Experiences with RMC during the Implementation of the Mt. Coffee Emergency Spillway

A. Wetzel, Dr. A. Trifkovic
Fichtner GmbH & Co. KG
P.O. Box 101454
70013 Stuttgart
Germany

Garret Kruger
Teichmann Structures
P.O. Box 1214
1665 Olifantsfontain
South Africa

W. Hakin
Hydrotec Pty Ltd
27 Yarralumla Ave
St Ives, NSW
Australia

Introduction

Reinstatement and rehabilitation works at the Mount Coffee Hydropower Plant (HPP) started in 2013 and commissioning of the first unit was achieved in December 2016.
Mt Coffee is currently the only large hydropower facility in Liberia and as such it is an asset of tremendous commercial and strategic significance for the future growth of energy production in the country and for potential export via the regional transmission project currently underway.
It was therefore considered necessary to understand why the dam was breached in 1990 and to try to incorporate a design approach that would reduce the probability of a similar occurrence in the future. It was determined that the main spillway discharge capacity of the scheme needed to be increased but in addition, a highly reliable, low maintenance, self-operating, low cost auxiliary spillway should also be provided. It was also determined that if possible, labour intensive construction would be utilized and as such it was agreed that a new “emergency spillway” would be constructed using Rubble Masonry Concrete (RMC).

There were however certain physical constraints to the design of the emergency spillway in the only practical place for its location. After a series of optimization exercises, the least cost solution was for construction of a 1.5m high Ogee shaped sill of overall length 250m in a 220 m wide channel excavated through an existing natural abutment. The 30m wide saving in excavation (over a length of approximately 300 m), was achieved by providing for a sill with (in plan), three large radius arches. Design and location of the structure was undertaken in such a way as to address the local geological conditions and the occurrence of good rock foundations within the abutments, and also to ensure that during flooding, discharge down the chute would not jeopardize the integrity of the permanent works or cause undercutting of the sill itself.

Overall construction costs were reduced by utilizing the rock excavated for the approach channel and the chute in the main dam reconstruction (mainly as downstream erosion protection material) and for construction of the RMC sill. RMC is regarded as an efficient and highly cost-effective construction material, which has been used for constructing mass gravity masonry dams for several hundred years now. Other key benefits are that due to the simplicity of the construction works and low requirements on equipment technology, the construction tasks can be achieved with simple machinery (mainly wheel barrows for material delivery) and local unskilled labour.

This paper provides insight into the design considerations as well as the construction methodology applied to the emergency spillway of the Mt Coffee Hydropower Project and illustrates the benefits of this type of construction, especially highlighting the social benefits of the selected construction method. The paper also provides information about certain technical details such as proper foundation preparation and the use of expansion joints.

1. Project Background

The Mt Coffee Hydropower plant is located approximately 25 km north of the Liberian capital, Monrovia. The scheme comprises a 35 m high main earthfill dam with a main spillway equipped with 10 radial gates across the St Paul River and three saddle dams, so called Forebay Dams. Water is diverted from the main river course through a Forebay Channel into an Intake structure and four penstocks to the four Francis turbines before returning to the main river course via an 820 m long tailrace.[2]

After commissioning in 1967 and the expansion in 1973 with two additional Francis turbines, Mt Coffee had an installed capacity of 64 MW. The scheme generated continuously until the start of the Liberian Civil war, when the operating staff were ordered to leave the facility even though only two gates were left partially open. Consequently, during the rainy season the water level in the reservoir increased and after several days of overtopping of the dams, a large section of Forebay Dam 1 breached on August 12, 1990. The power station was flooded and abandoned and some time thereafter almost all of the mechanical and electrical equipment was looted. The facility remained inoperable for over twenty six years since the breaching of Forebay 1 occurred.

The rehabilitation of this national asset critical to Liberia's future electricity supply started in earnest in 2013 with various grants provided to the Government of Liberia from the German Government through KfW, the Norwegian Government through the Norwegian Ministry of Foreign Affairs and a concessional loan from the European Investment Bank (EIB). In late 2015 the Millennium Challenge Corporation (MCC) of the USA joined the project in order to close the last financial gap.

