The application of Rubble Masonry Concrete (RMC) construction for African dams and small hydropower projects

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ABSTRACT: The use of Rubble Masonry Concrete (RMC) for the construction of small to medium sized dams is becoming increasingly attractive within the African context. Through recent successful developments in South Africa and the Democratic Republic of the Congo (DRC), RMC designs and construction techniques have been advanced. For projects where labour intensive construction approaches are preferred, RMC application provides the necessary skills training and job creation to regions that are desperately underemployed. From water supply projects in rural areas to remote run of river hydropower schemes, RMC offers a cost-effective, low-maintenance, unskilled labour-based, simple dam construction technology, resulting in a very robust lifelong asset that meets international dam safety standards. This paper and presentation will cover the design methods and standards applied to recent projects that have incorporated RMC weirs and the construction techniques that were successfully implemented. Case studies of RMC Dams constructed for water supply reservoirs and a remote (11 MW) hydroelectric power project will be presented and discussed.

RÉSUMÉ: L'utilisation de maçonnerie de pierre pour la construction de barrages de petite et moyenne dimension devient de plus en plus intéressante dans le contexte africain. Grâce aux récents développements réussis en Afrique du Sud et en République démocratique du Congo (RDC), la conception et les techniques de construction de barrages en maçonnerie a été perfectionnée. Pour les projets ou les concepts de construction à haute intensité de main-d'œuvre sont préférées, la maçonnerie facilite la formation et la création d'emplois nécessaires aux régions à fort taux de chômage. Qu'il s'agisse de projets d'approvisionnement en eau dans les zones rurales ou de projets hydroélectriques au fil de l'eau dans des régions éloignées, la maçonnerie offre une technologie de construction de barrages simple, peu coûteuse, à maintenance minimale et à haute intensité de main-d'œuvre non spécialisée, ce qui en fait un actif à vie robuste et qui répond aux normes internationales de sécurité des barrages. Cet article et présentation porteront sur les méthodes et les normes de conception appliquées aux projets récents qui incluent des déversoirs de maçonnerie et sur les techniques de construction qui ont été mises en œuvre avec succès. Des études de cas sur les barrages en maçonnerie construits pour des réservoirs d'approvisionnement en eau et un projet hydroélectrique en région éloignée (11 MW) y seront présentées et discutées.

1 RUBBLE MASONRY CONCRETE DAMS

1.1 *Introduction and brief history*

Stemming from an ancient beginning, the earliest account of major dam engineering work has been linked to the use of Rubble Masonry Concrete (RMC) as a durable dam construction material. Masonry structures proved to be far superior to the simple embankment dams that had been attempted before, with embankments often failing due to uninformed flood hydrology, materials strength and behaviour and limited manual compaction methods available at that time.

RMC origins date back to 4500 B.C., as seen in the remains of the abutments of Sadd el-Kafara Dam in Egypt, an 11m high gravity wall formed by rubble masonry, and regarded as one of the oldest dams constructed in the world (Jansen, 1980).

The oldest operational masonry dam is believed to be Quatinah Barrage (or Lake Homs Dam) in Syria. This 2 km long and 7 m high masonry gravity dam is presumed to have been constructed by the Romans during the reign of the Egyptian Pharaoh Sethi in around 1310 B.C.

Several examples of masonry dams have been recorded in history across the world, many of which still remain today. These early RMC dams were relatively low structures constructed using mortar and cut stone-block facing, configured as massive gravity walls.

Construction techniques and experimental understanding developed and higher masonry gravity dams were progressively attempted.

An example is the 41m high Alicante Dam constructed using rubble masonry in Spain. The dam construction started in around 1580 but was suspended some time afterward before resuming construction several years later. The unfinished structure had survived multiple seasons before being completed in around 1594. The dam became the highest operating dam in the world for well over 300 years.

