

***BRAZILIAN INTERNATIONAL ROLLER COMPACTED CONCRETE (RCC)
SYMPOSIUM, SALVADOR, BRAZIL 7 SEPT 2008***

RCC – NEW DEVELOPMENTS AND INNOVATIONS

By

Brian Forbes

Manager, Major Dams Projects

GHD Pty Ltd

Australia

RCC ACHIEVEMENTS TO 2008:

- 25 years - since Willow Creek
- 350 RCC dams - worldwide
- 190m high - filled and operational
- 272m high Basha dam construction - 2009+

RCC INNOVATIONS:

- Innumerable
- Most important ? In my opinion:
 - 1 - *Lift Joint Bond - Sloped Layer Method*
 - 2 - *Facing Concrete - Grout Enriched RCC*

1- LIFT JOINT BOND

- A concern and criticism of RCC dams
- Every 300mm, 10 x the number of CVC lifts
- Up to 1.5 MPa tension required across joints
- Cold, Warm, Hot joints and Maturity Index

TREATMENT OF LIFT JOINTS

- Surface clean up and 'green cutting'
- Application of a bedding concrete or mortar
- Coring shows only about 50% bonded
- Realisation in recent times:
*Reduced capacity to bond after **Initial Set***

Are these the lift joints we want?

*I don't think so – not for
a RCC high dam !*



PLACING LIFTS WITHIN INITIAL SET TIME

- Initial set time 2 hours – can retard to 24hrs
- Divide dam into blocks to reduce lift volume
- Retard and use high placing rates – 1 to 2 lifts/day
- Adopt sloped layer method
- Treat cold lift joints as for CVC

3.0m lift *Block Method* at Jiangya dam in 1997



1.2m lift *Block Method* at Koudiat dam in 2007



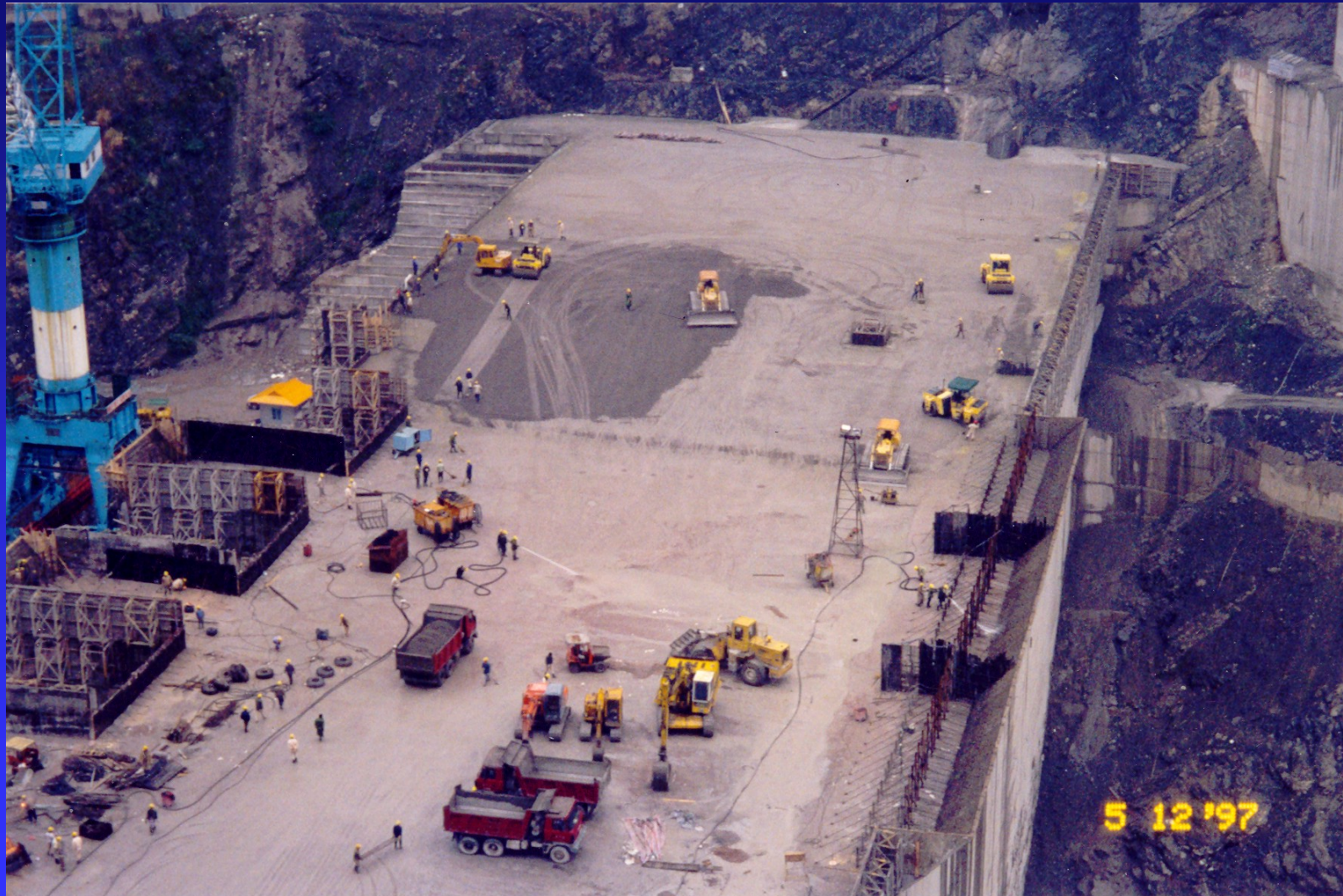
1.2m lift *Block Method* at Wadi Dayqah dam 2008