The national power utility, Liberia Electricity Corporation (LEC), engaged with Manitoba Hydro International (MHI) to form a Project Implementation Unit (PIU) to manage all aspects of the Mount Coffee rehabilitation project on behalf of the stakeholders. In spring 2013, the Norplan-Fichtner Joint Venture (NFJV) was assigned the role as the Owner's Engineer for the project.

The implementation of the works was significantly challenged and delayed by the devastating Ebola outbreak which hit Liberia in 2014 and 2015. Mobilisation of the main contractors only commenced again in May 2015, after the countries of Sierra Leone, Guinea and Liberia were declared Ebola free. The goal was then to be able to put unit 1 (out of the four 22MW units) into commercial operation by December 2016. Assembly, testing and commissioning of the other units as well as the main construction activities continued into 2017. The construction of the Emergency Spillway was not on the critical path and was implemented from the second half of 2017 to the second half of 2018.

Figure 1 - Power House before (2013) and after rehabilitation (2017)

1.1 Emergency Spillway Safety philosophy

Having in mind the history of Mount Coffee and due to the fact that the facility is the most important energy generating facility in Liberia and probably the country's most valuable single asset, special attention was focused on how to make the scheme as safe and sustainable as reasonably possible.[1]

Particularly in the light of the Mt Coffee dam failure, the rehabilitation had to be defined not only as a reinstatement of the breached dam and rehabilitation of the scheme to the pre-civil war condition, but also in terms of how to increase the safety of all water retaining structures as well as of the electrical, mechanical and hydro-mechanical components of the scheme. Having a radial gated spillway with 10 bays as the main flood release structure, the first measures implemented were to provide a higher degree of redundancy for the operation of the gates. Namely, in addition to the power supply from the powerhouse through a 22kV cable connection, a battery room was added in the south spillway control room for powering the control systems if required. In addition, an emergency diesel generator located adjacent to the spillway as well as the possibility of manual operation of the gate winches were included in the scope.

The above mentioned systems are still dependent on the correct and timely action of the operational staff. Their absence would still cause a similar "single cause total spillway unavailability" as occurred in 1990. The original design of 1967 provided only 2m between the top of the radial gates and the non overspill crest level (NOSC). This is just enough capacity over the spillway gates to discharge 400 m³/s which approximately corresponds to the turbine discharge of all four units in an event where all units are suddenly shut down. In the event that none of the spillway gates are available, a flood with an Annual Exceedance Probability (AEP) of only 1:1 years would still cause overtopping of the dam which could lead to breaching. Furthermore, photographic evidence (found quite by accident in an old tourism book in 2017), identified that spilling over the top of the radial gates occurred in 1983 even during regular operation of the plant, confirming the gate system unreliability.

Analyses undertaken during the inception phase of the project in 2013, showed that a necessary precondition for increasing the safety of the project, is to increase the level of the water retaining structures. The existing dam geometry allowed a maximum raising of the crest level from 31.1 masl to 33.4 masl. In addition, the raising of the bridge invert, on the spillway itself, from 30.4 masl to 32.6 masl increased discharge capacity over the closed spillway gates to an approximate Annual Exceedance Probability (AEP) of 1:1 year. At the same time, raising of the allowable reservoir level provided for a higher flood release capacity of the radial gates achieving the ICOLD recommendations from Bulletin 125 for a design flood with a 1: 10 000 Annual Exceedance Probability with one gate out of operation (i.e. so called n-1 criteria). Notwithstanding the above, for the case of "single cause total spillway unavailability" as occurred in 1990, no meaningful reduction in the risk of overspilling over the NOSC was provided so an additional water release structure was needed (the so called Emergency Spillway (ES)).

Naturally, prior to the decision to increase the maximum allowable reservoir level during flooding, a detailed analysis of the environmental, social and other impacts within the reservoir area, was undertaken.

