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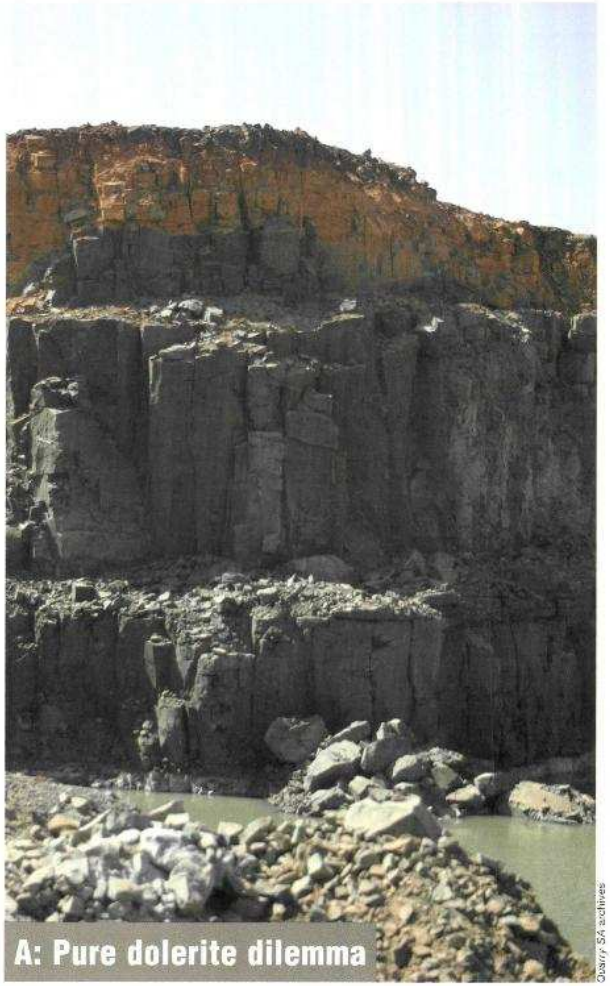
Five takes to PERFECTION

It took up to five mixes to achieve the desired result for the concrete used in the construction of Bramhoek Dam, *Quarry SA* learns.



A: Pure dolerite dilemma

Quarry SA archives

Work is forging ahead on the Bramhoek Dam, part of the construction of Eskom's Ingula pumped storage scheme in KwaZulu-Natal. Construction of the 337 m long and 37 m high grout-enriched roller compacted concrete (GE-RCC) dam, claimed to be the first of its kind in Africa, entails producing a workable concrete from only dolerite material crushed on site. This is no mean feat, challenging both the Bramhoek Consultants Joint Venture, which comprises Knight Piésold Consulting, SSI and Arcus Gibb, and the contracting JV of WBHO, Edwin Construction and Silver Rock, with Concor as the main contractor. It took as many as five different mixes and a significant investment in additives to achieve a mix suitable for the placement of RCC and GE-RCC.

The R389-million project will be completed by October 23 2010. At the time of writing, commencement of impoundment was scheduled for April 2 2010 with 75 000 m^3 of the RCC completed and 23 000 m^3 remaining. Meanwhile, 27 000 m^3 of concrete work had been completed with 2 000 m^3 remaining.