0.3m lift *High Placing Rate Method* at Yeywa dam 2008



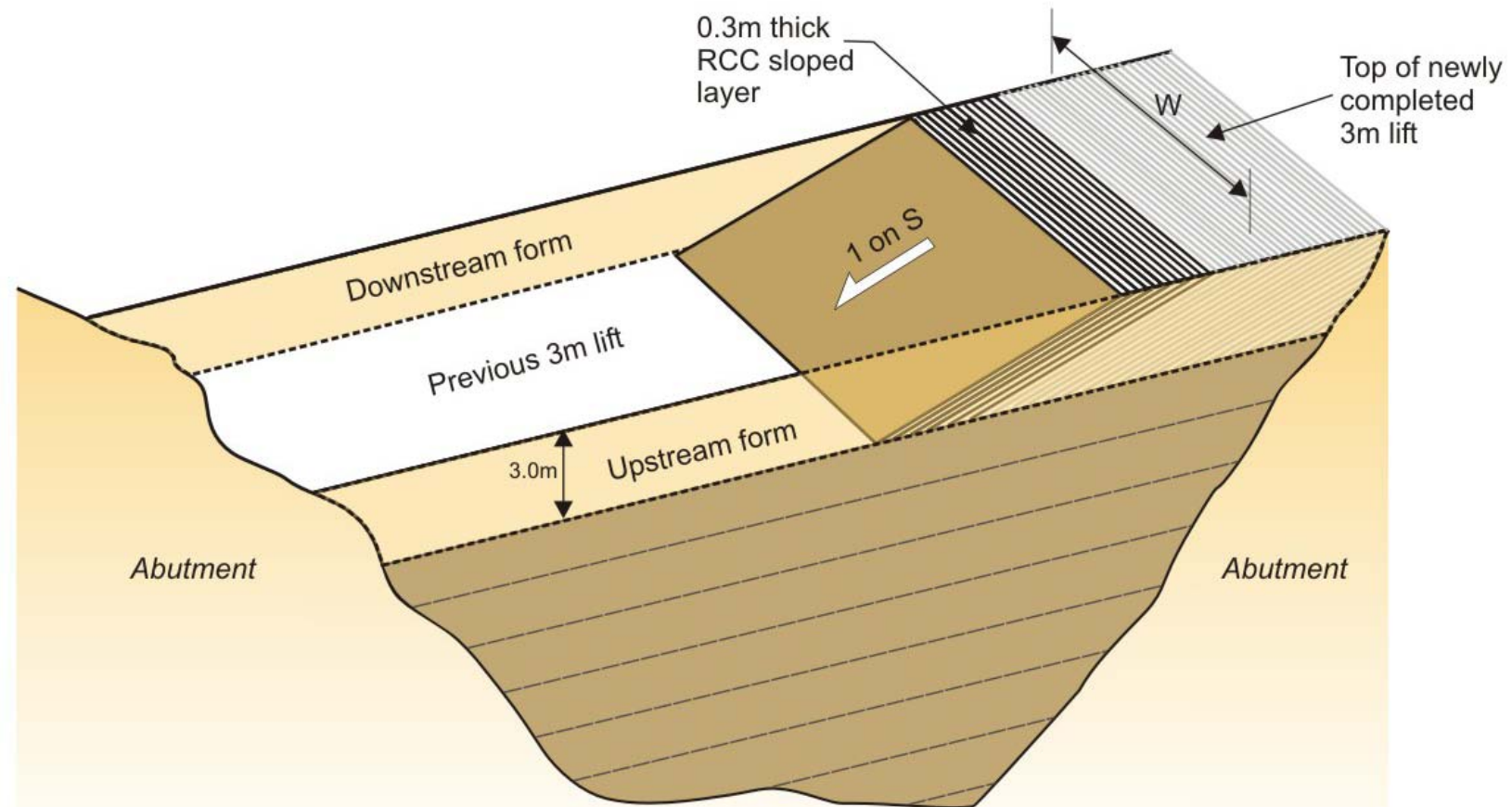
3.0m lift *Sloped Layer Method* at Jiangya dam in 1997



