EXPERIENCE GAINED DURING DESIGN AND CONSTRUCTION OF THE JEGIN RCC DAM IN IRAN

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ABSTRACT
Construction of the Jegin RCC large dam in Iran has been completed in January 2007. Jegin dam with 78 meter height and 400,000 cube meter in concrete volume is located in a remote area at the South-east of the Country, in a region with very high temperatures and extremely difficult working conditions. Although the original design was already a straight gravity RCC dam type, when performing the definitive construction design some improvements were introduced in order to achieve an “RCC- friendly” design. As a consequence the new design, together with the optimization of the construction processes, enabled the Contact to place the RCC rapidly and efficiently, which led to a better execution quality, a schedule reduction and lower cost. This paper deals with the original and actual design criteria and construction of RCC works including development of mix design and full scale trails. RCC placement, compaction and quality control procedures and other relevant aspects are also discussed.

1. INTRODUCTION
The Jegin Roller-Compacted Concrete (RCC) dam is the first large RCC dam in Iran; a smaller RCC dam that is essentially the core of a spillway was completed in 2002 on the Karkheh River in southwest Iran. Jahgin is 78 m high, 220 m long at the crest and was contain approximately 400000 m³ of concrete of which some 270000m³ was RCC.

The dam is in southern Iran some 350 Km east of Bandar Abbas and some 107 Km north of Jask that is on the coast (see Figure1). The conditions at the Jegin site are very challenging, probably as challenging as at the site of any RCC dam completed to date. There is a total lack of water and throughout the year the temperatures are high, particularly in the summer when they can be in excess of 50°C for significant periods. During 2002 there was no rain at all on the site and the maximum temperature was 54°C. There were also significant floods; the design flood is in excess of 10 730 m³/sec.

Prior to the start of the trial mix programme, an extensive search was made for sources of supplementary cementitious materials that were reasonably close to the Jegin site, two natural Pozzolans were found together with an air-cooled blast furnace slag and a copper slag.

In addition it was ascertained that a low lime fly ash from India was being
imported into the Country. None of the Iranian materials had ever been used in concrete before let alone in a structure as important as Jegin dam. The sources of the Iranian supplementary cementitious materials together with the two cement suppliers, both of whom added natural pozzolans in their cements, are shown in Figure 1.

2. CONSTRUCTION MATERIALS
2.1. Portland Cements
Two ASTM Type-II Portland cements were investigated during the trial mix programme; the preferred cement from Hormozgan and alternative cement from Kerman (see Figure1).

2.2. Pozzolans
An extensive search was made in southern Iran for suitable pozzolans. The following five possible materials were located;
- a natural Pozzolan from Khash;
- a ground slag from Esfahan (it was originally thought that this was a ground-granulated blast-furnace slag (GGBFS), but it was eventually ascertained that the slag was air cooled rather than granulated);
- an imported low lime fly ash from near Mumbai in India;
- a natural pozzolan from Sirjan;
- a ground copper slag from near Jiroft;
In addition, some fine river sand was also investigated, to see if it could be used as 'fine' in the mixes to reduce the quantity of natural pozzolan which might be required. The location of two cements and various potential pozzolans relative to the Jahgin site are shown in Figure 1.


Figure 1. Location of potential cementitious materials sources in southern Iran
2.3 Aggregates
The sandstone aggregates were obtained from gravel borrow pit in the reservoir area. Considering the Jegin dam site condition, it has been decided to transport RCC with vacuum chute system. In order to avoid segregation of the aggregate, 75mm maximum size aggregate given in the primary study has been changed by engineer to 38mm. It's to be mention that, the difference in cementitious material requirements for mixture with maximum size aggregate from 38mm to 76mm is less in RCC than in conventional concrete. An aggregate plant was designed to crush the oversize material and four size of aggregate were used; a partially crushed 20 t0 5mm material and two fine aggregates, the first crushed and second uncrushed (5).

