

RESTORATION AND REHABILITATION OF KRISHNARAJA SAGARA

MASONRY DAM BY POINTING AND GROUTING

(A Case - Study)



Er. Anupam Bidasaria

Managing Director, Ferro Concrete Const. (India) Pvt. Ltd.,

Indore - 452 003 (M.P). India

E-mail : anupambidasaria@gmail.com & ferroco2011@gmail.com

The region of Mysore and especially Mandya had historically been dry. A severe drought in 1875–76 had wiped out one-fifth of the population of the Kingdom of Mysore. The then Chief Engineer of Mysore Sir M. Visvesvaraya presented a blueprint of a dam to be built across the river Cauvery near the village of Kannambadi. The construction of K.R.S dam commenced in the year 1911 and completed in the year 1931. The dam is located at longitude 76°34' 30" E and latitude 12°25' 30" N.

The dam has a total catchment area of 10880.63 Sq.km consisting of 3229.58 Sq. km intercepted by reservoirs on major rivers of Harangi (419.58 Sq.km) and Hemavathy (2810 Sq.km) reservoirs and 7651.05 Sq.km independent. The reservoir formed by the dam has a gross storage capacity of 1400 MCum (49.452 tmc) and live storage capacity of 1276 Mcum (45.051 TMC), to facilitate irrigation to 78915 ha (195000 acres). The dam is built as a Gravity dam constructed in stone masonry with surki mortar of length 2621 m (8600 ft) and has a maximum height of 44.66 m (146 ft). Krishnarajasagara Dam is one of the major multi -purpose reservoir projects in India and has been considered as a Dam of National Importance.

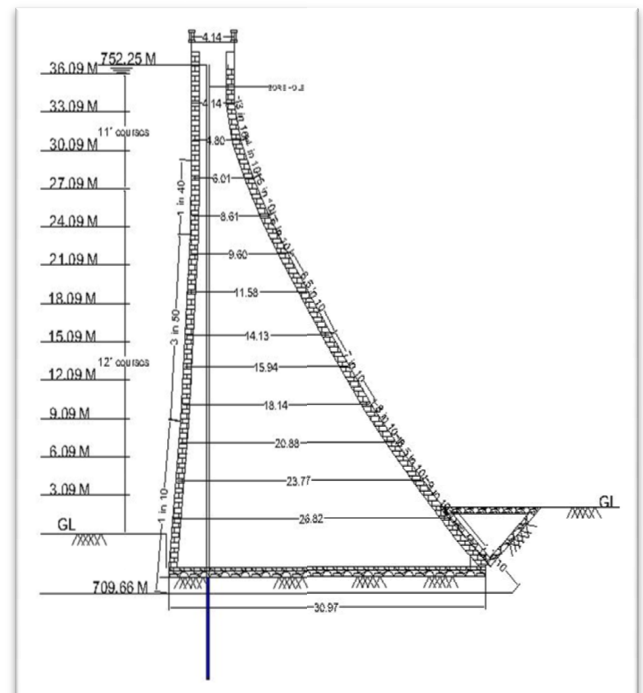
OBSERVATIONS BY DAM SAFETY REVIEW PANEL (DSRP)

During the inspection of the dam by the DSRP panel members periodically from the years 1996 to 2014, it is noticed that there is a deposition of lime on the downstream face presumably due to leaching of free lime in the lime-surkhi mortar used in the construction of the dam. The process of lime leaching is still continuing unabated although more than 80 years have elapsed since its first filling in 1931. As a result, it is apprehended that the strength of mortar and resulting in situ strength of masonry may have reduced which in-turn affect the structural stability of dam. The panel is seized of possible loss of strength of masonry owing to lime leaching and ageing of materials in the masonry. However in the absence of tests on in-situ strength of masonry of KRS Dam, the Panel had recommended to assess the same from the available test data of in-situ strengths determined for contemporary masonry dams in South India.

CWPRS (Central Water & Power Research Station) Khadakvasla Pune, took up a study with respect to design aspects, structural stability and soundness of the body wall as recommended by DSRP. CWPRS submitted their report in Sept 2013. Accordingly an

estimate was prepared for strengthening of body wall by pointing and grouting using specialised material.

A typical cross section of the KRS dam is shown in the figure:-



METHODOLOGY FOR REHABILITATION OF KRS DAM

This is the first time that the major rehabilitation for the KRS dam was executed from the month of July 2016, since it was built.