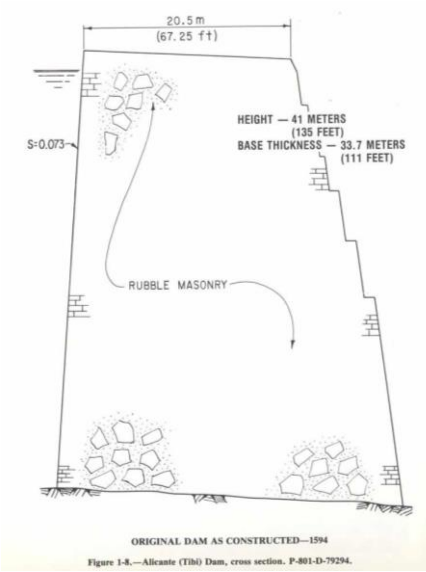

Figure 1. Alicante (Thibi) Dam – cross section

The industrial revolution and commensurate development of heavy mechanical plant and equipment changed the course of the RMC dam.

With specialized excavating plant, compacting equipment, blast quarrying and aggregate crushing facilities becoming readily available in developed countries, high embankment dams and mass concrete equivalent dam types could be built faster than the hand-built method. While RMC dam development was stinted, it remained attractive in countries with a high availability of low-cost labour. Today, the basic utilization of low cost labour still applies to the competitiveness of RMC dam construction.

Figure 2. Lucilia Poort Dam Wall – RMC arch structure

More challenging arch and multiple arch-buttress dam designs have since been successfully completed, particularly in Zimbabwe and South Africa.

The most ambitious of these is Lucilia Poort Dam, a 42 m high arch dam constructed in a narrow gorge on the Dwimbika River in Zimbabwe. The structure was constructed using granitic stone plums, founded on a banded ironstone foundation. The dam wall volume comprises approximately 22,000 m^3 and is potentially the tallest RMC arch dam under operation in the world.

1.2 *Basic concepts*

A comprehensive introduction to the evolution of RMC, its design principles and construction requirements is documented by Shaw/CIDB (2005).

RMC comprises a matrix of large stone plums embedded in a mortar binder surround. This should not be regarded as dressed stone but considered as a monolithic matrix containing large stone in a body of mortar. In some cases, the term, plum-concrete is used. Stone plums vary in size from 50 to 400 mm, depending on available materials, quality of the rock and what can be physically handled by the labourers themselves.

Advanced computational design by finite element methods and large-scale prototype testing have provided an analytical understanding of this ancient dam building material. These advances have allowed modern day RMC dam designers to set new precedents, blending ancient construction methods with state-of-the-art design approaches

In many respects, the design of a RMC dam now follows the same principles applied in conventional concrete dam design, starting with the basic requirement for competent rock foundations.

Some specific differences include:

- Conventional formwork is omitted. The upstream and downstream faces of the dam are constructed using face plums bound in thick mortar and arranged in a castellated pattern by stone masons. These face walls are permanent and are constructed approximately 300 to 400 mm high in advance of the inner structure. The trough that forms between is infilled to around half its depth with flowable mortar and the RMC core is brought up by placing and compacting multiple stone plums in the mortar by hand. Compaction is achieved by physically stamping on the lift surface, which must be continuously cleaned, prior to commencement of a successive lift.
- RMC dams are generally not affected by thermal complications arising from heat of hydration effects. This is the result in the combination of the thinner structural members applied (in the case of arch dams), the generally slow overall rate of construction (and low rate of wall lift rise) itself and the conductive effect of the large plums embedded in the mortar matrix. Significant adiabatic hydration heat gain does not develop and the requirement for transverse contraction joints is eliminated. Drying shrinkage cracking is, however, of particular concern and careful attention must be paid to temperature related effects in extreme temperature climates.
- An RMC structure is typically constructed horizontally, extending continuously from abutment to abutment. Partially constructed sections are therefore stable structures at any elevation.
- The durability of RMC also allows the designer to consider a reduced river diversion arrangement (particularly for off channel or dams constructed on small tributaries). The passage of floods directly over the dam wall during construction can be allowed with only minimal damage anticipated.
- Seepage. RMC dams seep, much like concrete reservoirs but tend to self-seal after a few months in operation. Minor calcium carbonate deposits (efflorescence/white streaking) become evident on the downstream face of most RMC dams after a few months in operation.

