance	-0 mm/+10 mm	-0 mm/+20 mm	< 0 mm or > 20 mm
3	Concrete 28-day compressive crushing strength	Complies with SANS 2001-CC1 clause 5.1.2 for the specified compressive strength		Does not comply with SANS 2001-CC1 clause 5.1.2 for the specified compressive strength
4	Concrete 28-day tensile strength	≥ specified tensile strength		< specified tensile strength

No	Quality criteria	Acceptance Grade 1	Acceptance Grade 2	Rejection
		Quality levels for unrestricted placement	**Quality levels for placement in designated zones**	**Quality levels for rejection**
5	Honeycombing	None	< 200 cm^2 for whole unit and < 10 cm deep	> 200 cm^2 for whole unit or > 10 cm deep
6	Settlement defect from fresh concrete hanging up on the formwork at the top of the cast	None	< 130 cm for whole unit	> 130 cm for whole unit
7	Shrinkage cracks on unformed top surfaces	< 0.1 mm width	< 0.5 mm width	> 0.5 mm width
8	Blow holes on formed surfaces	Largest blow hole < 2 cm^2 and < 1 cm deep	Largest blow hole < 8 cm^2 and < 1.5 cm deep.	Largest blow hole > 8 cm^2 or > 1.5 cm deep
9	Cracks at the transition of the dolos waist and fluke	None	< 0.1 mm width and < 13 cm long	> 0.1 mm width or > 13 cm long
10	Surface air bubbles	None	Largest air bubble < 12 cm^2 area and < 2 cm deep located at chamfer corners	Largest air bubble > 12 cm^2 area or > 2 cm deep located at chamfer corners
11	Surface delamination due to damage at stripping	None	< 200 cm^2 area for whole unit and < 2 cm deep	> 200 cm^2 area for whole unit or > 2 cm deep

5.2.5. CAU marking

The units must be clearly and legibly marked showing a serial number and the date on which the unit was cast. Such markings must be permanent (impressed 10 mm into the fresh concrete before setting) so that they can be easily read for a period of at least one year after casting. In addition, the number of each CAU must be painted in red with the aid of number stencils (250 mm number height) on opposing faces of the CAU with an accepted red paint not longer than 7 days before placing of CAUs in the seawall armour layer.

5.2.6. Handling and storing

Dolos CAUs must not be moved until the concrete has reached a tensile strength of at least 2.0 MPa, as determined by flexural tests or by correlation with compressive test results. Antifer CAUs may be moved at a lower tensile strength, to be determined by the *Contractor*.

The *Contractor*, when devising his methods and considering the risks takes cognisance of the risk of exceeding concrete tensile and bearing strengths at the time of lifting. The *Contractor* must submit calculations to the *Supervisor* for acceptance that indicate the stresses and safety factors in the CAUs during lifting. The units must be stored in a neat and orderly manner. The serial number and date of casting of each unit must always be clearly visible.

5.2.7. CAU stockpile

A stacking plan must be drawn up which is commensurate with the overall project planning, giving due regard to the casting yard capacity and production lead-in time.

Stacking areas must be sized taking into considerations the CAU size, access, weight limitations, manoeuvring and handling requirements. If possible, a one-way rotation system must be instituted for controlling traffic. The stacking area must be checked for existing services to avoid risk of damage.

The *Contractor* must prevent unauthorized pedestrian access, keep stockpile areas well-lit during night operation, maintain equipment in adequate working condition, and keep suitable backup equipment nearby.

The CAUs must not be used in the works before the specified minimum flexural and compressive crushing strengths are reached.

6. TOLERANCES

The CAU mould must be fabricated so that the leading dimensions are within a tolerance of -0 mm/+10 mm.

The mass of all CAUs, when weighed in accordance with Section 8.2.3 of this Specification, must equal or exceed 98 percent of the nominal mass.

The concrete compressive strength at 28 days must comply with the requirements of SANS 2001-CC1 and the Variations to SANS 2001-CC1.

The concrete tensile strength must be greater than the requirements of this specification.

7. METHOD STATEMENTS

The method statements required for the production of the CAUs are stated in the Coastal Structures Particular Technical Specification. The following aspects must be addressed:

a) Concrete mix:
- Material types and sources
- Mix quantities
- Concrete strengths

- Concrete density
- Risk of AAR/ASR

b) Casting yard

- Arrangement
- Concrete mixing equipment
- Mould details and usage
- Times of removal of side formwork
- Times of lifting from soffit form
- Curing method and timing
- Short term stacking
- Lifting and transport devices
- Dust and noise control
- Risk management:
    - Health, safety and environmental
    - Mould restraint
    - Generation of excessive concrete hydration temperatures
    - Damage to fresh CAUs (check on tensile stresses induced from lifting)

c) Stacking/storage yard

- Stacking arrangements
    - Plan layout
    - Stacking height
    - Surface bed and/or base details
    - Lighting
    - Dust and noise control
- Lifting devices
- Traffic flow
- Risk management:
    - Health and safety
    - Damage to CAUs in storage

8. INSPECTION, TESTING AND QUALITY RECORDS

8.1. Inspections

8.1.1. Inspection of mould before casting

The *Contractor* must give the *Supervisor* the opportunity to inspect each prepared and assembled mould before casting of concrete.

8.1.2. Post casting inspections

The *Contractor* must facilitate access for the *Supervisor* to inspect the CAUs after the units have been removed from the mould. The *Contractor* must provide the necessary equipment for safe personnel access to all faces of the units.

8.2. Testing

8.2.1. Concrete

Testing of all concrete must comply with SANS 2001-CC1 and SANS 5864 with variations and additions as per the Variations to SANS 2001-CC1.

a) Required concrete tests:
- Alkali aggregate reactivity potential
- Density of fresh mix
- Slump
- Compressive strength
- Tensile strength
- Hard concrete density

8.2.2. CAU formwork dimensions

The *Contractor* must measure and record the dimensions of all CAU moulds.

8.2.3. CAU mass

The *Contractor* must check the mass of at least 2 CAUs cast from each mould no earlier than 28 days after casting, using a certified weighing device accepted by the *Supervisor*. The weighing device must be accurate to ± 10 kg.

8.3. Quality records

As a minimum the following quality information for the CAUs must be recorded by the *Contractor*.

8.3.1. Concrete

a) Concrete material types and sources
b) Concrete mix details
c) Tests
    - Compressive strength
    - Tensile strength

- Density
- Alkali aggregate reactivity

d) Product certification:
- Admixtures
- Curing compound

8.3.2. CAU casting records

- CAU unique serial number
- Unique serial number of mould used
- Mould inspection before casting
  - Date
  - Inspector names
  - Condition of formwork
  - Other comments
- Casting of CAU
  - Date and time of cast
  - Weather conditions
  - Ambient temperature
  - Concrete mix used
  - Fresh concrete tests:
    - Density of fresh mix
    - Slump
    - Special arrangements for hot weather
- Curing
  - Curing method
  - If curing compound used:
    - Curing compound used
    - Date of application of curing compound
  - If moist curing used:
    - Moist curing method used
    - Date curing started
    - Date curing stopped

- Hard concrete tests
  - Compressive strength (intermediate and 28 day)
  - Tensile strength (intermediate and 28 day)
  - Density
- CAU Mass (if measured)
- Post-cast inspection
  - Date
  - Inspector names
  - Checks for quality criteria
  - Acceptance grade or rejection of unit
- Placement in structure
  - Date placed
  - Position placed
  - Confirmation that placed position matches acceptance grade