3. TRIAL MIX PROGRAMME–STAGE 1
The trial mix programme at Jegin was carried out in two stages. The objective of the first stage was to assess the performance of all the potential cementitious materials to see which could achieve the strengths required at Jegin dam. Three of the five pozzolans were considered to be 'base' materials: the natural pozzolan from Khash; ground slag from Esfahan and, the low-lime fly ash from India.

3.1. Optimum Workability/Water Content
After gradation has been optimized for each of the combinations of the base cement and the base supplementary cementitious materials, the RCC was visually optimized by using a "Standard" set of mixture proportions:-

- 100 + 100 (cement + supplementary cementitious materials) in the case of the natural pozzolan;
- 50 + 150 in the case of the ground slag;
- 120 + 100 in the case of the low-lime fly ash

In all three cases the optimum workability was in the range of a Loaded Ve Be (ASTM C1170) time of circa14 to 18 sec with an acceptable range (for the laboratory tests) of between 10 and 25 sec. The optimum water contents commensurate with these workabilities were:

- 140 Kg/m³ for the Khash natural pozzolan (for the 100 + 100 mixture proportions);
- 135 Kg/m³ for the Esfahan ground slag (for the 50 + 150 mixture proportions)- this was later found to be a little low;
- 127 kg/m³ for the Indian low-lime fly ash (for the 120+100 mixture proportions).

3.2. Mix Proportions
Two RCCs were to be used in the dam body at Jegin:

- RCC1 was to be used near the upstream face of the dam where the dynamic loading was greatest. This was to have a characteristic cylinder compressive strength of 200 kg/cm² at the design age of 365 days: a target (average) strength of 220 kg/cm² was defined
- RCC2 for the majority of the dam body; this was to have a characteristic
cylinder compressive strength of 120 kg/cm² at the design age of 182 days; a
target (average) strength of 145kg/cm² was defined.

Three sets of mix proportions were designed to obtain the requirements of RCC as
shown in Table 1. Most of the mix proportions have a total cementitious content of
195 kg/m³. The results of the stage-1 programme showed that there were
essentially only two pozzolans which were satisfactory for the RCC Jahgin, both in
terms of their strength development and also in terms of practically. These were the
natural pozzolan from Khash and the Indian low-lime fly ash. The Sirjan natural
pozzolan had a very similar performance to the Khash natural pozzolan, but there
were potential supply and transportation problems.

### Table 1: Chosen mix proportions for the Jegin Stage 1 trail mix programme

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement + natural Pozzolan + water</th>
<th>Mix No.</th>
<th>Cement + ground slag + water</th>
<th>Mix No.</th>
<th>Cement + low-lime fly ash + water</th>
</tr>
</thead>
<tbody>
<tr>
<td>HK.Mix1</td>
<td>70 + 125 + 139</td>
<td>HE.Mix1</td>
<td>30 + 165 + 139</td>
<td>HL.Mix1</td>
<td>45 + 150 + 127</td>
</tr>
<tr>
<td>HK.Mix2</td>
<td>95 + 100 + 140</td>
<td>HE.Mix2</td>
<td>40 + 155 + 140</td>
<td>HL.Mix2</td>
<td>70 + 125 + 128</td>
</tr>
<tr>
<td>HK.Mix3</td>
<td>120 + 75 + 142</td>
<td>HE.Mix3</td>
<td>50 + 145 + 142</td>
<td>HL.Mix3</td>
<td>95 + 100 + 129</td>
</tr>
<tr>
<td>HK.Mix4</td>
<td>145 + 50 + 144</td>
<td>HE.Mix4</td>
<td>70 + 125 + 144</td>
<td>HL.Mix4</td>
<td>120 + 75 + 131</td>
</tr>
<tr>
<td>HK.Mix5</td>
<td>170 + 25 + 146</td>
<td>HE.Mix5</td>
<td>90 + 105 + 146</td>
<td>HL.Mix5</td>
<td>145 + 50 + 134</td>
</tr>
<tr>
<td>HK.Mix6</td>
<td>195 + 0 + 146</td>
<td>HE.Mix6</td>
<td>110 + 85 + 146</td>
<td>HL.Mix6</td>
<td>170 + 25 + 137</td>
</tr>
<tr>
<td>HK.Mix7</td>
<td>240 + 0 + 150</td>
<td>HE.Mix7</td>
<td>130 + 65 + 150</td>
<td>HL.Mix7</td>
<td>150 + 30 + 135</td>
</tr>
</tbody>
</table>