Particular emphasis is placed on mortar and stone quality, and consistent adherence to efficient construction and placement techniques. Stone for RMC is typically sourced from blast rock in a designated quarry or by collecting river cobbles along stream banks by hand. To minimize cost of the mix design, stone content should be maximized (60-65 % is achievable), but the proportions and correct plum spacing and orientation must be maintained to ensure a homogenous materials behaviour. Considering a high strength mortar for RMC comprising between 350 to 400 kg cement per m^3 of mortar, a 50:50 mortar to stone ratio implies a final mix with a cement content of 200 kg/m^3 or less. An even lower strength mix is generally applied in mass sections where permeability concerns are less critical.

1.3 *Design and analysis*

Some design considerations include:

- The aggregate used in RMC dam construction is generally too large for direct modulus testing using standard laboratory equipment. In practice, only the mortar is sampled and tested to verify design compressive strengths.
- Material parameters are often experienced-based, obtained through back calculation on existing operational structures.
- Smaller structures can be designed using basic analysis tools for structural and stability calculations.
- For more complex structures (i.e. high arch dams) a finite element analysis model should to be developed to analyse 3-dimensional behaviour and principal stress intensities.
- Permissible stress limits aim at ensuring a linear response in the structure.

1.4 *Construction considerations*

RMC dam construction can be addressed under the following categories:

- Bulk excavation.
- Foundation preparation.
- Stone collection, loading and transportation.
- Sand procurement and delivery.
- Mortar mixing.
- Mortar delivery to point of placement.
- Stone delivery to point of placement.
- Stone and mortar placement and exterior surface finishing.
- Quality Control Requirements

1.5 *Specific benefits of RMC*

Specific benefits of RMC construction include:

- Simplicity of construction activities and use of unskilled labour.
- Highly labour intensive construction.
- Durability:
    - Ability to pass floods directly over the wall during construction.
    - Allows for continuous construction, or construction over an indefinite period of time.
    - Reduced river diversion facility requirements.
- Skills Transfer:
    - Masonry skills developed are useful in many other construction disciplines.
    - Site laboratories and offices are often maintained and staffed by local persons.

2 WORKING IN AFRICA

2.1 *Job creation – designing to allow for labour intensive construction*

Africa's population is expected to double from around 1 billion today to over 2 billion by 2050. Africa is already struggling with huge unemployment, lack of access to clean water and electricity and if innovative ways are not found to address these major issues then the situation will become even more desperate in many countries across the continent. New low impact hydro developments and responsible water reservoir developments can help to address these major issues with training of local labour and innovative design approaches that encourage labour intensive construction techniques.

The benefits offered by RMC in terms of low construction cost, employment creation and skills development make it an extremely appropriate solution to meet this growth. In the developing world, where low-cost labour is plentiful, RMC construction generally provides around 30 % cost reduction to the next competing dam type and boasts labour utilization of between 20 to 40 % direct wages, in relation to the overall dam construction cost. The use of rubble masonry concrete for the construction of dams and low impact hydro weirs is one of the major opportunities to promote labour intensive construction in Africa.

3 RMC FOR WATER SUPPLY RESERVOIRS IN SOUTH AFRICA

Table 1 lists some of the recent RMC dams constructed in southern Africa, mainly for the purpose of domestic or mining water supply and farming irrigation.

Table 1. Recent RMC dam precedents in Southern Africa

Dam	Max. Height (m)	Arch Radius Intrados (m)	Arch Thick-ness (m)	Arch Angle (Degrees)	Year of Completion
Mndwaka Dam	29	30	2.0 – 7.0	160	2015
Molepo Dam	18	14	1.8 – 3.6	140	2010
Mesica (Mozambique)	32.4	81	4.0	116	2009
Zir Thangi	12	13	1.5	120	2006
Ghorqand Ghuriah	13	14	1.8	140	2005
Lucilla Poort	42	Log-spiral arch	4 - 7	-	2005
Bellair	20	14	2	140	2005
Keta	9	N/A	N/A	N/A	2001
Aloe Cove	21	25	2	140	2005
Star	11	21	1.0 – 1.6	120	2000
Welgevonden	15	28	1.8	100	1999
Hogsback	11,5	20	1.0 – 1.6	143	1999
Genadendal	9	N/A	N/A	N/A	1996
Bakubung	14,5	12	0.9 – 1.6	120	1996
Maritsane	18	60	2.4	105	1996
Castle Coombe	12	12	1.0 – 1.8	120	1990

All of these RMC dam structures have proved successful, providing a means of constructing durable, small to medium sized dams at particularly low cost.