The rehabilitation work was performed in three phases:-

- PHASE -1 UPSTREAM FACE POINTING**
- PHASE -2 HORIZONTAL GROUTING**
- PHASE -3 DRILLING & BODY GROUTING FROM DAM TOP**

1) UPSTREAM FACE POINTING

For pointing work, UV resistant, high strength, non-shrink repair mortar for joint filling on u/s face of dam has been used. Masonry joints were raked up to a depth of 50mm (Minimum). This include removing loose mortar inside the joints and removing loose masonry by breaking using manual and / or mechanical means, removing of existing embedded M.S. bar if any, cleaning the joints surface and inside of joints with special chemical for algae-fungi removal and cleaning with pressure water jet, applying a bond coat suitable to bond masonry to mortar for achieving required bonding strength and providing a water repellent top coat after finishing,

Surface Preparation:

The masonry joints were cleaned by removing existing loose particles, by breaker machine, grinder, wire brush, cutting of existing steel bars, joint cleaning by high water jet and by other mechanical / manual means

The algae fungi were removed by applying special chemical.

Application of Bond Coat to the Prepared Surface:

A thin coat of bonding chemical is applied to the prepared surface by using brush. The utmost care is taken so that the bond coat is applied to the quantity of area which can be worked upon within one hour of application of bond coat, the duration which ensures the stickiness in the bond coat.

Filling of Masonry Joints with Mortar:

Before application of the Mortar, surface must be sound, clean and dry. The deep cavity / masonry

joints more than 50 mm and up to 300mm depth were filled with cement sand mortar with less water cement ratio and using non-shrink admixtures leaving about 5 cm from surface to be later filled up with special repair mortar. Where the depth of cavity is more than 300mm, 12.5mm dia, nozzles/ pipes were inserted for undertaking low pressure horizontal grouting.

The cavity and masonry joint of 5 cm depth were filled with special repair mortar. The mortar was cleanly and neatly finished on surface with raising on rock surface to minimum 10 mm on all sides and 10 mm thick on original masonry surface. (T- Pointing). A curing time of 3 days was allowed for mortar.



BEFORE T-POINTING



AFTER T-POINTING

Application of Water Repellent Top Coat on Treated Masonry Joints

A homogeneous mixture of top coat is applied on mortar by brush and then immediately dry sponge roller is applied on the same surface. It is to ensure that there should not be any gap, air

bubbles or lumps. This coating is cured by sprinkling water thrice a day for 48 hours. The surface is to be kept wet all the time.

2) HORIZONTAL GROUTING:

To consolidate the upstream face where ever deep cavities were seen during racking of the old mortar for Pointing and in the pier portion, special nipples of 10mm dia were installed and fixed with the mortar. These nipples were later used for pumping the low pressure grout to fill the cavity in the upstream face. The grout mixture consisted of water, cement and Admix as recommended by Central Water and Power Research Station (CWPRS). The amount of grout injected into the upstream face is recorded with respect to the time and the record for the same has been maintained. The figure below shows the grout being injected through Nozzle installed in the Pier portion.



NOZZLE INSTALLED IN THE PIER PORTION

3) DAM BODY GROUTING FROM DAM TOP

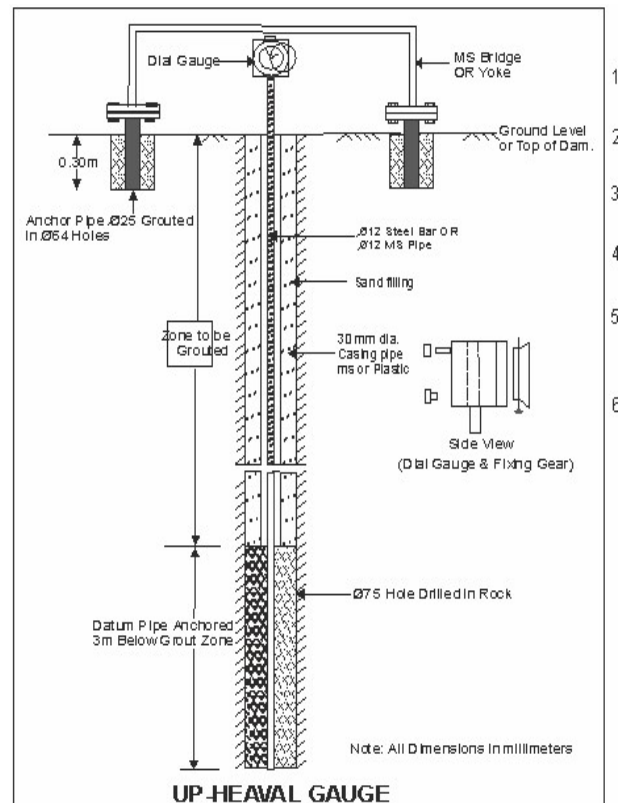
(a) Installation of Upheaval Gauges.