*KThe first letter of the Mix. No. refer to cement (H = Hormozgan) and the second the pozzolan
(K = Kash natural pozzolan), E = Esfahan ground slag, I = Indian low-lime fly ash*

#### 3.3. Development of Strength with Age of the Stage–I Mixes

#### 3.3.1. Khash Natural Pozzolan

Six mixes were designed containing the Khash natural pozzolan (and Hormozgan
Type–II cement), all with a total cementitious content of 195 kg/m³. The natural
pozzolan content varied from 0 Kg/m³ in HK. Mix6 (the H refers to the cement,
Hormozgan type II, and the K to the supplementary cementitious material, Khash
natural pozzolan) to 125 Kg/m³ in KH. Mix 1. The development of strength with
age of the HK series is shown in Figure 2. All the mixes are developing strength
much in line with expectation and they might be expected to continue to do so.

![Figure 2. Development of strength with age of the Stage-I HK (Hormozgan cement + khash natural Pozzolan) series of mixes](image-url)
A comparison was also made between the HK Series and the KK series of mixes (Kerman Type – II cement and Khash natural pozzolan). The strengths of the mixes containing the two different cements are very similar and it was determined that the two cement might be interchangeable.

On the basis of the data, it has been concluded that the Khash natural pozzolan could successfully be used as a cementitious material in the RCC at Jegin Dam.

3.3.2. Indian Low–Lime Fly Ash
Seven mixes have been designed containing the Indian flash. The development of strength with age of the HI series (Hormozgan Type – II cement and Indian fly ash) is shown in Figure 3.

![Figure 3. Development of strength with age of the Stage-I HI (Hormozgan cement + Indian low-lime fly ash) series of mixes](image)

The development of strength of HI.Mix2, HI.Mix3 and HI.Mix4 is very similar to the pattern found at Olivenhain dam in the USA (Pauletto & Dunstan 2003), where RCCs with cylinder compressive strengths of 40 kg/cm² to 70 kg/cm² at an age of 7 days achieved, strengths of 120 to 180 kg/cm² at 91 days and 230 to 330 kg/cm² at an age of one year.

As with the HK Series, apart from some scattered results with H.Mix4, HI. Mix6 between 91 and 182 days, all the mixes are developing strength in line with expectations.

A comparison was also made between the HI Series and the KI Series of mixes (Kerman Type-II cement and Indian fly ash). As with the KK Series the mixes containing the two different cements are developing strength along similar lines.
The two type – II Portland cement (Hormozgan and Kerman) seem to have similar characteristics when used in association with both the supplementary cementitious materials at Jegin.

It would be possible to design an RCC containing the Indian fly ash (it has very good fresh properties) to achieve the strength requirements at Jegin, but given that the material has to be imported, it was concluded that it would only be sensible to use the material if there was a serious problem with the supply of the Khash natural pozzolan.

3.3.3. Esfahan Ground Slag
Initially it was thought that the Esfahan slag was granulated when discharged from the blast furnace. It is now understood that the material is air cooled. No ground air–cooled blast-furnace slag has been used in an RCC dam to date.

Seven mixes were designed containing the Esfahan GBFS (ground-granulated blast-furnace slag) but unfortunately the performance was found to be very poor. On the basis of the data to date and considering the difficulty to mill the material and the 1450 km it would have to be transported (see Figure 1), it has been concluded that the use of the Esfahan GBFS as a cementitious material in the RCC at Jegin would seem to be unlikely and it is no longer being considered for use in the dam.

3.4. Supplementary Stage 1 Programme
Following the 91 days results of the stage 1 trail mix programme, a supplementary programme was designed so as to have a preliminary look at the RCC1 mix and the leveling concrete, together with some potential retarders. Only Khash natural pozzolan was used as a pozzolan in this Series.

