BAGMATI RIVER BASIN IMPROVEMENT PROJECT, PROJECT IMPLEMENTATION IRRIGATION UNIT,

GUHESHWORI, KATHMANDU

**DHAP CFRD**

# FIELD CHALLENGES, ISSUES AND SOLUTIONS OF DHAP DAM DURING CONSTRUCTION

PREPARED BY:

SUB. ER. DEVENDRA RIMAL

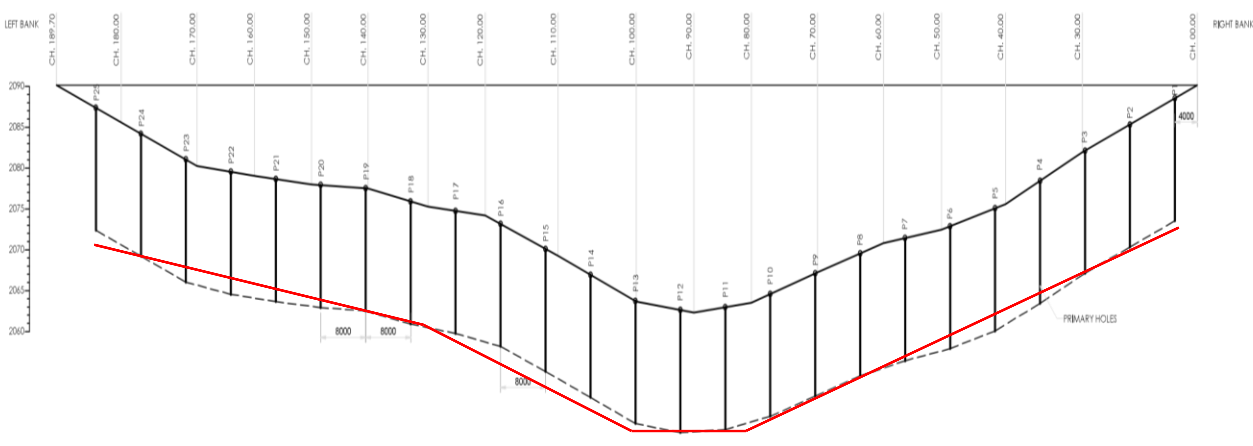
# Table of Contents

# 1. Introduction

CFRD of 24m height of Dhap Dam which is located at the northern belt of Kathmandu that lies in the Shivapuri Nagarjun National Park (SNNP) is the first ever such dam in Nepal which is in the construction phase and was halted a while due to the Covid-19. CFRD is considered to be safe, economically low cost, and fundamentally fitted to fragile geology to inhibit the leakage providing curtain grouting. However, the design of CFRD is empirical and based on precedent of past experiences. The present project is designed on the basis of ICOLD Bulletin 141, 2010 and other relevant standards. The length of the dam crest is 174.7m, slope of 1.7(H):1(V) on both upstream and downstream slope. The dam body consists of various zone like, 2A, 2B, 3A, 3B, 3C and 3D. The upstream slope covers with concrete slab of 300mm and is divided in 12 no. panels with a width of 15m. Although this is large dam as per ICOLD definition but in comparison to the other dams of the world, it is small and only holds 850,000m$^3$ water in the reservoir. This Paper focuses on the overall construction activities, challenges, site issues, solutions and recommendations about this project.

# 2. Initial Site preparation and Construction phases

As the crucial part of gravity dam is that it should preferably rests on sound rock foundation, removal of top soil and reaching the dam foundation up to good quality rock is utmost important. Exposed rock foundation should be cleaned with water jet and loose rock materials should be removed. Profile of cutting along the direction of dam axis and perpendicular to it should be straight lines as far as possible rather than curvilinear profile. It is so because it will be easier to locate line and level of perimeter joint and also makes easier when installation of copper water stopper. At Dhap dam, there was curvilinear cutting profile at foundation and because of that it had become difficult while installing the copper water stopper at perimeter joint.




PLINTH PROFILE SHOWING PRIMARY HOLES FOR CURTAIN GROUTING

In above picture dotted plinth profile is as per actual construction and red line is according to desirable profile.