Upheaval gauges are provided to monitor movement, if any, of the rock mass or concrete during permeability tests and pressure grouting, during consolidation grouting. These have been provided at five locations. These have been installed prior to the commencement of washing and grouting operations and being maintained in working order till completion of the work.

For installing upheaval gauges, holes of diameter 75 mm were drilled using Rotary Drilling

Machine, so as to accommodate a casing pipe of 50 mm diameter. The hole was drilled 6 m deeper than the deepest hole proposed to be grouted in the vicinity. After drilling the hole to required depth, the casing pipe was lowered into holes. Thereafter 25 mm diameter G.I. pipe was fixed inside the casing pipe by grouting the bottom of hole by means of cement slurry, for minimum depth of 0.6 m at the bottom of hole. The annular gap between the drilled hole and the casing pipe has been filled by pouring lean cement slurry. An iron yoke or a bridge was anchored to the surrounding rock, as shown in the sketch below.

Measuring tapes were set at the top of the pipe and on the underside of the yoke. A measuring dial gauge was rigidly connected at the top of the plate on the pipe and bottom of the yoke. The dial gauge installed is accurate to measure 0.0254 mm (0.001 inch) of upward movement.



(b) Drilling of Holes

Drilling has been done by using Rotary diamond drilling rigs (Rotary method) with water flushing system. Rotary (Diamond) drilling is recommended for drilling in weak and porous masonry dam, but it is very expensive and slow in progress.



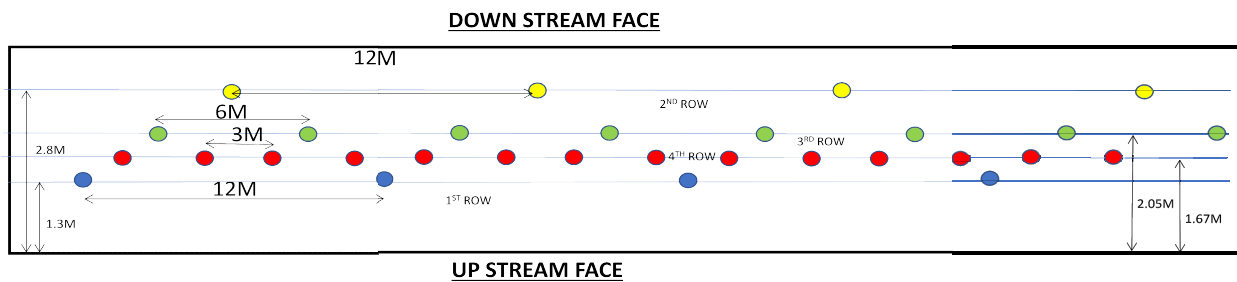
DRILLING & GROUTING WORKS IN PROGRESS



First of all a casing of 80 mm diameter is fixed at the location of the hole, at least ½ m in the masonry by drilling a suitable dia. hole and fixing the casing by caulking and grouting it in the drill hole.

Drilling in masonry has been performed in descending order method in the front row first, where holes were marked as designated in stages of 6 meters. The first stage so drilled is washed with jet of air and water till all the drill cutting comes out.

After grouting the holes of 1st row, 2nd row drilling and grouting was performed followed by 3rd and 4th row. The pattern of drilling adopted at the KRS dam is shown in the figure below.



- FIRST ROW (1.3 Mtr from UPSTREAM FACE)
- SECOND ROW (2.8 Mtr from Upstream)
- THIRD ROW (2.05 Mtrs from UPSTREAM FACE)
- FOURTH ROW (1.67 Mtr from UPSTREAM FACE)

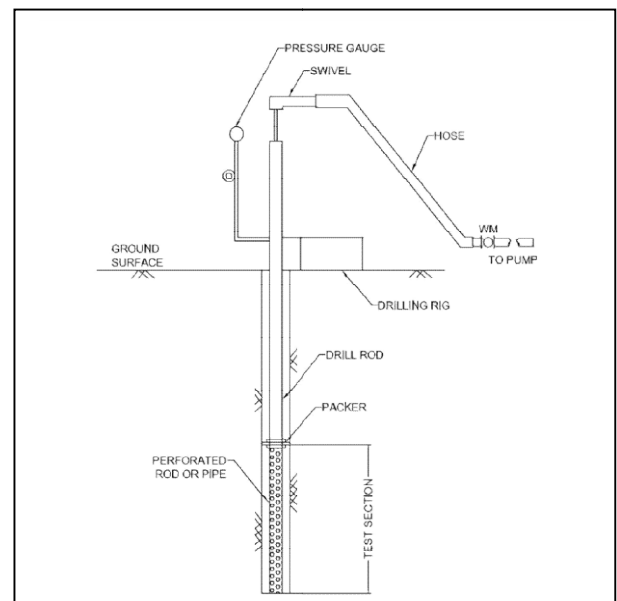
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c) Water Loss Test