3.4.1. RCC1
Three rcc1 mixes were tried in the supplementary programme: 175+50 (cement + pozzolan), the expected mix; 160 + 65 (a lower-strength mix); and, 190 + 35 (a higher-strength mix). All had a total cementitious content of 225 kg/m³. The mixes were designed to achieve target strength of 225 kg/cm² at the age of one year. To achieve such strength with a 100 percent Portland cement RCC, the same cement content of 225 kg/cm² would be required (HK. Mix6 and HK.Mix7) and as there would be little strength gain after an age of 56 days.

It is expected that RCC1-3 (190+35) almost achieve the target cylinder compressive strength of 225 kg/cm² at the design age of 365 days, and the supplementary Stage 1 programme showed that it was possible to achieve the specified strength even without an admixture, at a rather high cementitious content.

3.4.2. Leveling Concrete
Three leveling concretes were designed for the supplementary programme: 160+120+195 (cement + pozzolan + water) the expected mix; 145+135+195 (a lower-strength mix); and, 175+105+195 (a higher-strength mix). All the mixes had a total cementitious content of 280 kg/m³, and all were designed for a slump of 35
10 50mm and for a 182 day cylinder compressive strength of about 145kg/cm². The total cementitious content is necessary rather high, because of the very high water demand of the Jahgin aggregates.

3.4.3. Retarder
Admixtures from five or six different suppliers tested during the supplementary programme. After a number of preliminary tests, two retarders were chosen for future study: Sitka Retarder and Forsook Conplast R. After an extensive further study Conplast R was chosen for use in the RCC for Jegin.

4. TRIAL MIX PROGRAMME – STAGE 2
4.1. Aggregate
The Stage 2 aggregate was obtained from the same source as the Stage 1 aggregate, but the shape was rather better, this was a function of the development of the new aggregate plant.

4.2. Optimization of Mixture Proportions for Stage 2 Trial Mix Programme
Following the stage-I trial mix programme, it was agreed that the natural pozzolan from khash be used in the RCC for the Jegin. The RCCs containing Khash natural pozzolan will have the properties, both fresh and hardened, required for the dam. It was decided that the following mixes be studied in detail in the Stage-II trial mix programme.

The necessary dosage of retarder to produce an initial set of 15 to 20 hours at different temperature; an RCC2, and RCC1 and a leveling concrete with both the Khash natural pozzolan and the Indian fly ash as detailed in Table 2; Grout Enriched Vibratable RCC for the interface (upstream and downstream faces and against the abutment).

It has been agreed that the khash natural pozzolan should be the preferred option and that the Indian fly ash should be a back up.

Three batches, from each of which eight cylinders were manufactured, were made for each of the mixes in Table 2.

The cylinders are being tested at ages of 7, 14, 28, 56, 91, 182, 365 and 1000 days. The development of strengths with age of specimens manufactured (in Stage–II trial mixes) with Hormozgan Type–II cement and khash natural pozzolan as well as Indian fly ash are shown in Figures 4 and 5.

4.3. Recommended Mixture Proportions Used in Jegin Dam
Three mixes were required for the main dam at Jegin:

- RCC1 designed for required cylinder compressive strength of 200 kg/m² at the design age of a year;
- RCC1 designed for required cylinder compressive strength of 120 kg/m² at the design age of 182 days;

A leveling concrete placed against the foundation as a platform for the RCC having a required cylinder compressive strength of 200 kg/cm² at the design age of a year.
Table 2: Suggested mixture proportions for the concrete studied in the Stage-II trial