3.1 *Mndwaka Dam - project overview*

Mndwaka Dam is situated near Hole in the Wall on the Wild Coast of South Africa and is configured as a multiple arch-buttresses dam across the Mndwaka River. It is constructed from RMC and with a maximum height of 29.6 m and an overall volume of approximately 30,000 m^3. This dam represents the highest structure of its kind in South Africa.

Founded on Tillites on a relatively wide and open valley, the site presented a number of challenges to the alignment and configuration of a suitable structure. The dam comprises an uncontrolled, free discharge spillway with Ogee-shaped crest cap and projecting lip constructed on top of the central arch and split into five segments. Divided by crest splitters, the three central spillway segments have a crest some 850 mm lower than the outer two, to allow the passage up to the design flood within the central portion of the structure. The

Figure 3. Mndwaka Dam wall – RMC arch/gravity structure

outer spillway segments come into operation for greater return periods.

Utilising the river section between the buttresses, a tailpond toe wall is constructed below the free overflow spillway to develop tailwater within the central arch and assist with energy dissipation during spillway operation.

3.2 *River diversion*

The catchment of the Mndwaka River at the dam site is small, but subject to frequent flash flooding. For the river diversion, only four 900 mm diameter steel pipes were provided, installed in a concrete encasement just below the foundation level of the dam in the central arch.

This provided adequate capacity to pass all normal river flows. Under extreme flow conditions, back-up in the basin of the dam was anticipated and construction was planned to leave a low portion on the central arch to allow flood water to overtop the partially completed structure.

Heavy rainfall during the construction period gave rise to flooding, causing damage to the access roads across the river on the upstream and downstream sides. The temporary diversion along the quarry was breached and completely washed away and the freshly placed lift surface on the central arch, which now acted as a broad crested weir overtopped for several hours with a head of as much as 1 m.

When the rainfall ceased, the water level quickly receded and thorough inspection revealed that no structural damage had been incurred. Debris trapped on the protruding plums was simply manually removed from the placement surface, which was cleaned thoroughly thereafter, before construction continued as normal.

General & Hydrological	
Location	32°03'34'' S;
	29°01'24'' E
Catchment area	21.51 km^2
Material Volumes	
RMC Structure	
Excavation	60,000 m^3
RMC	29,600 m^3
Spillway Concrete Volume	170 m^3
Rockfill Embankment	
Fill	1,000 m^3
Clay Core	1,005 m^3
Dam Statistics	
River Bed Level	RL 75.5 m
Full supply level (FSL)	RL 102.0 m
Spillway Crest Level 2	RL 102.85 m
Non Overspill Crest Level	RL 104.6 m
Reservoir surface area at FSL	24 hectares
Gross Storage at RL 102.0m	1.92 Mm^3
Dam Crest Length – RMC	315 m
Spillway Crest Length	86.7 m
Spillway capacity	685 m^3/s
Maximum scheme pumping rate	2.5 Ml/d at a max of 850 m^3/hr for 22 hours

Figure 4. Mndwaka Dam – river diversion structure

Figure 5. Mndwaka Dam – central arch overtopping during construction

3.3 *RMC construction*

Owing to its isolated location, construction and related materials procurement activities necessitated careful planning to produce materials for some 29 600 m^3 of rubble masonry.

To enable efficient materials procurement and delivery and so minimise operating costs, the contractor implemented several innovative strategies to source all natural materials required for the construction from the upstream basin as near as possible to the dam wall.

These dam construction facilities included:

– Establishing a quarry from where some 40,000 m^3 of blast rock could be sourced, (This was excavated in the river section upstream of the dam wall and now forms part of the impoundment, completely inundating its footprint);
– Construction of a grizzly screen to separate plums from fine crushed material;
– Establishment of a crushing and screening plant to produce both coarse and fine aggregate for concrete stone, mortar sand, and filter sand;
– Setting up a batch plant on the left spur from where mortar was pumped to the dam wall;
– Erection of an aerial cableway (“blondin”), spanning some 270 m across the river valley, to swiftly deliver large plums and equipment to the labourers on the wall.