1.2 Emergency Spillway Design[1]

In the case of a total gated spillway unavailability scenario, the overall flood release capacity is obtained as the sum of the overtopping over the radial gates and the spilling capacity of the Emergency Spillway. The theoretical value of the possible flow over all 10 radial gates (in their closed position) at the reservoir level of 33.4 masl would be approximately 2 150 m³/s. Considering this discharge over the closed radial gates at maximum water level (MWL) the following table summarizes the required additional spilling capacity for different flood AEP's :

	AEP flood (years)				
	1:2	1:5	1:10	1:20	1:50
Design Flood [m³/s]	2 770	3 655	4 260	4 840	5 580
Discharge over closed radial gates at MWL [m³/s]	2 150	2 150	2 150	2 150	2 150
Required ES capacity [m³/s]	**620**	**1 505**	**2 110**	**2 690**	**3 430**

Table 1 - Required additional spilling capacity for different flood AEP's during a gated spillway unavailability scenario

The question to be answered then is which Annual Exceeding Probability (AEP) should be considered for the capacity of the Emergency Spillway?

For spillways the criteria for selecting the Design Flood or the Safety Check Flood is given by local guidelines or recommendations such as the ICOLD Bulletin 125[2]. But, there exists no guidelines or standards which define the required safety which has to be provided against "total non spillway gate unavailability".
The occurrence probability of the spillway unavailability scenario that occurred in 1990 and the overtopping of the gates in 1983 (due to presumably a breakdown in system operations/management), is virtually impossible to quantify with any degree of assuredness. Nevertheless, considering the history of the project and the two above mentioned events, it does seem that in the environment in which the Mt Coffee HPP operates, the risk of total spillway gate failure is quite high/likely. Therefore, after due consideration of the risks, costs and technical feasibility it was agreed

to select a Flood of 1:50 years as a design criteria for the determination of the Emergency Spillway's capacity at the Mt Coffee Hydropower Plant.

The selection of the Spillway Design Flood also took into consideration the history of the plant and the strategic importance of the hydropower scheme for power supply in Liberia. Furthermore, and as an additional benefit, the total spillway capacity, assuming all radial gates are fully open, is increased during extreme flood events from 13 750 to 17 350 m^3/s, thereby also allowing the probable maximum flood (PMF) event to be passed through the improved spillway systems.

Since no movable or mechanical elements should be considered for the Emergency Spillway and it shall have no effect on the hydropower generation, it was obvious that the fixed spillway crest must be above the full supply level of 29.0 masl. The Emergency Spillway crest is set at 29.5 masl in order to provide certain flexibility in operation and to avoid water spilling over it too frequently. Having in mind that water retaining structures (apart from the top of the radial gates that are at 29.1 masl), reach up to 33.4 masl, a theoretical value of 3.9 m of overflow height is available for the Emergency Spillway. For the above given flood capacity, this yielded a necessity for a 250 m length of free ogee shape spillway crest.

The 250 m long Ogee shaped weir is positioned in the form of three large radius arches, within a 220 m wide spillway channel with horizontal approach channel at 28 masl and subsequent 3% inclined spillway chute downstream of the spillway sill as shown below.

