Mike Chemaly
Associate
WSP Africa Coastal Engineers
mike.chemaly@wspgroup.co.za

Failure of the Gansbaai leeward breakwater

BACKGROUND

Gansbaai's New Fishing Harbour is located in an area along the South African coastline subject to severe wave conditions (heights of 8 m to 9 m are not uncommon during an average winter season). It is located approximately 65 km northwest from the southernmost tip of Africa. Emergency repairs became vital when sections of the 200 m long leeward breakwater failed. A total of 60 m (Ch 66 to Ch 126) of breakwater had failed by March 2011 when the contractor, Guerrini Marine Construction, arrived on site.

EXISTING CROSS SECTION

In the 60 m of damaged area (Ch 66 m and Ch 126 m) the existing breakwater cross section was made up as follows: The core consisted of 0–500 kg material. The grading distribution of the core was unknown at the time of tender. The core was overlain by a 500 mm thick x 7 m wide concrete roadway. The sea-facing roadway edge had a 900 mm high parapet wall. The core slopes were shaped to 2V:3H and overlain by a double layer 1-3 t armour rock.

The entire breakwater cross section is underlain by a near horizontal

Table 1 Summary of failure mechanisms related to the Gansbaai breakwater failure

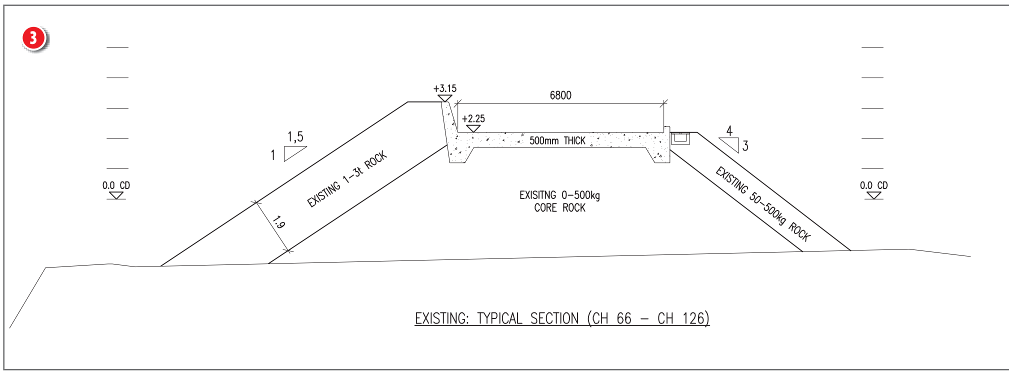
Ch 66 m – Ch 96 m	Failure Mechanism 1	Failure of armour rock to shoulder, slope and toe
Ch 66 m – Ch 96 m	Failure Mechanism 2	Loss of fines in core and collapse of concrete roadway
Ch 96 m – Ch 126 m	Failure Mechanism 1	Failure of armour rock to shoulder, slope and toe

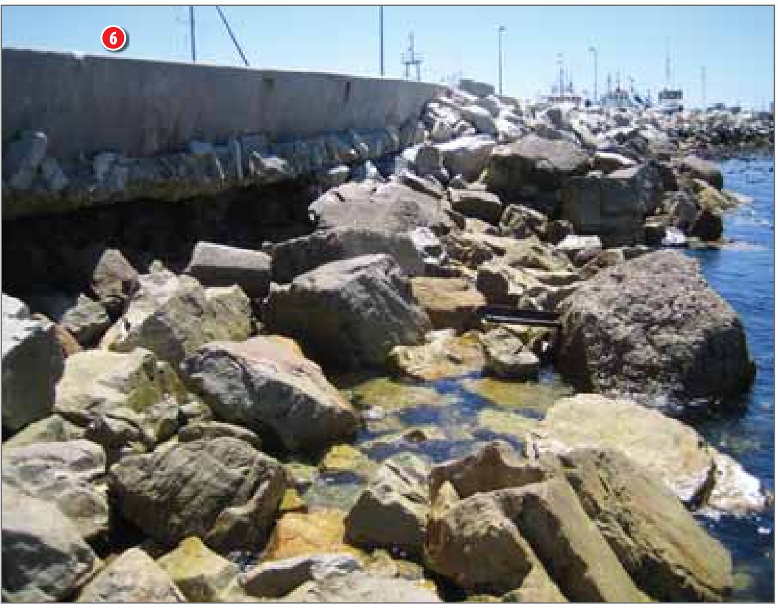
plane of bedrock. This bedrock profile has a final ground level on roughly +0,3 m CD. This level coincides with the Mean Low Water Spring level of +0,27 m CD. This horizontal plane of bedrock extends roughly 2 m past the armour rock toe, after which it dips steeply to form a vertical reef-like edge.