<table>
<thead>
<tr>
<th>Mix</th>
<th>Cement (kg/m³)</th>
<th>Pozzolan (kg/m³)</th>
<th>Slump (mm)</th>
<th>L. V Be time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HK.RCC.1-1</td>
<td>150</td>
<td>75</td>
<td>10-15</td>
<td></td>
</tr>
<tr>
<td>HK.RCC.1-2</td>
<td>165</td>
<td>60</td>
<td>10-15</td>
<td></td>
</tr>
<tr>
<td>HK.RCC.1-3</td>
<td>180</td>
<td>45</td>
<td>10-15</td>
<td></td>
</tr>
<tr>
<td>HK.RCC.2-1</td>
<td>90</td>
<td>105</td>
<td>12-18</td>
<td></td>
</tr>
<tr>
<td>HK.RCC.2-2</td>
<td>105</td>
<td>90</td>
<td>12-18</td>
<td></td>
</tr>
<tr>
<td>HK.RCC.2-3</td>
<td>120</td>
<td>75</td>
<td>12-18</td>
<td></td>
</tr>
<tr>
<td>HK.Levelling.1</td>
<td>135</td>
<td>145</td>
<td>10-40</td>
<td></td>
</tr>
<tr>
<td>HK.Levelling.2</td>
<td>150</td>
<td>130</td>
<td>10-40</td>
<td></td>
</tr>
<tr>
<td>HK.Levelling.3</td>
<td>165</td>
<td>115</td>
<td>10-40</td>
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<tr>
<td>HK.Levelling.4</td>
<td>165</td>
<td>85</td>
<td>10-40</td>
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<td>HK.Levelling.5</td>
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</tr>
<tr>
<td>HK.Levelling.6</td>
<td>195</td>
<td>55</td>
<td>10-40</td>
<td></td>
</tr>
<tr>
<td>HI.RCC.1-1</td>
<td>95</td>
<td>125</td>
<td>10-15</td>
<td></td>
</tr>
<tr>
<td>HI.RCC.1-2</td>
<td>110</td>
<td>110</td>
<td>10-15</td>
<td></td>
</tr>
<tr>
<td>HI.RCC.1-3</td>
<td>125</td>
<td>95</td>
<td>10-15</td>
<td></td>
</tr>
<tr>
<td>HI.RCC.2-1</td>
<td>70</td>
<td>125</td>
<td>12-18</td>
<td></td>
</tr>
<tr>
<td>HI.RCC.2-2</td>
<td>85</td>
<td>110</td>
<td>12-18</td>
<td></td>
</tr>
<tr>
<td>HI.RCC.2-3</td>
<td>100</td>
<td>95</td>
<td>12-18</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Development of strength with the age of the RCC-1, RCC-2 mixes containing Khash natural pozzolan

Figure 5. Development of strength with the age of the RCC-1, RCC-2 mixes containing low-lime fly ash
In order to decide the final mixes used in the dam body, it was of interest to compare the results from the cofferdam RCC with the strengths of RCC2-3 from the Stage-II programme and with HK.Mix3 from the Stage-1 programme (see Table 3). As can be seen in the Table 5, RCC2-3 has higher long term strength than HK.Mix3 (because of water reduction of the retarder). However the strengths of the specimens manufactured from the RCC placed in the coffer dam are significantly higher than those of RCC2-3, by about 15% at the design age of 182 days.

Table 3. Comparison between the strength of the various RCC mixes having proportion of 120+75 (Hormozgam Portland cement + Khash natural pozzolan)

<table>
<thead>
<tr>
<th>Cylinder compressive strength (kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Cofferdam</td>
</tr>
<tr>
<td>Stage-II RCC2-3</td>
</tr>
<tr>
<td>Stage-I HK.Mix3</td>
</tr>
</tbody>
</table>

4.3.1. Optimization of Mixture Proportions Of RCC2

In the stage –II of the trial mix programme, three mixes were tried, RCC2-1 (90+105), RCC2-2 (105+90) and RCC2-3 (120+75), all with Hormozgan Portland cement, khash natural pozzolan and Fosroc Conplast R as a retarder/water reducer, together with a free water content of circa 130kg/m³.