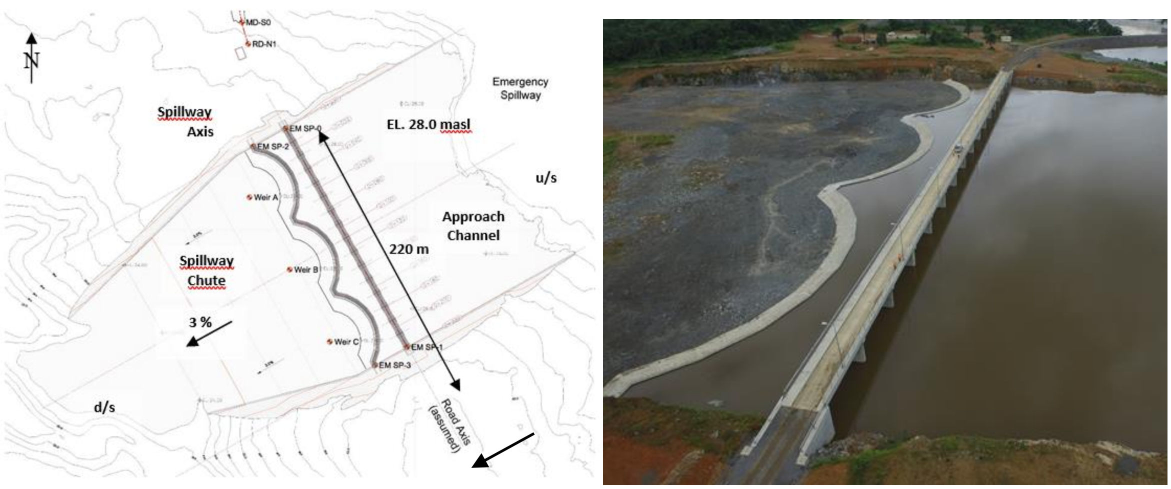

Figure 2 - Left: Layout of the Emergency Spillway; Right: Implemented ES with concrete bridge

The typical cross section of the spillway crest is given in the following figure.

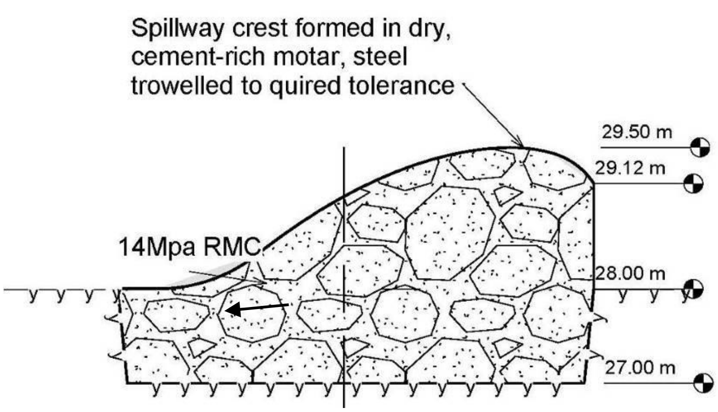

Figure 3- Typical cross section of the spillway crest

The 5 m wide Rubble Masonry Concrete weir forms the hydraulic control section for the Emergency Spillway (ES). It has been designed in an Ogee form for an adequate hydraulic capacity with a sill elevation at 29.5 masl. The Ogee profile was constructed in unreinforced Rubble Masonry Concrete (RMC).

RMC was found to be an efficient and highly cost-effective approach for such types of weir structure. RMC is a matrix of large stones in a mortar binder. The mortar used provides typically 28-day compressive strengths between 9 MPa and 14 MPa. Rock sizes vary from a minimum of around 50 mm to a maximum of 300 mm, the largest dimension being dependent on the thickness of the member under construction and the restrictions of manageable weight. RMC for dams is not a series of stones cemented together using mortar, but rather a monolithic matrix, containing large stone within a body of mortar, similar to mass concrete with a significantly larger maximum aggregate size.[3,4]

2. Implementation

The works for the Emergency Spillway (ES) were awarded to Teichmann Structures from South Africa on September 10th 2017 following a competitive tender process. Nine months later, the works on the Emergency Spillway Weir and the bridge over the approach channel were completed (i.e. on June 26th 2018).

2.1 Construction methodology
Even if the ES has only a comparatively low height of 1.5m, the correct preparation of the foundation was identified as very important in order to prevent leakage under the ES structure and at its abutments.

The foundation is mainly characterized by Gneiss, a dominant Dolerite Dyke and other Mafic Intrusions which are competent foundation material for the ES weir with a rock rating into class II and III according to the RMR system by Bieniawski. The rock foundation was cleaned and washed numerous times using industrial type vacuum cleaners, blowers or compressors, chipping hammers, buckets, sponges and clean water to assure that loose particles, dust or water was removed prior to the placement of RMC.

Figure 4 - Left: Foundation preparation using industrial type vacuum cleaners, Right: Walling off the section to be poured with mortar layer

Proper cleaning was also necessary before placing each mortar layer in top of the previous since there was constant traffic nearby the structure causing debris dust and water which accumulated on the previously placed layers.

As can be seen, firstly the outside walls were constructed using a 'sticky mortar' in lifts of approximately 500 mm. Once a section has been walled off, the ingress of water was prevented from surrounding ponds and filling between the walls with RMC in the matrix could be done.

This process was repeated until the structure reached 300 mm from the top of concrete level. After each layer was placed a dedicated team kept the RMC wet by spraying it with water until the next layer was placed. Constant checks on the levels and profile were done whilst approaching the final heights.

