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

Proposed typical section (Ch 66 – Ch 96)
Proposed typical section (Ch 96 – Ch 126)
After removal of concrete deck:
  test hole at 1 m deep
After removal of concrete deck:
  test hole at 1.5 m deep

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

Stage 1: Demolition of existing concrete roadway
Stage 2: Trimming back existing sand core
Stage 3: Placing geotextile with 10-50 kg layer overlay
Stage 4: Construction of 10-500 kg layer to profile
Stage 5: Casting 800 mm segmented roadway panels
Stage 6: Completing double layer 1-3 t rock
Stage 7: Stitch-casting parapet walls to concrete roadway
Stage 8: Completing single layer 4-6 t rock
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.

Table 2
Summary of quality control on concrete and rock

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