DAMAGE

Along the first 30 m (Ch 66 – Ch 96) of the 60 m section of failed breakwater, rock armour had been displaced over a distance of 30 m from the breakwater, due to severe wave action in May 2010. Wave-breaking along this section of the break-water is in the form of plunging breakers on a hard rock bed (resulting in Failure Mechanism 1 – see Table 1). In addition the original core that predominantly consisted of fine material, unprotected by a geomembrane, had washed out from the

1. Gansbaai – South Africa
2. Gansbaai – New Fishing Harbour and location of damage
3. Existing typical section (Ch 66 – Ch 126)
4. 1 000 mm deep by 30 m long entrance under structure
5. Shear crack running for 30 m along structure length
6. Rock armour defence collapsed
7. Breakwater founded on rock reef





breakwater core (Failure Mechanism 2). This resulted in a massive cavity 30 m long by 0,5-1 m deep forming under the concrete roadway. Subsequently the concrete roadway started to collapse into this cavity.

Along the second 30 m (Ch 96 to Ch 126) stretch of this 60 m section of failed breakwater, armour rock was displaced downwards from the toe, slope and crest areas of the breakwater. This in turn exposed the underlying core. In addition the parapet wall was exposed and had to absorb direct wave impact.

SOLUTIONS

The client, the Department of Public Works, acted swiftly and blocked off access to the breakwater, and fast-tracked the design, tender and procurement phase in order to get the contractor on site as soon as possible. Combining budgetary constraints and innovative design by WSP Africa Coastal Engineers, the following actions were taken:

In general

WSP Coastal salvaged and re-used all existing 1-3 t rock.

Along the first 30 m of damage sustained (Ch 66 to Ch 96):

- The existing concrete roadway was demolished.
- The existing sandy core was trimmed back and overlain with geomembrane, 10-50 kg rock and 10-500 kg rock.
- The concrete roadway was rebuilt to 800 mm thickness and the precast parapet walls were stitch-cast to the roadway.
- The original 1-3 t double rock protection was reconstructed.
- A new single layer of 4-6 t armour rock was constructed.

Along the second 30 m of damage sustained (Ch 96 to Ch 126):

- The original 1-3 t double-rock protection was salvaged and reconstructed.
- A new single layer of 4-6 t armour rock was constructed.

Quality control

Strict quality control on all concrete and rock was imposed throughout the project. In addition, all existing 1-3 t rock was salvaged and re-used. Quality control on rock was performed at the quarry and on site. The closest quarry that could produce

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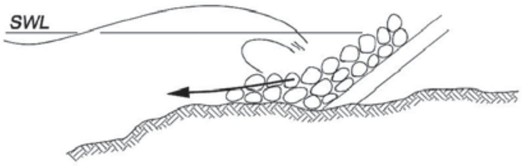

Instability of toe and foot of armor in shallow water when placed on hard seabeds and exposed to wave breaking

- *The forces from breaking waves cause displacement of the blocks unless they are several times heavier than conventional toe blocks and heavier than the main armor blocks. On smooth rock surfaces it is necessary to bolt or anchor the toe block if a trench is not made.*

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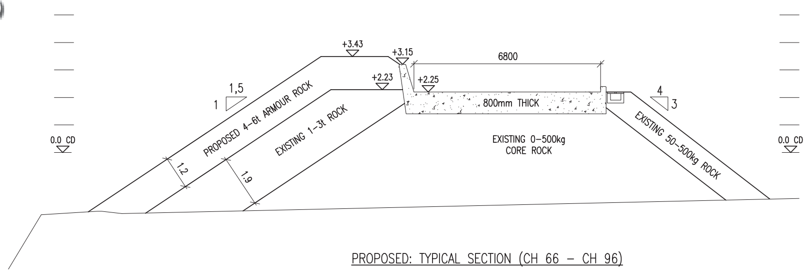

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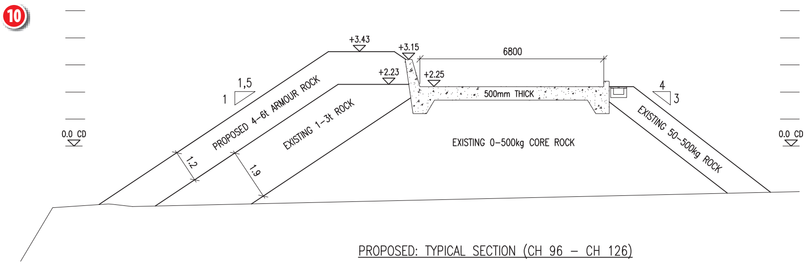

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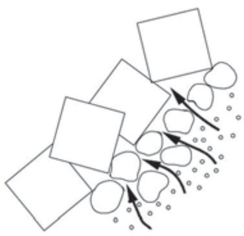
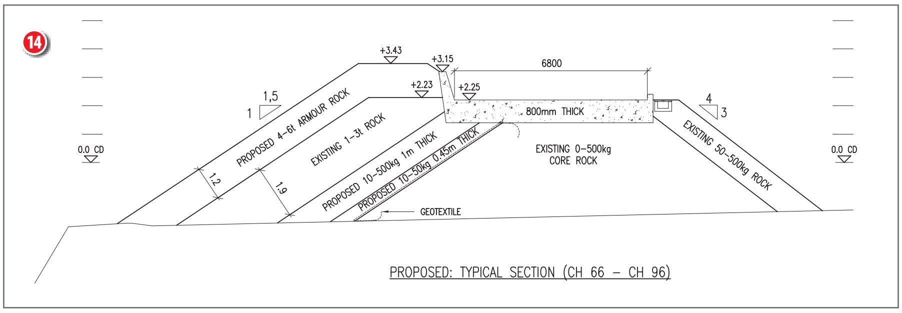