THE SLOPED LAYER METHOD

- SLM does not require the RCC to be retarded
- Up to 10 layers of RCC 300mm thick
- Each layer placed in < 2hours
- No surface treatment or bedding applied
- Allows time to prepare the cold lift surface

Explanation of the Sloped Layer Method



Selecting the Slope to Match the Placing Rate

- Generally 1 on 10 to 1 on 40
- Dependant on placing rate and initial set time
- Dependant on width of dam, steeper at base

An Example to Select the Slope

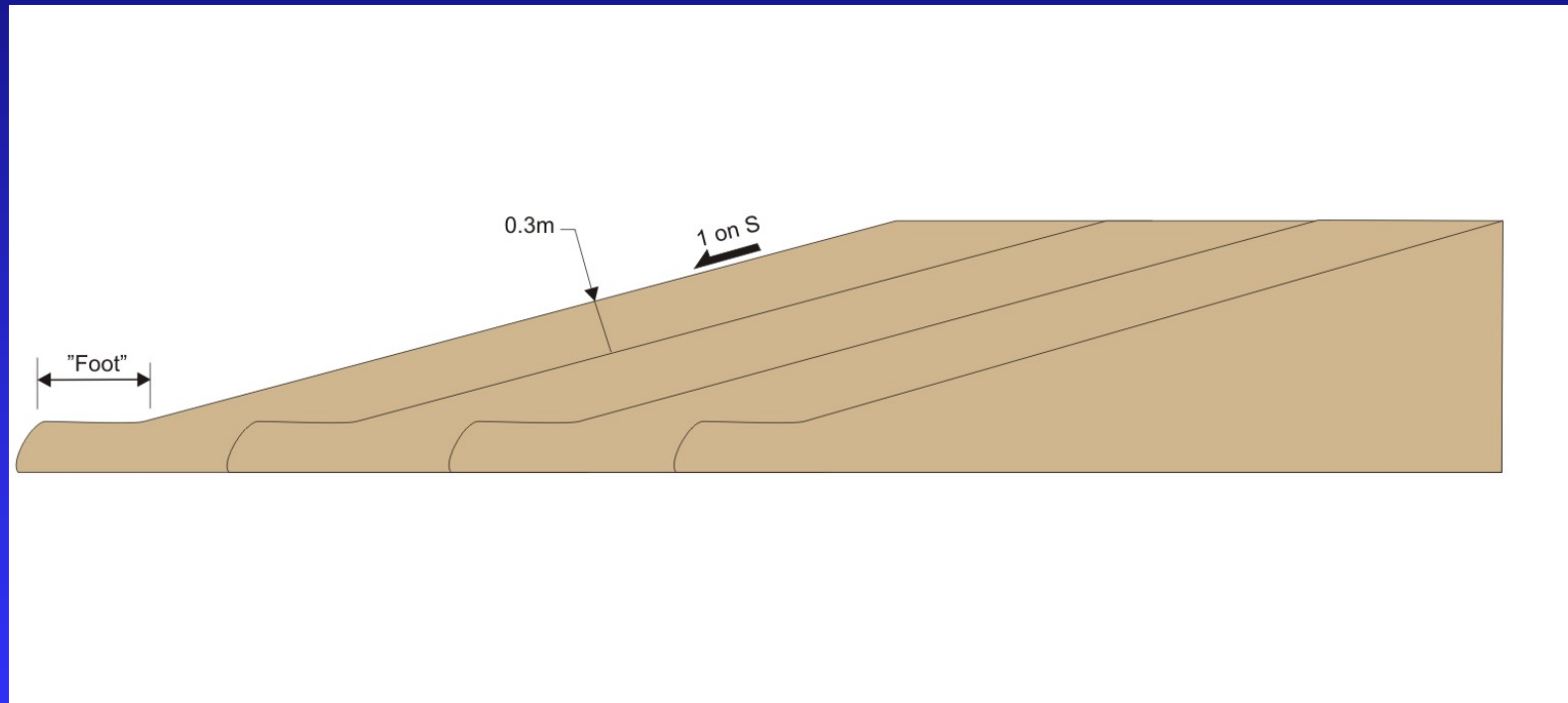
Assume:

Width between u/s and d/s faces	= 'W'
Initial set time of RCC	= 2 hours
RCC placing rate	= 500m ³ /hr
Total lift height (10 layers)	= 3m
RCC layer thickness	= 0.3m

Then:

$$\text{Slope 'S'} = \frac{2 \times 500}{W \times 0.3 \times 3} \text{ ie. } \sim \frac{1000}{W} \text{ if } W=100\text{m, } S=10$$

Dealing with 'feathered edges' using a 'foot'



Starting a sloping layer at Jiangya dam with a 'foot'



Placing 1.2m high lift at Tannur dam without a 'foot'



Tannur dam - SLM near the crest, 9m wide, 1:40 slope



Kinta dam - cold lift preparation ahead of next layer



Kinta dam – two 3m sloped layer lifts



Kinta dam – precast blocks to form 0.6m steps



Koudiat dam – crawler placer for SLM in 1.2m lifts



Advantages of the Sloped Layer Method

- Achieves monolithic RCC across 300mm lift joints
- Suits a range of placing rates without retarder
- Reduces lift joints by up to 90%, placing rates increased by up to 50%
- Lift joint preparation, form setting off 'critical path'
- Reduces RCC heat gain and rain/freeze damage

Results from cores



Response from site

Brian,
25/09/2005

Ozaltin started SLM last Wednesday. It went so well they ran out of cement ! Brilliant concept, why isn't it compulsory?

Regards
Clive Miller

Chief Resident Engineer
Montgomery Watson Harza
Al Wehdah Dam Project

2 - FACING CONCRETE – GERCC

- Many facings tried - CVC, precast panels, PVC etc
- Objective - durable, impermeable, aesthetic, cost etc
- CVC to RCC connection suspect, RCC uncompacted
- RCC, CVC differ only in amount of cement and water
- GERCC-adds extra cement and water to spread RCC

GERCC Process

- Generally uses a cement water grout $w/c=1$, add superplasticiser if $w/c > 1$ to reduce viscosity
- Apply 20mm bedding mortar to set lift surfaces
- Spread RCC lift, hand trim, do not compact
- Pour grout over the loose RCC surface
- Poker vibrate after grout has soaked into RCC

Procedure - Kinta Dam



Procedure - Kinta Dam



Typical results - Kinta dam



Observations

- Meets all facing objectives, low cost, <US\$15/m²
- Modifies RCC in place to achieve CVC
- No special mixing or transport plant, simple process
- Excellent finish, monolithic with RCC body
- Low slump, no tendency for drying cracking
- Elastic modulus and strength as for parent RCC

Uses for GERCC

- Can generally replace CVC on RCC dams
- Upstream and downstream facing
- Stepped spillway facing
- Rock abutment 'contact' or 'interface' concrete
- Encasement of waterstops, pipework, built-in items
- Reinforcing steel encasement