Figure 6. Mndwaka Dam – site layout

This ensured that only cement was transported in bulk to the site. In addition, innovative sliding guide-forms, which double as hand rails, were designed, so that the incremental raising of the guide-forms on the sloped surface is kept simple, accurate and efficient.

Although certain aspects required refinement and optimisation, the contractor reliably produced around 70 m^3 of placed RMC per day after a few months, to a targeted maximum of 110 m^3

Construction commenced in April 2012 with completion at the end of July 2015. Some 305 local labourers were employed and utilised throughout the core construction activities, ranging from the operation of the batch plant, aerial cableway, and crushing plant, the construction of the dam wall and the running of the stores and site laboratory to ensure quality control.

The social benefits that construction of the dam brought to the rural population of the Mncwasa area are significant.

Not only does the final product benefit the local population in the long-term, but the short-term construction activity allowed a source of income and upliftment, as well as providing an opportunity to facilitate the transfer of skills into the local community.


Figure 7. Mndwaka Dam – construction

The dam provided approximately 146,000 local labour days at the completion of the works and an estimated 25 % was spent on local labour directly. A total of 33 local workers who entered employment and were trained up on the project were reportedly subsequently recruited by the mines and now have permanent employment.

3.4 *Lessons learned*

Figure 8. Mndwaka Dam – view from upstream face

- For large volume RMC dam initiatives, confirm the aggregate source early in design phase. The bulk volume of stone required for the construction will approximately equal the final total volume of the structure.
- The management of stone on site must be carefully addressed.
- Separate stone plums from crusher material by means of a grizzly screen or some other effective screening method.
- Good quality sand is crucial to the development of high strength, impermeable mortar. Sand is obtained either directly from the river banks (subject to compliance testing) or by crushing and screening of finer blast rock, or blending of both.
- Ensure pumps and supply lines are appropriately sized if pumped mortar is considered. The supply lines block easily and many hours can be lost in a day as a result.
- Avoid extensive foundation shaping and provide for the correct equipment to excavate into and prepare rock foundations. Controlled blasting methods and pre-splitting for foundation shaping and shear key provisions are onerous, particularly in remote locations.
- Provide for appropriate cement storage facilities, and make sure that cement supply is never exhausted.
- Enforce strict survey control.
- Profiles and scaffolding methodologies must be carefully considered for construction of high elements such as spillway crest caps.

4 RMC FOR SMALL HYDRO PROJECTS IN THE DRC

4.1 *Project overview*

RMC dams are also applicable for the development of small hydropower stations. The 11 MW Azambi Hydroelectric Project is located approximately 1,800 km northeast of Kinshasa in the Democratic Republic of Congo. The project was developed and is operated by the Kibali Gold Mine, a subsidiary of Randgold Resources (now Barrick). It will produce approximately 64 GWh of renewable, cost-effective and reliable electricity each year to power the remote mine and local communities and provide a legacy renewable energy asset for future generations when the mine closes down. The project started in July 2015 and it was successfully commissioned in July 2018.

The project includes the following; a small diversion structure and overflow weir, a run-of-river power intake equipped with sediment exclusion facilities and control gates, a power canal and emergency spillway, headrace structures including fine trashracks and control gates, a surface powerhouse housing the turbine-generator units, a tailrace channel isolated from the main river and the switchgear and transmission line.

Key innovative project details for the major components of the project are summarized in the following sections. Project parameters are summarized below:

- Rated capacity of the plant: 11 MW
- Design flow: 106 $m^{3/}s$
- Power canal length: 1.1 km
- Gross head: 14.7 m
- Turbine(s): Two horizontal Kaplan pit turbines
- Switchyard: 11 kV to 66 kV transformers
- Transmission line: 8.3 km of 66 kV transmission line

A cost-effective project was designed that promoted local community and contractor involvement and reduced the overall cost of energy to the mine and reliance on fossil fuels. This included changing the design approach, by focusing on designs that promoted labour intensive construction techniques and the ability for local contractors in the region to be fully involved.