Fig. Zigzag line of perimeter joint due to undulated and curved profile of plinth at Dhap Dam.

After preparation of rock foundation detail survey is carried out and according to actual site survey data new layout of plinth is proposed if there is any deviations from the design. After that dental concreting of plinth shall be done. After inserting desired rock anchor bars and HDPE pipe for grout holes, plinth shall be casted monolithically. As there is perimeter joint between internal and external plinth and it is required to install copper water stopper, it shall be better to cast the concrete at perimeter joint at second stage. At Dhap dam, initially internal and external plinth were casted separately and it was not monolithic. However, the plinth is later made monolithic by adding extra U reinforcement bar between internal and external plinth.

Fig. U reinforcement bar tied between internal and external plinth.

After locating precise line and level of perimeter joint, internal plinth can be casted. Then filling of dam zoning materials (after gaining full strength by concrete) and casting of external plinth can be done simultaneously as the external plinth construction is outside the dam and do not interfere with embankment placement. However, at Dhap dam filling of zoning materials had been started without finding the precise line and level of perimeter joint. This resulted in curved profile of dam face at u/s during construction and corrected later by shifting the plinth horizontally outwards and inwards so that the face slope and the dam axis remained as per original design. The next step after external plinth casting shall be grouting. As grouting is fairly uncertain and may take substantial time period, it shall be started as soon as the external plinth get full concrete strength. Therefore grouting and filling of dam zoning material shall go simultaneously.

# 3. Plinth

The plinth or toe slab connects the foundation with the face slab. It should be watertight and also acts as grouting cap for consolidation and curtain grouting. The plinth should be firmly connected with foundation rock. For this purpose, a number of anchor bars are placed at suitable interval. At Dhap dam, 5 nos. of anchor bars along widthwise have been placed at the spacing of 3 m along the length of plinth. Dia. of bars is 26 mm and the hole is of dia. 28 mm with the depth of 3 m. The anchor bar is L-shaped. The bottom vertical portion which is 3 m is total inserted into the hole and fixed with cement slurry. The upper 1 m horizontal portion is later inserted into mid-section of external plinth.

Fig. Plinth reinforcement and Anchor bars at external plinth

Concrete pouring at plinth shall be started at deepest section and moved towards the abutment on both sides gradually so that the proper concrete compaction will be ensured. If the slope of plinth is high then inclined fixed formwork may also be required. Internal and external plinth shall be monolithic and reinforcement bars shall continue along the whole length of the plinth. No expansion and contraction joints are allowed in plinth.

# 4. Perimeter Joint

The perimeter joint connects the concrete face slab and the plinth of the CFRD to complete the u/s water barrier of the dam. It should maintain a seal against full reservoir load while allowing for anticipated movements between the plinth and face slab. At Dhap dam, two barrier waterstop system has been used that is bottom copper water stopper and upper water barrier consisting of mastic sealant (E.g. Bitumen graded sand mixture covered with rubber band).

During field observation following points were found:

a. Bottom waterstop system:

   It consists of w shaped copper water stopper of 1mm thickness. One wing is embedded in the plinth while another wing is rested on flexible bitumen sand asphalt layer and hold by face slab from the top. Brazing of copper water stopper has been done at standard temperature using specified brazing rod. It is observed that brazing shall be done inside closed room so that the air should not disturb the brazing process as far as practicable. At Dhap dam, brazing of copper had been done inside the closed room upto the length of 8 to 10 m so that transportation would not become difficult and then further brazing had been done at the site with due care. Every copper joints have been tested by NDT and vacuum test.

   It is observed that after successful embedment of one wing of copper in plinth at plinth concrete another free wing started to buckle gradually as the concrete setting goes on. It is found that this tendency is more pronounced near curved geometry of plinth in plan at left bank of Dhap dam. Due to this buckling of copper, it bends upward and creates a substantial gap between copper and top surface of sand asphalt base. First contractor filled the gap with higher sand asphalt, however later it is found that at that section face slab thickness will be compromised. So, again the excess sand asphalt was removed and the copper is pressed down during face slab casting so that the gap is minimized as long as possible. To minimize such effect it is recommended that plinth geometry should be straight and after installing copper in plinth concrete the free wing should be loaded vertically to keep it in original position.