Washout of fine material

- *The wave-induced pressure gradients cause washout of finer material through coarser material if the criteria for stable filters are not met.*
- *Washout causes cavites and local collapse of the structure.*



8 Illustration of Failure Mechanism 1. Source: Coastal Engineering Manual (CEM) EM 1110-2-1100 (Part VI), 1 June 2006, Figure VI-2-39

9 Proposed typical section (Ch 66 – Ch 96)

10 Proposed typical section (Ch 96 – Ch 126)

11 After removal of concrete deck: test hole at 1 m deep

12 After removal of concrete deck: test hole at 1,5 m deep

13 Illustration of Failure Mechanism 2. Source: Coastal Engineering Manual (CEM) EM 1110-2-1100 (Part VI), 1 June 2006, Figure VI-2-40

14 Proposed typical section (Ch 66 – Ch 96)

15 Stage 1: Demolition of existing concrete roadway

16 Stage 2: Trimming back existing sand core

17 Stage 3: Placing geotextile with 10-50 kg layer overlay

18 Stage 4: Construction of 10 -500 kg layer to profile

19 Stage 5: Casting 800 mm segmented roadway panels

20 Stage 6: Completing double layer 1-3 t rock

21 Stage 7: Stitch-casting parapet walls to concrete roadway

22 Stage 8: Completing single layer 4-6 t rock

23 Stage 9: Completed 7 m wide, 800 mm deep concrete roadway

4-6 t rock of the quantity, strength and size needed was located approximately 120 km from the site. Table 2 indicates indices tested for, specification requirements of the indices, as well as actual test result averages obtained.

CONCLUSION

The contract commenced on 4 March 2011 and was completed within the contract period on 5 September 2011. ◻

24 Rock armour grading

25 1,5 m high drop test – crushed rock onto steel plate

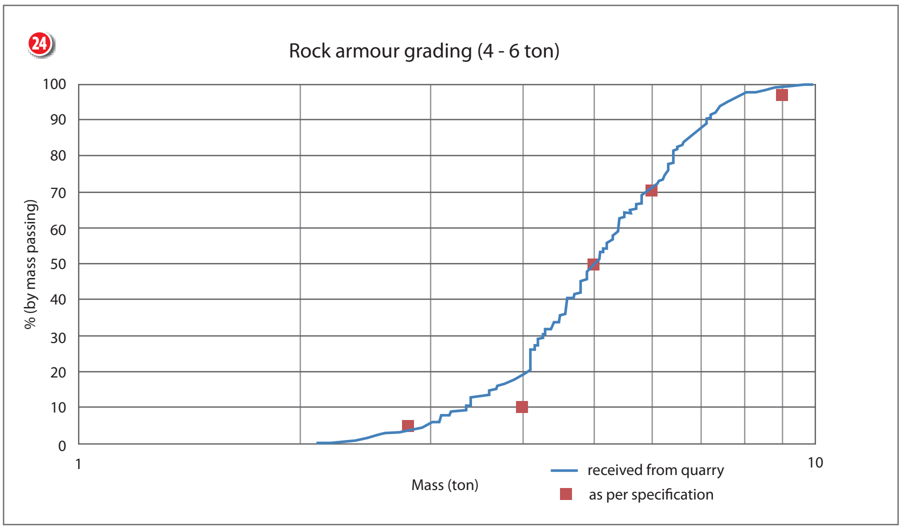


Table 2 Summary of quality control on concrete and rock

	Specification requirements (avg)	QC test result (avg)
Rock dry density	> 2 600 kg/m³	2 650 kg/m³
LA abrasion value	< 22%	11,9%
Drop test @1,5 m onto steel plate	Bn < 10% (armour rock)	< 1%
Water absorption	< 2% of dry weight	0,53%
Shape of armour	Cubicle to rectangular	Cubicle to rectangular
Greatest to least dimension GTL	Less than 5% should be > 3:1	Average 2,35; 13% was less than 3:1
Grading armour	M50 = 4,5 t; NUL 6 t; NLL 4 t	See graph (Figure 24)
Grading core	M50 = 250 kg; 0-10 kg = zero; NUL = 500 kg	M50 = 250 kg; 0-10 kg = zero; NUL = 500 kg
Crushing strength core	Hard, sound, durable, 80 MPa	Hard, sound, durable, 111 MPa
Block coefficient armour	> 60%	Approximately 65%
Testing frequency quarry	20%	10%
Testing frequency site	10%	20%
Rock type	To *Rock Manual* or as agreed	Quartzite

Source:

http://www.saice.org.za/downloads/monthly_publications/2011/2011-Civil-Engineering-december/#/0