The results of compressive testing of three mixes (see Figure 4) have been compared to the results of testing of the HK series from Stage-I of the programme presented in Figure 2. There is a reasonable correlation, so much so that the best-fit relationships did not change significantly at any age. At the design age of 182 days, to achieve the design strength of 145 kg/cm², the cement and natural pozzolan contents required were almost exactly those of RCC2-2 (and HK.Mix3). Given the significant difference between the strengths achieved in the field and the laboratory with RCC2-3 (120+75), it might be expected that there could be a similar difference with RCC2-2 and thus a reasonable margin between the required strength and that achieved during the full-scale placement. It has been agreed that RCC2-2 will be used in the dam itself subject to a satisfactory full-scale trials.

4.3.2. Optimization of Mixture Proportions Of RCC1

None of the three mixes, RCC1-1 (150+75), RCC1-2 (165+60) or RCC1-3 (180+45) tried in Stage-II of the trial mix programme achieved the design strength at an age of 182 days and as there does not seem to be significant increase in strength between the ages of 182 and 365 days, none of the mixes is likely to achieve the design strength at the design age at 365 days.

The strengths of the stage-II RCC1 mixes, all of which had a total cementitious content of 225 kg/m³, have been plotted in Figure 4. The results are rather scattered (as might be expected with a set of data being the average of three RCC2 mixes. In the Figure it can again be seen that none of the mixes (apart from the all-Portland cement mix) achieved the design strength (225 kg/cm²) at an age of 182 days. In order to achieve the required strength of RCC1, the total cementitious content will
have to be increased.

There is a very reasonable correlation between the Portland cement content of the all cement mixes and their long-term strength (see Figure 2), e.g. HK.Mix6 (cement content=195 kg/m³) with a long-term cylinder compressive strength of circa 200 kg/cm² and HK.Mix7 (cement content=240 kg/cm³) with a long-term cylinder compressive strength of circa 245 kg/cm². In order to achieve the design strength of 225 kg/cm², it was decided that the mixture proportions of RCC1 be 160+90+130 (cement + pozzolan + water).

Coincidently this has the same natural pozzolan content as RCC2. Thus in order to change from RCC2 to RCC1, a further 55 kg/m³ of cement is added to RCC2.

Test results obtained from leveling concrete at Stage –II indicate that a leveling concrete having mixture proportions of 185+105+150 (cement + pozzolan + water) could be used against the foundation.

5. COFFER DAM

5.1. Preliminary Full-Scale Trial

In early March 2003, preliminary full–scale trial was conducted on the site (see Figure 12). The trial showed that an RCC containing Hormozgan Portland cement and Khash natural pozzolan was cohesive, and could be placed in very high air temperatures without segregation or any other major problem.

40 days after completion of the trial, 100-mm diameter cores were extracted from the trial section. In spite of the very early age and the small diameter the cores through the suitably-retarded RCC were very good.

Following the successful cores, placement of RCC started in the cofferdam (see Figure 13), placement of 20000 m³ was used to train all the personal involved with the project, to refine the construction methodology and to further prove the maximum proportions of the concretes used in the dam itself (3). The final full-scale trial was conducted at the top of coffer dam using the final mixtures proportion for RCC1, RCC2 and GEVR. The extracted 45 days cores are shown in Figures 8 and 9.

Figure 6. Photograph of the initial full Scale trial at Jegin dam

Figure 7. Photograph of RCC placement in coffer dam at Jegin with chute in background
6. DESIGN OF THE DAM
Before construction of main dam and in agreement with all parties involved in Jegin dam, a number of modifications were made to the original design of the dam so as to make construction easier and thus more rapid and of a higher quality. There were two main changes: first, all the galleries were made either horizontal or vertical. The latter were shafts and were separated in to 'man access' or 'equipment access'. The second main change was to move the bottom outlets to the left abutment, and to construct them within traditional concrete blocks, thus separating them from the RCC placement in the main body of the dam. The bottom outlets discharged on the concrete steps before joining the river downstream of the main stilling basin, see Figure 10.

A further change to the construction procedure was to remove the traditional facing concrete and replace it with GEVR (grout-enriched vibratable RCC). This had been tested successfully in the coffer dam. The dam thus relied on the RCC itself for impermeability (5).