Fig: Removing excess sand asphalt from copper below.

Hypalon Band is kept in between Sand asphalt mixture and copper water stopper in perimeter joint which is missing in original design and drawing.


Fig: Details of perimeter joint (Sand asphalt mixture, Hypalon band, Copper water stopper, Polyurethene foam and Bitumious fiber from bottom to top).

Polyurethene foam shall cover around the rib portion of copper water stopper so that direct contact with concrete from both plinth and face slab is prevented.

Fig: Polyurethene foam pressed down by fresh concrete of starter face slab

Neoprene foam filler shall fill the full depth of rib of copper water stopper and shall continuously run throughout the length of copper water stopper without any gap. At joint where brazing is done at the site, it is not possible to insert the neoprene before brazing and sometimes there is more chances to remain gap at those joints. Those gap shall be filled by inserting some pieces of Neoprene filler after brazing.


Fig: Neoprene not filling the full depth of rib of copper water stopper

Fig: Filling the gap along the length of neoprene at joints.

Bituminous fiber shall be kept in place only after completion of reinforcement work on face slab. Otherwise during moving reinforcing bars, bituminous fiber get damaged.

Fig: Damaging of bituminous fiber during laying of reinforcement bars.


Fig: Brazing of copper water stopper .


Fig: Joint at intersection of vertical and horizontal copper water stopper

b. Upper waterstop system:

Upper waterstop system at Dhap dam uses Mastic joint sealant. It consists of forming a reservoir of mastic at the top of the perimeter joint by chamfering the top edges of the plinth and face slab. Mastic is then placed into the joint until it forms a mound above the surface of the joint. However, this technique didn't give satisfactory shape of the mound. The mastic material used in Dhap dam is bitumen graded sand mixture. First BG sand mixture is heated to specified temperature and then poured into semi-circular iron pipe of the same size of that the mastic mound at suitable onsite facility. After setting, those mastic logs are transported to the nearby site and are joined by heating each end, and then pressing each end together. But those logs are only for final upper semi-circular shape. For bottom chamfered area, heated mixture is directly applied and top surface is levelled with face slab slope. Each layer of mixture shall stick well together.

Fig: Moulding of bitumen graded sand mixture at onsite facility.


Fig: Bitumen pouring inside chamfered portion of joint


Fig: Final shape of the mastic mound at perimeter joint

The moulded mastic sealant shall be covered and protected with hypalon band and anchored with galvanized rigid steel angles and nut bolts at suitable interval. If the permanent covering will be delayed due to some reasons then the temporary covering shall be provide to protect the mound from direct sunlight, rain and other possible damages until then.


Fig: Disfigured shape and some minor head cracks on the surface of mastic mound due to lack of proper covering

# 5. Face slab

The primary water barrier of the CFRD consists of concrete face slabs laid over underlying support zones of the rockfill body of the dam. Dhap dam is only 24 m high and the face slab concrete is of B25 grade having uniform thickness of 30 cm. However, a dental concrete of 50 mm thickness shall be provided over the immediate face slab supporting zone (e g. 2B zone). Dental concrete over the 2B zone facilitates uniform face slope and protect the 2B zone from scouring during rain. The whole face slab is divided into 12 nos. of panel and the width of panel adopted is 15 m.

