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Grout Enriched RCC (GE-RCC, GEVR or any other name)

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1. Introduction

A number of processes have been used to construct the upstream and downstream faces of RCC dams. These have included:

- *Pre-cast concrete panels with and without welded polyethylene or PVC membranes.*
- *Internally vibrated conventional concrete facing placed either before or after the RCC has been placed but prior to initial set.*
- *Extruded concrete kerbing.*
- *Plastic membranes applied directly to the upstream face.*
- *No treatment of the RCC other than compaction against the face.*

The Chinese commenced the use of grouted enriched RCC or "anomaly" concrete at the Yantan Coffer dam in 1987. They followed this at projects such as Puding RCC arch dam 1992, the 88m high Fenghe No 2 dam in 1998, 131m high Jiangya dam completed in 1999, 114m high Dachaoshan dam completed in 2001 and the 132m high Sharpei arch dam completed in 2002.

Outside of China, the first dam to employ the process was Cadiangullong dam (43m high 1996, Australia). This was followed by Horseshoe Bend dam (14m high 1999, New Zealand), Tannur dam (60m high 2000, Jordan), Miel I dam (190m high 2002, Colombia) and on Ralco dam (155m high 2003, Chile). It has been used successfully on the 85m high Kinta dam in Malaysia.

2. General Description

The method involves the introduction into the placed, but uncompacted, RCC of a small amount of grout resulting in increased workability that is suitable for vibration with immersion vibrators. The RCC is modified to produce either a facing or an interface concrete. This can be used not only against formwork on the upstream and downstream faces but could also be considered for use against the abutments and formed conduits.

In the case of abutments, grout or bedding mortar is spread over the rock followed by placement of the RCC while where forms are used a small quantity of grout is initially placed as a thin band along the preceding layer. Grout is then poured on top of the RCC and the interface zone is then consolidated by immersion vibration.

The applicability of the method to the upstream face is based on the fact that the completed high paste RCC dams are generally found to have permeabilities of the RCC exceeding 5 x 10^{-9} cm/sec. It would seem therefore that it is more beneficial to concentrate upon known leak paths than leakage through the RCC itself.

3. Construction Advantages

From a construction perspective the grout enrichment method has a lot to commend it.

- *It significantly increases the amount of time available for the placing of roller compacted concrete compared with other methods of upstream facing.*
- *It results in a shorter construction period.*
- *The bond strength between layers will increase because the delay between placing subsequent layers is reduced. This will increase the shear and tensile capacity of the dam.*
- *The compaction along the upstream face is more positively achieved because the grout enriched RCC has a far higher bearing capacity when wet than the high slump conventional concrete used in this location. This enables more effective compaction plant to be used.*
- *Production of conventional concrete is minimized and the size of the construction crew is reduced.*

Various methods have been used to mix the grout and compact the grout enriched RCC:

- *At Cadiangullong Dam the parent RCC only required very slight modification and at times it produced quite an acceptable finish without the addition of grout. This meant that the small amounts of grout could be mixed by hand in a small barrow and ladled into position.*
- *At Eidsvold Weir and elsewhere small grout mixers are used.*
- *On very large projects dedicated mobile truck mounted grout mixers are used*

The size and type of mixer is determined by the volume of grout to be mixed per hour, the local labour rate and the availability of labour to carry out the internal vibration of the grout enriched RCC.

The use of a dedicated grout mixer provides a superior quality of grout and ensures the cement remains in suspension. Grout mixers also ensure that measured amounts of fluidisers can be used where the water cement ratio needs to be kept as low as possible.

Upstream Forming of Eidsvold Weir using the Grout Enriched Vibratable RCC Process

4. Design Issues

The method may supersede the use of conventional concrete veneers. Its potential advantages as a superior method of construction are:

- *Reduced degree of shrinkage and thermal cracking caused by lower cement contents.*
- *Higher density and better grading compared to conventional concrete. Essentially conventional concrete and RCC are less strain compatible.*
- *Lower hydration heat generated in the facing concrete is more compatible with the heat generation of the RCC.*
- *Variable degree of bonding of conventional concrete and RCC is caused by differing rates of initial set, weather conditions and plant malfunction. RCC lifts often slope to the upstream face where excess amounts of water from clean down activities and light rain are trapped by the conventional concrete band placed ahead of the RCC. This causes a poorly bonded layer along the upstream face.*
- *Grout enriched RCC also has significant advantages over very sophisticated upstream methods employing precast panels. These methods place large demands on cranes and labour and have the potential to slow down the rate of placement.*
- *Designers have at times required the grout enriched RCC to have the same strength as the parent RCC and even the same or higher density. To achieve a similar strength requires that that the water cement ratio be similar to the RCC. This is not achievable unless water reducers and super plasticisers are used to achieve suitable viscosities. If the grout is too thick penetrate the RCC sufficiently and the vibrators will not consolidate the mix. Care should be taken to ensure that upon removal of the vibrator a void is not left behind. If this occurs, the grout is either too thick or an insufficient quantity has been applied or the vibrators are unserviceable.*