For the final ogee spillway shape two wooden profiles spaced between 5m and 8m with fish line strung across at 100 mm c/c were erected to guide the placing and shape of the spillway crest. The final shape was built in sections of 5-8 m widths. Care was taken in the selection and placement of the final layer of stones so that as smooth as possible final surface without irregularities was obtained. Once the final shape was constructed and set, blankets were placed over the structure and constantly cured by wetting with hose pipes and buckets of water until the final strength was achieved.

Figure 5 - Left: Use of shutter ply profiles and fish line for Final Shape, Right: Smooth finish of ogee spillway shape

As the construction took place, access on and around the site changed constantly due to the size and formation of the structure. Ramps, planks and walkways had to be constantly moved and secured to ensure easy, quick, economical and safe access for the personnel executing the works

Since the RMC weir is a water retaining structure, special care was taken to provide for the impermeability of the weir. It has been calculated that thermal expansion/contraction could vary between 60-70 mm over the whole structure. Therefore, the weir structure was divided with two contraction joints into three sections. The thermal expansion/contraction of the individual sections is in the range of 20 mm and consequently 25 mm asphalt boards in conjunction with 24 cm width water stops were installed.

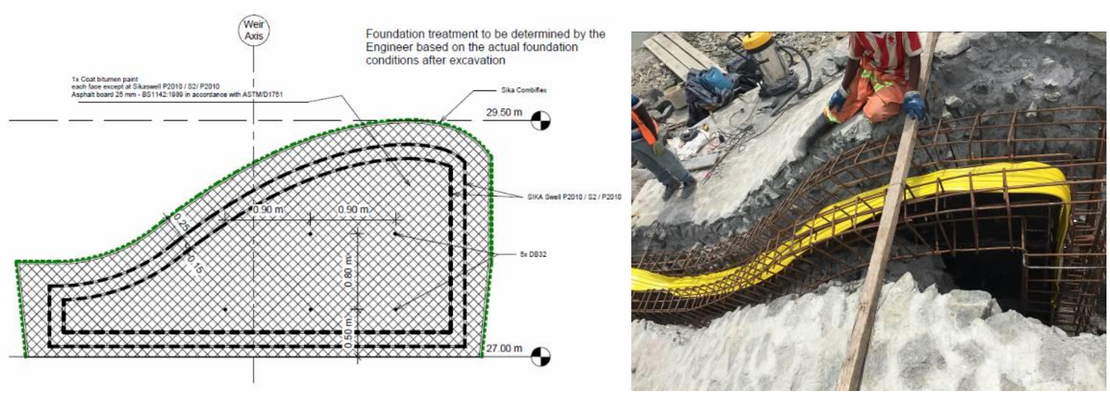

Figure 6 - Left: Design of the contraction joint, Right: Implementation of the contraction joint with asphalt board and waterstop

2.2 Material and labour input

As previously mentioned, the emergency spillway (ES) for the Mt Coffee HPP has a simple design with low requirements on the equipment technology and high demand on local labour.

For the execution of the ES works, two concrete mixers one with 350 l capacity and one with 500 l capacity have been used. The batching area was established adjacent to the weir on the centerline to minimize travel times for the rock, aggregate and mortar.

The majority of the tasks, which are labour-intensive works, were undertaken by unskilled local from the surrounding communities which promoted local employment, capacity building and an economic benefit to the local economy. Before the local workers were deployed on the construction site, they received training in their respective jobs, use of personal protective equipment and of course health and safety briefings. For the construction of the ES weir, on average 145 local workers were employed (at the peak of production up to 180 local workers were hired).

According to the activities, the 145 workers were distributed as follows.

- 14 workers collecting and sorting rock
- 20 workers batching and sieving sand
- 33 workers carting mortar and rock
- 30 workers cleaning and pumping water
- 3 workers supervisors
- 45 workers placing

As a labour-intensive project the management and coordination between individual teams becomes crucial to ensure overall success. One Senior Foreman and 2 local Junior Foreman were managing the works and the workers were subdivided into smaller manageable teams consisting of 10- 20 people with a team leader having special tasks as listed above.