7. CONSTRUCTION OF DAM
7.1. Concrete Production
The geometry of the dam site and the relatively reduced space to locate the installations were the additional difficulties for the design of the plants. Figure 11 shows the final layout of the concrete and cooling plants at right abutment at Jegin dam site. The supply of the aggregate from the main stockpiles was done by 25-tonne dump trucks. Those trucks downloaded on receiving hoppers with a capacity from 4 to 6 hours average production. The hoppers were connected with the batching plant by automatic control systems that could feed the material into the
weighing hoppers. The concrete plant had a nominal capacity of \(2 \times 160 \text{m}^3/\text{hour}\), and consisted in two plants each with two 2,250m3 capacity horizontal twin-shaft bath type mixers. The cooling plant combined with a water chiller plant to cool the mixing water to 4degree centigrade and the flak ice plant with total capacity of 180 tone of ice per day. The cementitious materials were transported from the cement factories to the site by road, and the natural pozzolan from Khash to the site were deliver by big-bag. In order to have a storage for cementitious materials to supply the production of more than one week, four large 800-tonne silos and eight further small 60 tone silos were erected closed to the concrete plants. A combination of both pneumatic transportation systems and screw conveyors is used to feed the receiving hoppers of each mixer.

### 7.2. RCC Transportation

The transportation systems selected for the transportation of concrete was a combination of 45 degree inclined steel chute and trucks on the dam. Still chute was built up in such a way that it could be removed as the dam was raised. As shown in the Figure 12, the chute was supported on the excavation on the right abutment. A surge hopper at the top of the chute regulated the flow of concrete out of mixers. The chute ended in a swinging element that moved to change its loading position from one truck to the other. Figure 12 shows a view of the chute that has been used for the transportation of roller compacted concrete in Jegin dam (1). The chute has worked successfully, and the high-paste concrete in the RCC mix has not shown any segregation. The flexible cover on the top of the steel chute has been working as a protection against solar radiation, and thus avoiding excessive drying of the mix in its way down to the placement.

![Figure 11. View of vacuum chute used at Jegin dam and general view of site lay out](image)

### 7.3. RCC Placement

The RCC was transported from the delivery point of the steel chute to the point of placement on the lift by dump trucks. Dozer type D4 was then used to spread the RCC and single-drum 11 tones vibratory roller were used for compaction (see
However in areas where the access for the larger roller was difficult or closed to the forms, the compaction was done by small double-drum 3.5 tones roller.

A special type of cantilever formwork was used to form the faces of the dam. GEVR (grout-enriched vibrated RCC) was used against the forms instead of the conventional immersion vibrated concrete. The great advantage of the GEVR is that just a water/cementitious material grout applied onto the surface before the RCC is spread on top of it, and then consolidated by immersion vibrators. Transverse joints were formed inserting galvanized sheets into the fresh fully compacted RCC that are left in place acting as joint inducers. PVC membranes were inserted in the GEVR in the upstream face of the dam and downstream spillway sections to seal the transverse joints. The surface of compacted RCC was continuously cured by means of low-pressure water jets creating a thin nebula on top of the surface. Due to the extreme high temperatures on site, this was a major activity at Jahgin. Depending on the time elapsed between consecutive layers and weather conditions, different steps of treatments of the horizontal joints were defined. Cleaning of the surfaces was done by brooms and high capacity vacuum trucks.

Conclusions

- A suitable supplementary cementitious material has been found in Iran for use in the RCC dam at Jegin;
- In spite of the Khash natural pozzolan having never been used in concrete before, suitable concretes containing the material have been designed and tested in the laboratory;
- Both the construction methodology and the RCC have been successfully tested at full-scale.
- In spite of the very challenging conditions at the Jegin dam site, a suitable methodology has been developed for the construction of the dam and a very forgiving RCC designed.
- The plant layout and the construction methods have been optimized and
adopted according to the changes incorporated to the design.

- We believe that with these changes and an efficient management of all activities involved, a successful RCC experience have been achieved in our project.

REFERENCES
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