  In attempting to achieve a grout enriched RCC with the same density as the parent material it should be borne in mind that the grout has a lesser density than the aggregate that it replaces and so the arithmetic impossibility is self evident.
- *Grout enriched RCC is not an impermeable water tight barrier. It is intended to provide an acceptably tight and erosion resistant face to the RCC. It is the higher density well bonded RCC that provides the water barrier. Grout enrichment will not overcome the higher permeability associated with low paste RCC though it will provide an improved finish against which a membrane can be placed.*

5. Proposed Method

Grout-enriched vibratable RCC is a proven method of placing RCC against formwork, structures and foundation contact zones. At the edges of the structure at the abutments, the RCC is 'enriched', by the addition of grout so that the workability changes and the RCC can be compacted using immersion vibrators.

The actual refinement of the technique will be adjusted to suit each project and the method should be refined at the trial RCC stage prior to placing in the main embankment.

Typical View of Immersion Vibration of Grout Enriched RCC

A suggested method will consist of:

- *Place a band of grout or mortar on the top surface of the previous layer and against the contact surface of formwork, rock or pipe structure. T It is intended to provide a source of grout which will migrate up through the RCC during subsequent vibrating.*
- *Where the method is used against rock abutments which are flatter than around 2H:1V it will be necessary to remove the leading edge of RCC from the previous layer to a depth of around 50mm and 100mm wide to ensure that no uncompacted or disturbed material remains.*
- *Place and spread the RCC of the next lift loosely over the previously placed band of grout mix.*
- *Mix the grout to be placed on the top of this layer. Higher strengths in the grout enriched zone will be achieved by using lower the water/cement ratios.*
- *Ladle or pour via hose the grout onto the loose RCC layer. Only sufficient grout should be added to mobilise the mix. From previous experience when the loaded Vebe was in the region of 10secs, hand vibration achieved a satisfactory result without the addition of any grout*
- *Introduce a 50mm hand held concrete vibrator into the mix and mobilise the material until air bubbles up and cease and then grout emerges at the top layer.*
- *Following completion of the hand vibration, a conventional heavy roller is used to compact the parent RCC. Note that the remainder of the loose RCC can be compacted prior to the grout enrichment proceeding. It is only necessary to leave the narrow 500mm band uncompacted so that the immersion vibrators can be used.*

The question of the size of vibrator used often arises. Most RCC dams currently use 50mm minus aggregate and in these cases 50mm diameter vibrators are quite adequate. With larger aggregate or low paste RCC mixes of higher plasticity then larger vibrators or higher input energy may be required. On some projects large gang vibrators with 4 x 150mmϕ or 4 x 100mmϕ units mounted on a mobile equipment have been used. It is self evident however that this intensity of vibration is not required for the small volumes of grout enriched RCC actually used. At Cadiangullong dam and Eidsvold Weir, poker vibrators as

small as 50mmϕ were used. It is actually far more important to ensure that the vibrators are achieving their design frequency and have sufficient power applied.

Rolling the interface between parent RCC and the grout enriched zone

After a suitable length of the grout enrichment process has been completed, the interface with the adjacent RCC shall be compacted. In practice this distance will depend on the time since the RCC was first placed, the ambient temperature and the practicalities of access. It has been found that, unlike conventional concrete, the grout enriched zone will support the roller without the characteristic deformation and mess created at the interface with conventional concrete.
The integrity of the RCC and its strength can be determined by selective horizontal and inclined coring and compression testing.

Spreading grout against an abutment at Olivenhain dam

Completed Grout Enriched RCC at abutment

Rob Parker Engineering is available to provide full support for your next RCC project using grout enriched RCC be it "GE-RCC" or "GEVR" or any other terminology. We can provide:

1. ***Site training and instruction of field crews to carry out the method.***
2. ***Detailed calculation of the required water cement ratios and amount of grout required.***
3. ***Recommendations for the mixing and vibrating equipment to be employed and***
4. ***Additives required to achieve suitable water/cement ratios.***
5. ***Methods of testing the integrity of the finished product.***