### a. Slope correction

The most challenging issue at Dhap dam is face slab slope. As dam axis, face slab slope, and locus of perimeter joint is geometrically dependent to each other, if one component will deviate from the original design then other components will also be affected. Locus of perimeter joint at Dhap dam was initially not in correct position and during filling of dam material it was realized that upstream face of central portion of dam (panel no. 7 and 8) was bulged outward. Also panel no. 10 and 11 had steep face slope than the actual design. Different corrective measures were proposed like shifting of plinth horizontally outward, lifting the plinth vertically upward and lifting only the plinth portion around perimeter joint by expanding the original shape of it. Expanding the plinth around perimeter joint was rejected due to bulky design and lifting of whole plinth was also rejected due to heavy cost. Near panel no. 10 and 11 further excavation is carried out and the plinth is shifted horizontally outward and the slope of face slab is maintained by putting extra lean concrete. Therefore, the thickness of corrective lean concrete is up to 1.5m and more at some sections near perimeter joint. But near panel no 7 and 8 the excess filling material is scrapped from the bulged surface and plinth is shifted inwards.

Fig: Red line shows the bulging of face slope near permanent outlet


Fig: Slope correction by scrapping 2B material above permanent outlet and adding lean concrete on the surface near deepest section.


Fig: Pouring corrective lean concrete at S-10 panel as slope correction


Fig: Removing 2B zone material near permanent outlet where slope is flatter than design slope.

### b. Starter slab

Starter slab is casted manually where slipform can not operate. Starter slab starts from perimeter joint. At dhap dam starter slab is casted using only fixed formwork at vertical joints and no formwork on top surface. It was observed that due to lack of surface formwork no proper compaction had been ensured. It also took longer time than initial setting time of concrete to finish the top surface of concrete. Therefore it is realized that surface formwork is necessary at starter slab for good quality concrete.

Fig: Starter slab concreting

### c. Main face slab

Main face slab is casted using slipform moving at the rate of 2 m per hour. Slipform at Dhap site is locally fabricated. Such type of slipform is used first time in Nepal. Therefore there were many challenges regarding design, fabrication and its application. There were many corrections and trial running of slipform. The first panel casted using slipform was S-9 panel. Upto 2 m, slipform worked well but after that slipform got lifted up. Alternate lifting and falling of slipform resulted in undulated surface of face slab and quality of concrete was also affected. Then for other subsequent panel so many improvements were done:

i. International expert of face slab from Iran visited the site and gave valuable instructions. Expert himself supervised the work in close coordination with the contractor and concrete work got improved significantly.
ii. First improvement was that moving of slipform was made intermittent but not continuous. The winch was started only after hardening of concrete sufficiently within the slipform. The controlled procedure is slipform fixing on rail, concrete pouring, compacting with vibrator, removing excess concrete from top end of slipform, resting for hardening of concrete, slipform unfixing from rail, starting the winch and moving the slipform up to 0.75 m to 1 m, stopping the winch and slipform fixing on rail and again the process started until the panel got completed.
iii. Extra dead load (i.e. Concrete cube) also added on slipform.
iv. A platform was joined at lower end of slipform to facilitate labors to stay safely while trowling the concrete surface below.
v. Double winch system was provided.
vi. Slipform was clamped with rail using mechanical jack and Nut bolts to prevent uplifting during concrete pouring and compacting.

Other learnings regarding face slab and slipfom:

i. Slipform would not require side plate to acts as moving formwork on left and right side of slipform. It will be better to have fixed steel or wooden formwork rather than such side plate attached to the slipform. Moving side plate leaves the concrete still when it doesn't reach proper hardening. Therefore side fall of concrete is common. And during manual chamfering near vertical joint, concrete will also be disturbed.

ii. There is no absolute significance of bond break between underlying thin lean concrete and face slab concrete. However, if there is sufficient thick lean concrete like when curb method of slope protection (ICOLD Bulletin 141, Section 8.3.5) is adopted at the interface between the concrete slab and the rockfill zone and if excess lean concrete is used for slope correction like at Dhap dam, then such lean concrete and concrete curb should be treated to prevent bond. Asphalt as well as plastic sheets shall be used to prevent bonding. At dhap dam no bond breaking technique has been applied. (See details on ICOLD Bulletin 141, Section 6.6)

iii. Width of slipform used in Dhap dam is 2 m. However 1.2 m wide slipform is handy and easy to operate. And at small dam like Dhap dam, panel width of face slab could be 12 m only rather than 15 m.