Figure 9. Azambi HEP – RMC diversion weir, intake structure and power canal

Dense vegetation and a requirement to develop the hydropower works on the opposite bank of Kibali River implied that the site was near inaccessible. The topography and availability of local construction materials were studied and although the option of constructing a large dam and integrated hydropower works was considered, this was soon eliminated on the basis of risk, cost, topography and geology. Instead, a diversion weir and canal system was proven as the most economical, low risk option for Azambi HEP implementation.

The project headworks are positioned at an outside bend of the river, at a location where a small island divided the river naturally. The diversion weir axis was aligned across this island and approximately perpendicular to the river channel and regional dip of rock strata. This greatly simplified channelling and diverting the river during construction and minimised overall extent of foundation preparation works required for the weir.

The headpond is formed by the small reservoir created behind the weir and since Azambi HEP will not operate as a peaking station, only limited storage was provided. The weir is constructed to reduce the velocities of approaching river flow whilst directing water to the intake structure, and to pass flood events in a controlled manor. The headpond will only settle out a limited amount of sediments with the key silt purging facilities being installed and managed directly from the concrete intake structure.

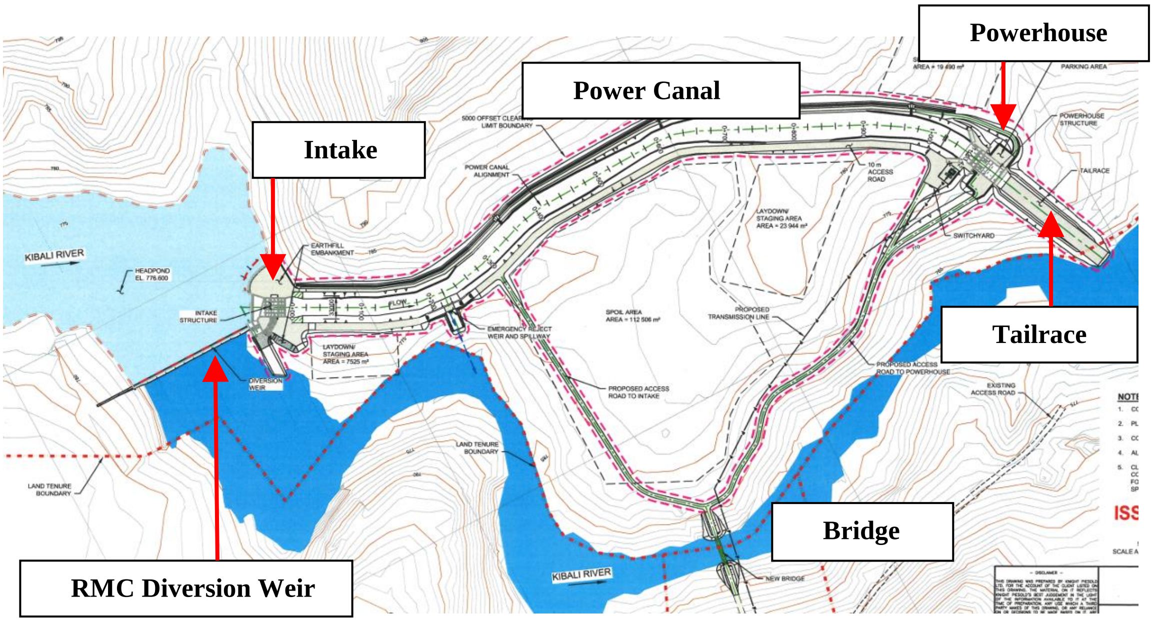

Figure 10. Azambi HEP – Plan view of the run of river hydroelectric project on the Kibali River

Preliminary designs for three different weir types were completed, including:

- Rubble Masonry Concrete (RMC) Weir
- Reinforced Concrete (RC) Weir
- Hardfill Concrete (HFC) Weir

For each weir type, the availability of construction materials, weir configuration and associated quantities were evaluated. With a large volume of blast rock becoming available from the canal and powerhouse excavations and numerous boulders in the river bed, the rock was suitable for reuse as stone plums for RMC construction, with limited treatment being required. Furthermore, although Azambi HEP will become a legacy asset to the community at the end of the mine operations, community involvement during the relatively short-term construction activity itself allowed a source of income and local community upliftment as well as an opportunity to facilitate transfer of skills into the local community. Construction methods that would maximise the local labour content were accordingly given preference.