A water loss test was carried out in alternate stage of a hole. For each water loss test, water is injected under pressure into the hole for a period of not less the 10 minutes. The quantity of water loss is measured for this period. The Lugeon Value is calculated by the following equation:

$$\text{Lugeon} = \frac{\text{Water Intake (L/min)} \times 10}{\text{Stage length(m)} \times \text{Pressure(KPa)}}$$

A schematic diagram of the arrangement for the Water Loss Test is shown below:-

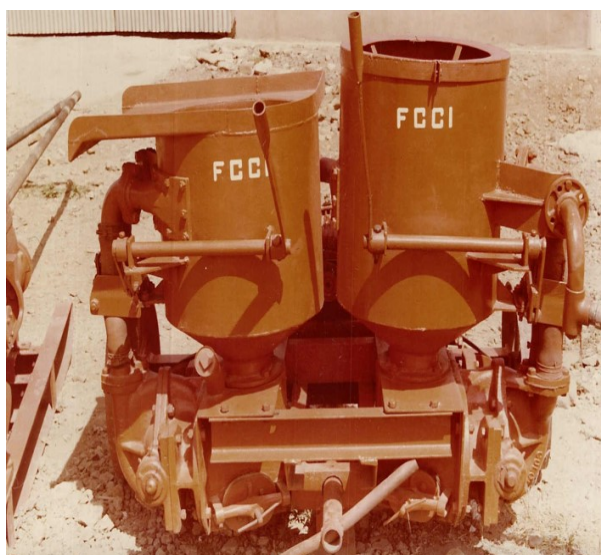


PACKER ARRANGEMENT

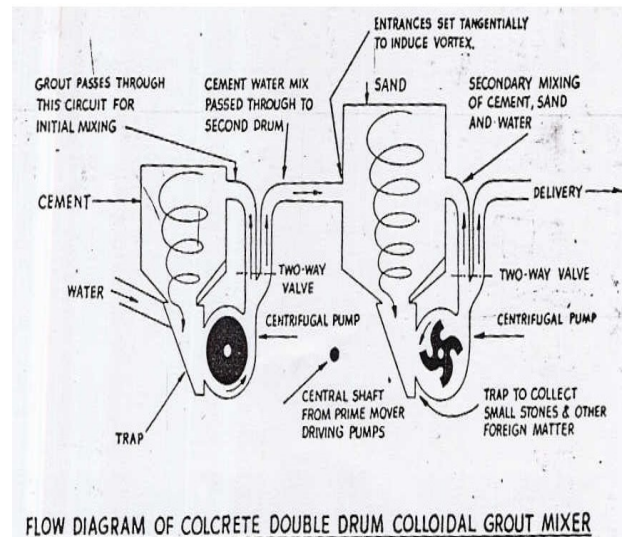


d) Grouting:

Grouting has been executed as per IS 6066 by starting with thin mix of 1:10 cement to water and thickening the same as the grouts intake increases and ending with 1:1 by weight. Cement used is 43 grade Ordinary Portland cement conforming to Indian standards “IS: 269-1989”/IS 1489-1976/IS 12600-1989/IS 12269 or their latest revisions along with the admixtures as recommended by CWPRS. The admixture is suitably mixed with the cement grout as per technical specifications. Grout is then passed through a 1200 micron sieve located between the agitator and the pump. The pump used is a screw type pump capable of running at least 12 hours continuously under normal load.



COLLOIDAL MIXER



The grout is left in the first stage to set after grouting, for 24 hours and then by re-drilling is done through the set grout followed by drilling of second stage of 6m depth. Same procedure, as described above is followed till a hole reaches to full depth ie 3 m in rock foundation to grout the upper layer of foundation. After completion of grouting of a hole, in all the stages, the entire length of the hole is backfilled with a grout of 1:1 cement to water.

CONCLUSION

The KRS dam is an iconic dam. It is a marvel of engineering produced in the era when no computer etc existed. To be associated with the rehabilitation of this iconic dam was a proud moment for the company. The work done by us at the dam was awarded the best rehabilitation work by DRIP for the year 2017.

The total quantity of pointing executed for the KRS dam is around 42000 m², which is sort of a record for the pointing work executed in a period of nine months.

The technical and professional approach toward drilling and grouting work has resulted in consolidation of the 100 year old KRS dam and the seepage of water towards downstream was arrested to a very large extend.