GERCC experience – Jiangya Dam 1997, 131m high



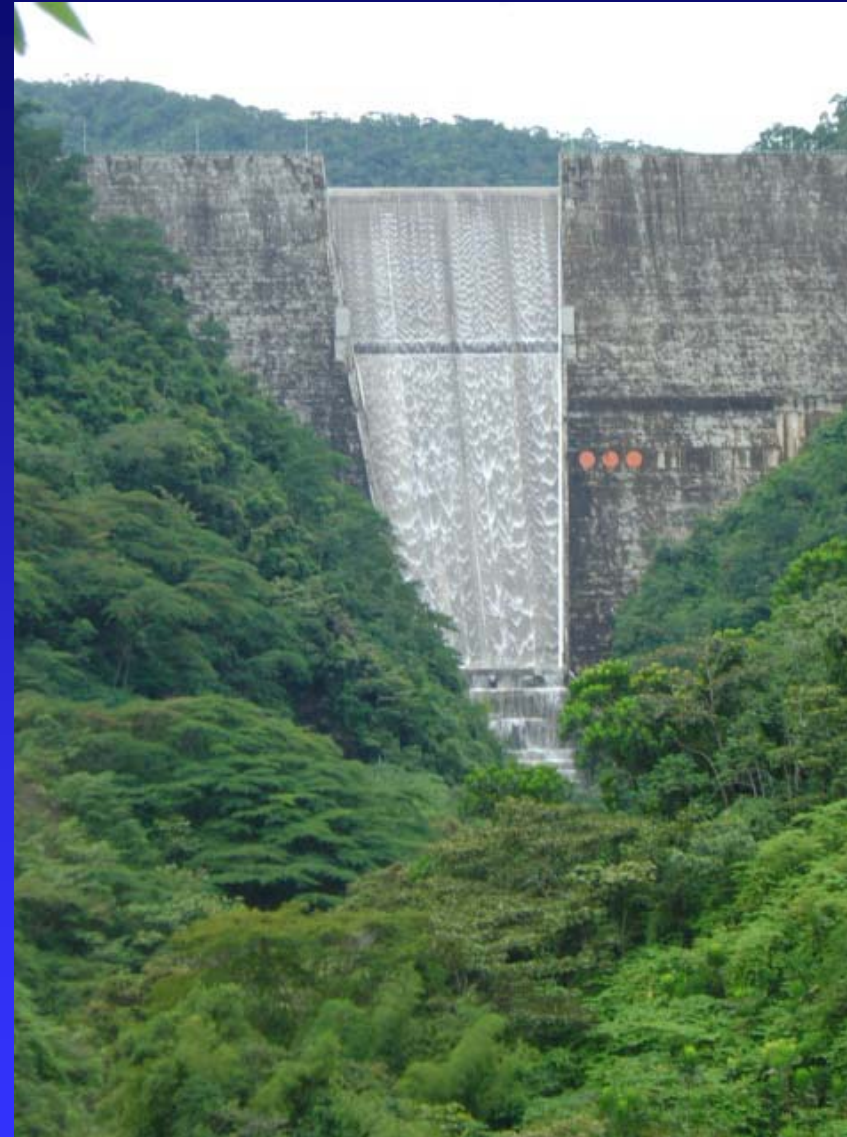
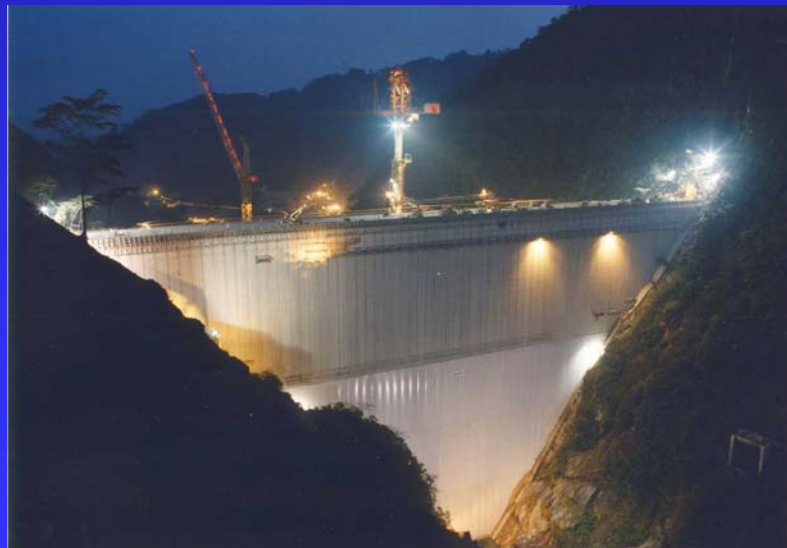
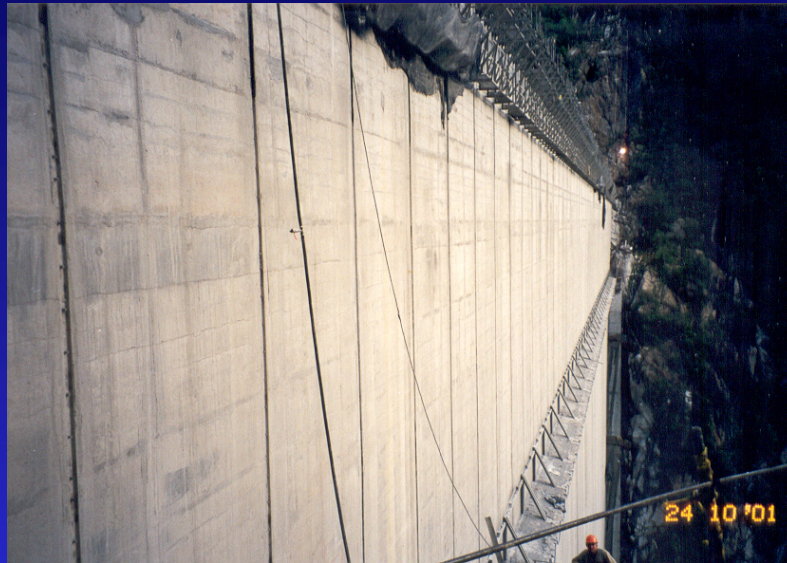
GE-RCC experience – Cadia Dam 1997, 40m high