4.2 *RMC dam design and construction*

The diversion weir was configured as a standard gravity wall constructed out of RMC, having a maximum height of 7 m, a 185 m concrete lined ogee-shaped spillway and a total volume of approximately 7,500 m^3. The weir structure terminates on the left bank against the reinforced concrete intake structure and as a non-overflow crest section on the right bank.

Figure 11. Azambi HPP – construction of spillway crest cap

The application of RMC for the small weir structure proved to be very successful. Whilst promoting cost savings compared to a mass or reinforced concrete equivalent, it directly involved the community around the mine. The selected layout allowed construction of the weir to remain off the critical path and be implemented in parallel with the major civil structures.

4.3 *River diversion*

Diversion phasing had to be viewed in tandem with the envisaged construction program, as delay in the river diversion construction could endanger or cause undue delay to the completion of the Works.

The river diversion philosophy comprised two stages of construction. For Stage 1, a temporary embankment was constructed on the left bank of the river, enclosing the Intake Works. The cofferdam axis was aligned to traverse over the exposed island section, before wrapping back downstream of the concrete intake structure footprint. The river could be maintained in its natural channel right of the island, allowing for dewatering and construction of the entire hydropower intake works and the first 90 m of the permanent RMC diversion weir.

Figure 12. Azambi HPP – stage 1 diversion works

For Stage 2, an essentially mirrored cofferdam arrangement was applied, whereby the first stage embankment was deconstructed whilst a second embankment was initiated from the right bank of the river, aligned to abut against the completed portion of the permanent weir and terminating on a reinforced concrete crest splitter wall. During Stage 2, under normal river flows, water was diverted leftwards into the intake structure and back to the river through two 6 m wide by 4 m high sluice and scour radial gates. Water could also be conveyed into the power canal, allowing commissioning in the powerhouse and generating facilities to advance concurrently with the construction of the remaining portion of the permanent RMC diversion weir. During high flow periods, additional flood discharge capacity was afforded over the completed spillway section of the permanent weir, constructed as part of the Stage 1 works.

Figure 13. Azambi HPP – stage 2 diversion works

4.4 *Lessons learned*

For low gravity dams with a straight axis, it is very beneficial to let the contractor construct his access road against the upstream face of the dam. This allows efficient transportation and delivery of materials to the point of placement and limits pedestrian movement on the placement surface, resulting in better overall quality.

It is useful to rotate the dam axis perpendicular to the main joint orientation of the underlying rockmass to limit the extent of foundation preparations required.

A carefully planned and timeously executed river diversion philosophy is required and should be incorporated into the design stage, for even small RMC dams constructed in a large flow river systems. If a phased diversion approach is applied, ensure that the entire RMC construction can be completed off the critical path. A rate of around 25 to 30 m^3 per day can be expected for program purposes.

Establish suitable communication channels to ensure the smooth running of the project between the contractor and local labour community;

Encourage community participation, with the selection and employment of local labour done through a Community Liaison Officers (CLO). Agree on a process of labour rotation to ensure suitable and fair opportunity for employment whilst developing and retaining the key skills.

Communities should list their workers on an employment register which categorized workers according to skills, gender and age.

Figure 14. Azambi HPP – completion of RMC diversion weir

5 CLOSING

By combining ancient hand-built methods with modern design and construction approaches, RMC dam technology still offers an effective and cost competitive means of constructing small to medium sized dams. This is applicable for both water supply and low head hydropower projects at particularly low cost, promoting an unparalleled utilisation of labour in remote areas that are in desperate need of employment. By actively addressing unemployment, construction of dams using RMC provides a positive economic impact in terms of skills transfer and community development, much needed financial injection as well as an opportunity to develop engineering excellence using a proven technology that is often overlooked by today's modern dam engineers.

6 REFERENCES

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