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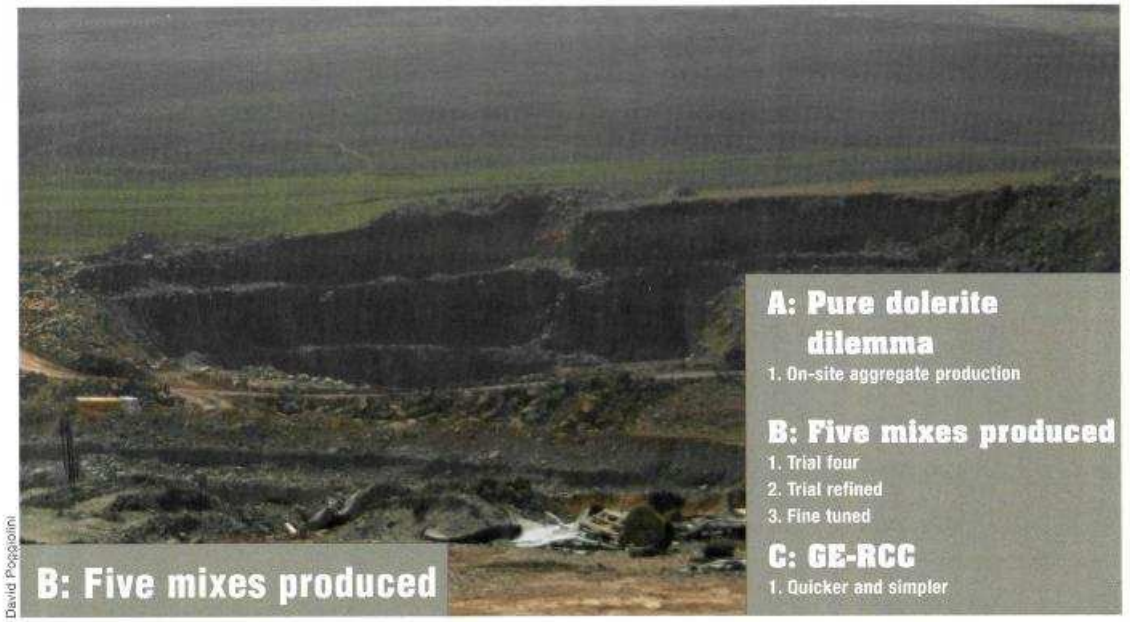

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A: Pure dolerite dilemma

1. On-site aggregate production

100 m³/hour

The RCC aggregates and other processed stone materials are mined from a nearby quarry. The quarry is owned by Eskom, with crushing and screening sub-contracted to B&E. Crushed material is then sent to a Tsekoura-Icon batching plant located at the right flank, about a kilometre from the dam. The plant averages between 80 m³/hour and 100 m³/hour. It is able to mix 2 m³ at a time and has a total capacity of 135 m³/hour. The RCC is transported to site using three 30 t ADTs. Each ADT is loaded with 10 m³ of RCC per trip.

Crushing and screening has been sub-contracted to B&E.

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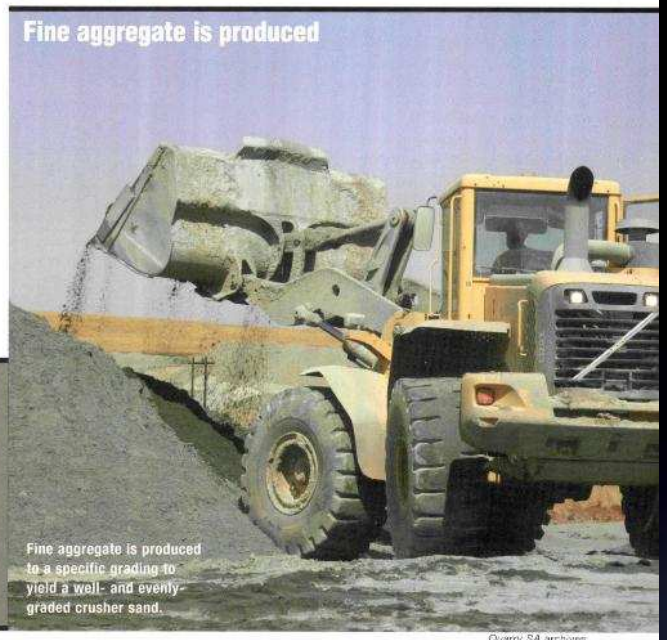
1 On-site aggregate production



Fine aggregate is produced to a specific grading to yield a well- and evenly-graded crusher sand.