In total over 350 local workers were hired for the implementation of the ES together with the concrete bridge. Although a local employment agency was appointed to handle contracts and payments to the local workers, it was still challenging to manage the local force in terms of adherence to local legislation and labour laws as well as to local culture, attitudes and expectations.

Figure 7 - Local workers employed for the RMC weir construction

An important challenge concerning the employment of local unskilled workers relates to adherence to the health and safety requirements of the construction site. Special attention to safety training and briefings considering the risks and hazards of the construction site needed to be constantly implemented and regularly updated. From this point of view, it can be said that RMC construction methodology due to the presence of sharp edges and slippery rocks, over which the workers needed to walk carrying more stones, presented a significant health and safety risk that needed to be properly addressed.

Similarly, the presence of tropical diseases had to be considered during the planning of works and corresponding mitigation measures had to be implemented. Finally, with temperatures of over 30 degrees and high humidity, it had to be ensured that enough drinking water was made available to the local workers to assure they were always well hydrated.

3. Analysis of performance

The following analyzes the performance of the RMC weir construction and compares it to performances obtained in the other countries like South Africa.

In total the overall volume of RMC placed was 3100 m³ in the timeframe of 35 weeks. Since the RMC weir was not the only structure built under Teichmann's contract, but also the bridge over the ES approach channel, local workers were assisting with the bridge work too. This explains the fluctuation in RMC production (actual volume) as can be seen in the following chart.

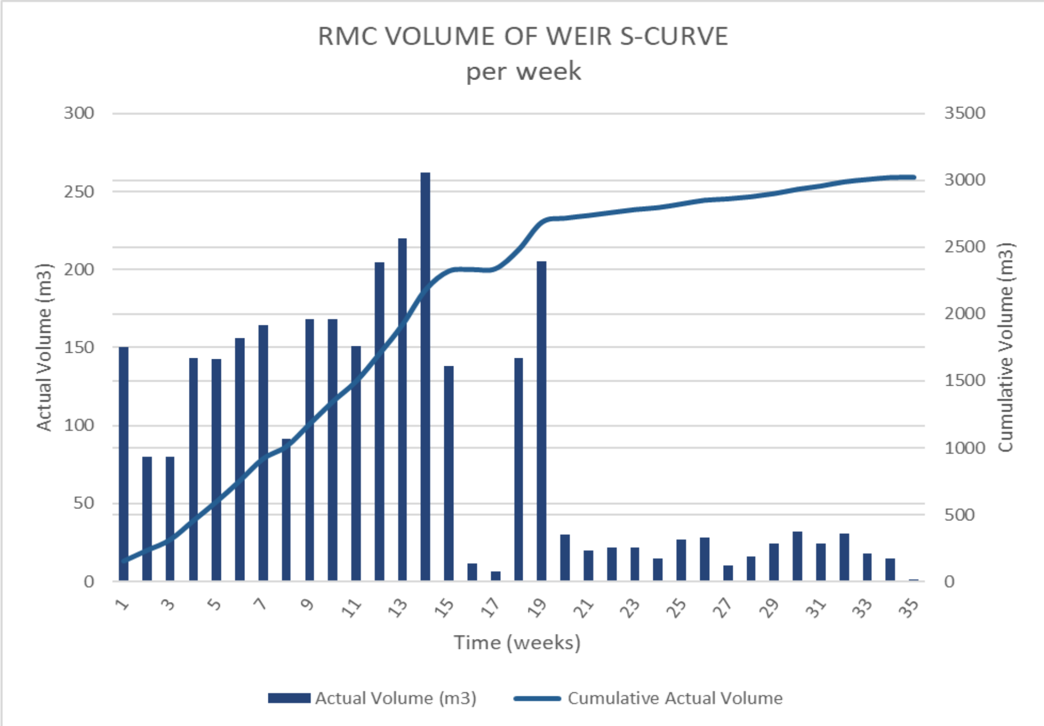

Figure 8 - RMC production S-Curve

It can be seen from the above S-Curve that at the beginning, with high volumes to be placed and large areas available the production was much faster than towards the end of the project when the ogee spillway crest was shaped. It can be noted that RMC production and labour decreased considerably in the second half of the period. The spillway crest construction took almost 3 times as long as the mass infills due to the time necessary for proper rock selection, neat placement and filling in accordance with the specification on the ogee section. The demand for mortar was also much lower whilst building the crest therefore the size of the batching team could be reduced. Based on the above, two RMC production rates can be distinguished:

- up to week 19 where the mass infills of the weir took place, the average RMC production was around 28 m³/day.
- from week 20-35 where the major work consisted of shaping the spillway crest, the average RMC production rate was around 6 m³/day

For the sake of comparison, production rates as per the Construction Industry Development Board (CIDB) have been used. CIDB (2005:33) measures productivity rates by volume of masonry placed per day per worker. "Worker" means all construction staff directly involved in the production and placement of masonry. Site management staff, technical staff and laboratory staff are excluded. CIDB (2005:34) continues: productivity rates vary widely, from as little as 0.3 m³ per person per day up to 5 m³ per person per day. The latter productivity rate can only be achieved if the manual transportation of masonry rock and mortar onto the wall is replaced with mechanical delivery systems. If the entire process from rock stockpile and mortar batching plant to construction of masonry walls are done with manual labour, then typical productivity varies between 0.5 m³ per person per day to 1.0 m³ per person per day.

When looking at design reports from Q. Shaw[6,7] production rates are very rarely above 0.5m³ per man per day for RMC dams in South Africa. Concerning the RMC weir, based on the average labour of 145 workers for the RMC weir and a total of 151 productive days for a total RMC volume of 3100 m³, the overall production rate can be calculated at 0.14 m³/person/day. Following the aforementioned distinction between mass infill (week 1-19) and crest shaping (week 20-35), the production rates are 0.2 m³/person/day for mass infill and 0.09 m³/person/day for crest shaping respectively.

The relatively low production rate is based on two major factors. Firstly, having a relatively low height of around 1.5m and width of 5m, there is quite a large surface area compared to the volume per running meter. As previously mentioned, the work on the spillway crest is particularly time intensive and therefore lower productivity rates are the consequence compared to dam structures with a height of 10 to 30 meters.

Secondly, when comparing the production rates, special emphasis needs to be given to the climate. The tropical climate in Liberia with its monsoon like rains during the wet season negatively affected the works and additional water management and cleaning had to be done after heavy rainfalls.

Nevertheless, productivity rates in future could be increased by adding additional batching areas closer to the sections where pouring needs to be done. Therefore, travel distances could be shortened which is particularly advantageous in long structures. The net length of the weir is 220 m and the batching plant was stationed in the center, therefore mortar had to travel over 100m when constructing the abutments and further reaches. Increased automation of some operations, such as machine screening, would of course further increase productivity, but on the other hand would also give less work to locals.

4. Conclusion

Besides complying with the accepted general recommendations and guidelines for dam safety, when designing hydropower facilities, dams and, in particular, spillway systems, cognizance should also be taken of the environment (social and political) in which the facility operates and the possible strategic value of the asset to the national interest.

The breaching of a dam at the start of a thirteen year civil war due to the actions of insurgents may perhaps be described as an “outlier” but such devastating events cannot be ruled out in the future. Design philosophies and approaches to dam safety should take into account the particular circumstances of each project and at Mt Coffee it was determined that the addition of an emergency spillway, for a relatively small incremental increase in the total project cost, would provide a high level of risk reduction entirely appropriate for the environment in which the scheme operates.

The Emergency Spillway at the Rehabilitated Mt Coffee Hydropower Project achieves its design objectives (increased safety in the event of malfunction of the main spillway gates), with a well thought out design which employs a simple, cost effective and labor intensive construction methodology. The emergency spillway design finally adopted comprises a 250 m long ogee shaped weir in the form of three large radius arches within a 220 m wide excavated approach channel. Together with existing structures, this additional spilling capacity, enables the safe release of a 1:50 year AEP flood event in the case of “total non-spillway gate unavailability” at the main spillway.

The structure itself is made of Rubble Masonry Concrete (RMC). The use of RMC was found to be an efficient and highly cost-effective approach for spillways and dams and is well suited for use in developing countries since it provides the opportunity for economic empowerment of the local population during the construction period.