iv. Construction joint in slab should have green cut. Green cut is done after 5 to 6 hours of concrete casting by water jetting in such a way that the loose mortar and aggregate shall be washed way. If green cut is not possible then chipping of loose concrete with jack hammer shall be done. All dust, loose mortar should be cleaned out from the joint before receiving new concrete. The horizontal construction joint shall be straight and normal to vertical joint. The only mandatory construction joint lies between starter slab and main face slab but other horizontal construction joint should be avoided as far as possible.

v. Slipform should overlap with starter slab by at least 1 m so that initially concreting shall be done inside remaining only 1 m. Because of that upward thrust of concrete on slipform will be minimized and chance of uplifting is reduced. Again sufficient setting time shall be allowed before leaving the concrete by slipform.

vi. After 4 hours of concrete casting, curing shall be done. Before that fresh concrete surface shall be protected from rapid evaporation and moisture loss during sunny day by spraying curing compound which is economical, easy and effective technique. Face slab concrete generally requires constant curing with jute sheet covering up to at least 90 days.


Fig: Loading Slipform on rail for trial running

Fig: Concrete casting of S-9 panel using slipform

Fig: Uplifting of slipform guide roller on S-9 panel during concreting

Fig: Moving side plate of slipform not able to hold the concrete and concrete is covering whole rib portion of the copper water stopper which necessitates manual chamfering.

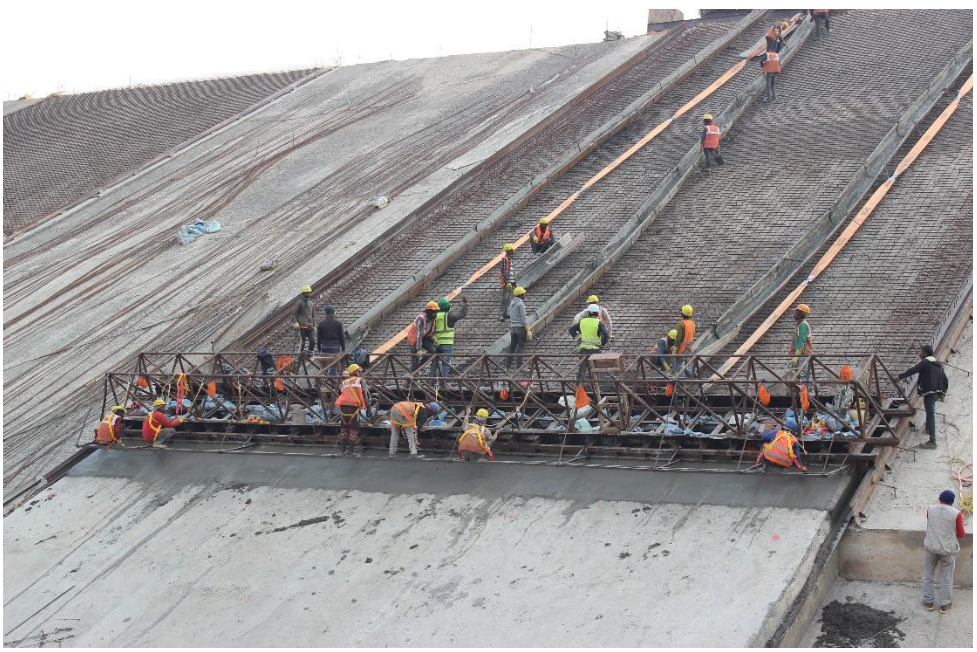


Fig: Concreting on S-5 panel with slipform using double winch, adding extra dead load, joining platform for labour to sit while trowling.


Fig: Clamping the slipform with rail

Fig: Finished surface of face slab

Fig: No overlap of slipform within starter slab. Chances of concrete leaking from this gap is high.

Fig: Removing loose concrete from joint using jack hammer


Fig: Repairing honeycomb concrete with repairing mortar

# 6. Grouting

Purpose of grouting through plinth is to ensure a competent seepage barrier in rock foundation as well as to improve the properties of plinth foundation. While seepage barrier is ensured through provision of grout curtain, improvement of plinth foundation is ensured through consolidation grouting. At Dhap dam, the grouting has been done through a systematic curtain and consolidation grouting and GIN method has been used. The objective of grouting at Dhap dam is to achieve a tight foundation with permeability not exceeding 3 lugeons.