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Three broad grading bands

B&E is producing three broad grading bands for the course aggregate. This includes 4,75 mm to 19 mm, 19 mm to 37,5 mm and 37,5 mm to 53 mm. The RCC fine aggregate is produced to a specific grading to yield a well- and evenly-graded crusher sand, Mike Neumann, consultant of Bramhoek, tells *Quarry SA*.

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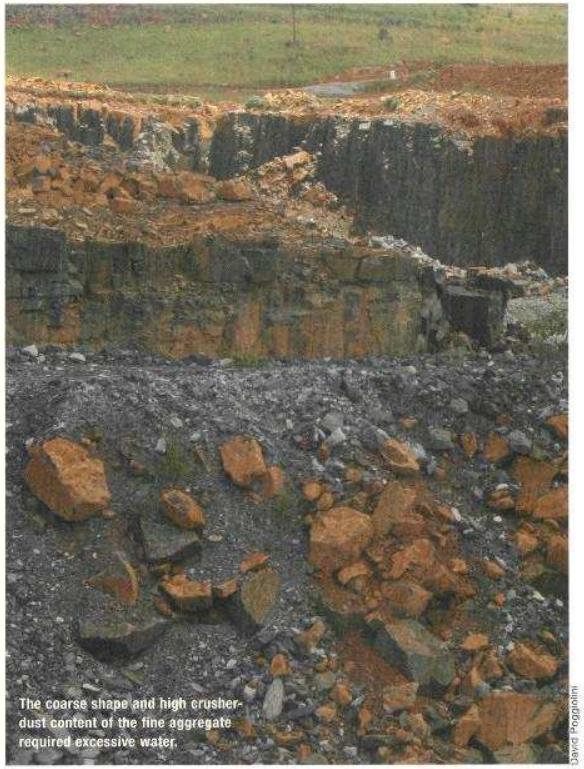
B: Five mixes produced

1. Trial four
2. Trial refined
3. Fine tuned



The coarse shape and high crusher-dust content of the fine aggregate required excessive water.

Dávid Poggiolini

A harsh mix

The original mix presented an array of workability challenges, considering that everything it comprises is produced from materials on site. "The coarse shape and high crusher dust content of the fine aggregate required excessive water to provide a measure of workability," says Neumann. "The harsh mix yielded Vebe times exceeding 45 seconds."

1 Trial four

Closer to perfection

Four modified mixes were tested before arriving at mix T4. The following adjustments were made to eventually arrive at T4:

- The cementitious content was raised;
- The fly ash content was raised, which resulted in increased lubrication of the mortar fraction;
- The course aggregate content was significantly increased, with emphasis on the coarser bands; and
- The crusher sand content was significantly reduced, which enabled a significant reduction in the water content.

Constituent	Description	Specific limits	Original mix	Mix T4 used test section 1
Cementitious	Cement CEM 1 42.5	> 57 kg/m³	70	55
	Fly ash	> 45%	70	95
Aggregates	37,5 mm – 53 mm	Max 53 mm, water absorption	400	487
	19 mm – 37,5 mm	-	450	675
	4,75 m – 19 mm	Water - absorption <1%	400	423
	RCC crusher sand	-	1 780	926
Liquids	Water	-	135	195
	Admixtures	-	None	None
Ratios	Water/cement	0,5 – 1,0	0,96	0,70
	Aggregate/cement	-	17,4	16,7
	Sand/aggregate	0,33 – 0,45	0,49	0,37
	Paste/mortar	> 0,35	0,35	0,37
	Vebe (seconds)	10 – 25	35 – 40	90 – 80
Strength (MPa)	7 days maturity	4,5	4 – 6	3 -5
	28 days maturity	12,5	11 – 13	9 – 12
	90 days maturity	17,5	15 – 18	14 - 16