Unskilled labor can be trained relatively quickly to undertake the required tasks using unsophisticated and low cost equipment. It is envisaged that the skills learnt by the locals employed on this project will be easily transferable to similar dam projects and other civil infrastructure undertakings in Liberia.

During implementation of the works, it was recognized that although RMC construction requires a low level of technology, equipment and know-how, there are still challenges and they lie in the effective organization and management of a large number of local labor as well as in implementation of correct health and safety practices.

Technical challenges such as proper cleaning and preparation of the foundation, curing of the RMC works and attention to detail while placing and filling of the surface layers does not differ much from other similar construction methods.

Overall however the use of RMC for constructing the emergency spillway at Mt Coffee was found to be entirely appropriate and cost effective and should be an attractive approach in other projects where complex methods can be replaced with technically less demanding but more labour-intensive ones. This is particularly important when considering that the low level of skills and the high unemployment rates in Africa, (and developing countries in general) is one of the major constraints to progress, economic development and poverty reduction.

References

1. **Stangl, M., Trifkovic, A., Hakin, W.,** "Emergency Spillway for the Mt Coffee Hydropower Plant in Liberia", *Hydro 2017*
2. **ICOLD Bulletin 125**, "Dams and Floods/ Guidelines and cases histories", Paris 2003
3. **Shaw, Q.H.W.**, "Rubble masonry concrete dam design and construction", *SAICE Journal*, 1998
4. **ICOLD Bulletin draft, "**Rock-Filled Concrete Dam", Version 12.07.2016
5. **CIDB (Construction Industry Development Board)**. *Rubble masonry concrete dam construction technology. Best Practice Guideline – Part 4-2*. Pretoria: CIDB, 2005
6. **Shaw, Q.H.W.** *Molepo Dam Concept Design Report*. Submitted by Goba (Pty) Ltd – ARQ (Pty) Ltd Joint venture for the Department of Water Affairs. Pretoria: ARQ, 2006
7. **Shaw, Q.H.W.** *Mashashane Dam Preliminary Design Report.* Submitted by Goba (Pty) Ltd – ARQ (Pty) Ltd Joint venture for the Department of Water Affairs. Pretoria: ARQ, 2006

The Authors

A. Wetzel graduated in Civil engineering at the University of Karlsruhe in 2012. In the same year he joined Fichtner as project engineer and worked for various small and large hydropower projects in Europe and Africa during feasibility level and tender design. Position in the project: Andreas worked as project engineer for the Owner Engineer for the Mount Coffee HPP being involved at all stages of the project from procurement up to design and implementation.

A.Trifkovic graduated in Civil Engineering has a MSc in Environmental Engineering from Imperial College and PhD from University of Stuttgart, Germany. Within hydropower, he specialized in fields of hydraulic design, power production, layout development and optimisation, rehabilitation and upgrade of hydropower projects and structures. He leads the design teams for the detailed design of the hydropower projects and already participated in successfully implementation of project such as Bujagali, Isimba and Nyagak in Africa, Middle Marsyandy, Faizabad and Golen Gol in Asia and some medium size project in Balkan countries such as Cijevna 3. Position in the project: One of the JV Directors for the Owner Engineer for the Mount Coffee HPP.

G. Kruger graduated in Civil engineering at the University of Johannesburg in 2014. One year later he joined Teichmann as Site agent. As such he was dealing with the daily construction and project management of the site, quality and safety documentation as well as cost and performance monitoring during the implementation and construction of the Emergency Spillway at the Mount Coffee HPP. MT Coffee HHP was his second large project involving Hydro-power in Africa.

W. Hakin (Bill) graduated from the University of Bradford, UK with a B Eng in civil and structural engineering. He has worked in the dams and hydropower sector for over thirty years in Africa, Australia and Europe and has been involved in the upgrade of over twenty dams during his career as project director. As the author of multiple papers presented at ICOLD and various national committees, he has a strong interest in ensuring engineering approaches take into account the social, political and environmental factors in which the projects will operate. Bill's role on the Mt Coffee Rehabilitation Project is the Project Director for the Project Implementation Unit.