Both drilling and grouting operations shall be carried out based on Split spacing method. A stable grout mix, as finalized during the trial grouting, shall be adopted. After completion of grouting of each sequence of split spacing i.e. primary, secondary and tertiary, the results of water pressure test and grout consumption are to be plotted and analyzed. This shall be the basis of decision for additional drilling and grouting.

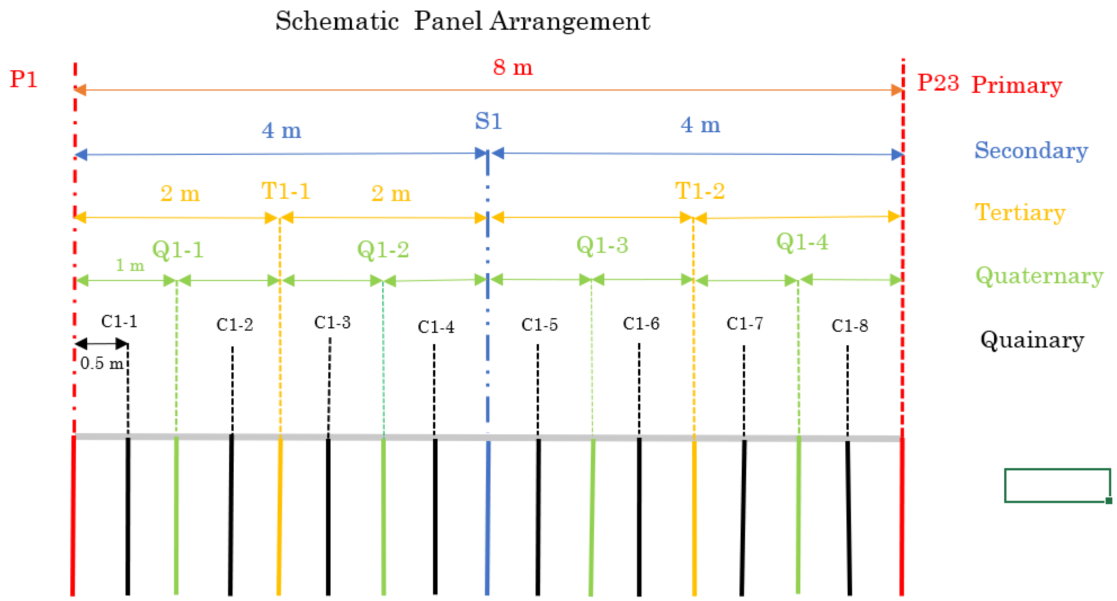



Fig. Schematic panel arrangement of Split Spacing Method

i. Grouting work shall be started as soon as the plinth concrete gets its 100% strength (28 days strength) from beginning of the project because grouting is independent activity with dam filling work.

ii. Suitable number of exploration borehole shall be drilled with comprehensive lugeon test and coring along the plinth from left to right abutment prior to curtain grouting work started. Based on the results obtained from exploration bore holes., curtain grouting shall be designed.

iii. Any open excavation, holes and gap between external plinth and abutment cut side shall be packed with lean concrete to minimize side leakages during grouting.

iv. Split spacing method shall be strictly followed for both drilling and grouting.

v. Rotary drilling is preferred where rock to be drilled is weak.

vi. Wet drilling is also preferred to dry drilling.

vii. A stable grouting mix shall be designed which shall have bleeding less than 5% after two hours.

viii. Grout temperature shall be checked time to time and should not exceed 32 degree celcius.

Fig: Normal drilling with ROC macchine

Fig: Rotary drilling machine for core drilling


Fig: Core logging


Fig: Colloidal mixture, agitator, piston type grout pump, digital flowmeter set


Fig: Side leakages of grouting


Fig: Lean concreting in trench adjacent to external plinth to minimize grout leakages.


Fig: Marsh cone flow test of grout