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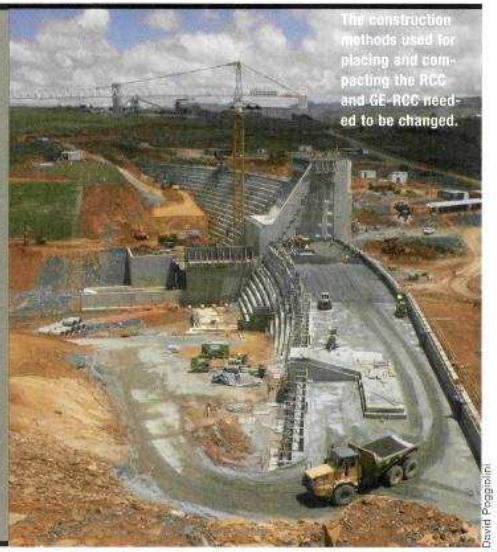
2 Trial refined

Workable, but...

Neumann discloses that this mix was used for the first trial section cast on site in late February 2009. The slab was 60 m long by 10 m wide in plan and cast in four layers . Each layer had a 300 mm compact thickness.

Although mix T4 yielded a workable RCC, achieving the specified Vebe times still proved difficult. "The mix appeared somewhat harsh, prone to segregation when levelled with a dozer and dried out rapidly," he says. "When cores were extracted in March 2009, it became apparent that the construction methods used for placing and compacting the RCC and GE-RCC needed to be changed. The vertically extracted cores broke apart at nearly every horizontal layer interface and the horizontal cores broke apart at the GE-RCC/RCC interface. The 90 day strength of core sections that could be salvaged did not exceed the design strength of 15 MPa by a sufficient margin, and a further refinement was implemented to arrive at mix T5."



The construction methods used for placing and compacting the RCC and GE-RCC needed to be changed.

David Poggiolini

3 Fine tuned

Constituent	Description	Specific limits	Original mix	Mix T5 used test section 2
Cementitious	Cement CEM 1 42,5	> 57 kg/m³	70	70
	Fly ash	> 45%	70	95
Aggregates	37,5 mm – 53 mm	Max 53 mm, water absorption	400	500
	19 mm – 37,5 mm		450	640
	4,75 m 90S – 19 mm		400	423
	RCC crusher sand	Water absorption <1%	1 160	905
Liquids	Water		135	110
	Admixtures		None	None
Ratios	Water/cement	0,5 – 1,0	0,96	0,67
	Aggregate/cement		17,4	15
	Sand/aggregate	0,33 – 0,45	0,49	0,37
	Paste/mortar	>0,35	0,35	0,38
	Vebe (seconds)	10 – 25	35 – 40	15 – 20
Strength (MPa)	7 days maturity	4,5	4 – 6	5 – 7
	28 days maturity	12,5	11 – 13	12 – 14
	90 days maturity	17,5	15 – 18	17 – 20

The concrete did not segregate, retained its moisture and remained workable for longer, compacted to a smooth finish with the vibratory roller and retained a slight 'sponginess' after compaction.

T5

T4 was fine tuned to yield a RCC that did not segregate, retained its moisture and remained workable for longer, compacted to a smooth finish with the vibratory roller and retained a slight "sponginess" after compaction.

Neumann says that the placing and compaction of the RCC was closely monitored to ensure that the time from batching to final compaction did not exceed 40 minutes. Measured quantities of grout were poured inside wooden open frames sized especially for the grout quantity required over the 400 mm wide and 300 mm deep facing concrete. The grout was left to settle for five minutes before the facing concrete was compacted with immersion poker vibrators. To verify the GE-RCC/RCC compaction, the formwork was stripped from one corner the following day and a 1 m x 1 m section ripped off with an excavator. The interface was not discernible, proving the suitability of the revised construction methods. Cores were extracted after 56 days maturity, but these still tended to part at the horizontal layer interfaces. It was surmised that extraction of cores from RCC with a low cementitious content and high fly ash percentage, require extended curing times and cannot be performed with the type of core drill found in most laboratories.