GERCC experience –Tannur dam 2000, 60m high



GERCC experience - Miel Dam 2001, 190m high



GERCC experience - Ralco Dam 2003, 155m high



GERCC experience - Al Wehdah dam 2006, 103m high



GERCC experience - Wadi Dayqah dam 2008, 80m high



Other uses for GERCC



Quality Assurance and Control

- Full, uniform, poker vibration for good surface finish
- Strength will be slightly lower than the RCC (5%)
- Coeff. of Uniformity similar to the RCC (0.1 - 0.25)
- Slump taken after vibration, best 15 - 30mm (max)
- Grout quantity depends on RCC VeBe (<12s=nil)

Quality Assurance Testing

- Grout stability – sample bleed
- Grout quantity – control area and application (approx)
- Slump cone after vibration+ strength test sample
- Extract cores – horizontal + vertical – observe
- Test cores – density, compressive strength etc

Aspects of GERCC for Future Research

- Significantly increase strength above that of the RCC for stepped spillway durability – maybe by adding silica fume or polymers to the grout.
- Determine the best way to incorporate a freeze-thaw admixture effectively into the GERCC via the grout.

CONCLUSIONS

- Placing RCC lifts within the initial set time of the RCC in the lower lift ensures full bond and joint tensile strengths equivalent to the RCC itself.
- The Sloped Layer Method is simple and efficient in achieving this – the very high RCC dams planned can now be developed with the necessary confidence.
- The addition of grout to any loose in-place RCC will allow transform it into CVC so it can be used where previously CVC would have been anticipated.

CONCLUSIONS (continued)

- GERCC uniformity, off form finish, strength and its excellent connection to the adjoining RCC are well proven; over 60 dams have used it to date. The process is simple and low cost. Some aspects for future development remain.
- SLM and GERCC are but 2 of many innovations in the developing technology of RCC – there will be more in the future, hopefully some as beneficial to the RCC process as these described to you.



“Thank you for your attention”
“Obrigado”



CLIENTS | PEOPLE | PERFORMANCE

Kinta Dam 90m high - used SLM and GERCC

