# Yeywa Hydropower Project, an Overview

**U. Win Kyaw, U. Myint Zaw, Alan Dredge, Paul Fischer, K. Steiger**
Department of Hydropower, Ministry of Electric Power, Myanmar & Colenco Power Engineering Ltd, CH

## Introduction

The 790 MW Yeywa Hydropower Project is located on the Myitinge River (lower reach of Nam Tu River), approximately 50 km southeast of Mandalay in central Myanmar. The project comprises principally of a 134m high roller compacted concrete dam (RCCD) with a 790 MW power station located on the left bank at the foot of the dam and an ungated spillway located in the central section of the dam for flood water discharges. Two concrete lined river diversion tunnels are located in the right bank, one of these being subsequently converted into a bottom outlet enabling reservoir drawdown and control on reservoir filling, maintaining of riparian flows to the river downstream during the impounding period and in the emergency case of all turbines being closed down.


Project Location Map

Project General Layout

The power generation facilities comprise of 4 power intakes, 4 steel penstocks and 4 vertical axis Francis turbine and generator units and associated electro-mechanical and auxiliary equipment installed in the open air powerhouse. Two double circuit 230 kV transmission lines connect between the main transformers located on the downstream side of the powerhouse to an open-air switchyard, located on the left bank 550m downstream of the powerhouse, and then some 40 km to Kyaukse Substation in the west, just south of Mandalay, and some 110 km to Meiktila Substation in the southwest..

Key parameters include:

| | |
|---|---|
| - Storage Reservoir | 2.6 / 1.6 x $10^9$ $m^3$ Gross / Active Storage |
| - Full Supply Level | 185.00 m.a.s.l. |
| - Minimum Operating Level | 150.00 m.a.s.l. |
| - RCC Dam | 134m max height, crest length 690 m, |
| - Diversion Tunnels | 2 x 10m dia (lengths approx 450m & 500m) |
| - Ungated Spillway | 157 m overall width at crest (net 136m), |
| - Francis Turbines | 4 x 197 MW (installed capacity / max. power) |

| | | |
|---|---|---|
| - | Maximum Discharge | 4 x 210 m3/s |
| - | Minimum Plant Discharge | 100m3/s (Riperian release) |

This article provides an overview of the project development and design, investigations in search of natural pozzolans and ongoing construction of the project. It briefly describes, in this context of the overall project development, some of the key issues involved in the project implementation, this being carried out under the rather unique conditions for the construction of such major projects existing in Myanmar. Some of these issues are themselves the subjects of separate papers reporting in more detail on these subjects.

## 1. Background

Following on from a review of the Feasibility Study, completed by others in 1999, the basic design of the project and construction designs of the river diversion tunnels were carried out in parallel with the reconnaissance, investigation and testing in search of natural pozzolans in Myanmar for use in the 134 m RCC dam, instead of fly ash which is not available in Myanmar. The actual construction of the river diversion and access roads also commenced at the beginning of this period, during which time investigation galleries into both dam abutments were carried out, along with further field investigation works at the project site.

The further design of the Yeywa dam and its associated structures proceeded in parallel with the mentioned important construction material investigations which were particularly aimed at confirming the pozzolanic properties of materials from the different sources in order to select the most suitable site for development of milling facilities in time for use on this largest dam in Myanmar.

The design of an RCC dam requires particularly to try to minimise the interferences to RCC placing and compaction in order that, not only the full time scale benefits of RCC dam construction can be exploited, but also to the quality benefits achieved by rapid placing of the RCC, particularly for the joints between the layers. The construction sequences themselves, as also their timing, also play a major role in ensuring continuity of RCC placing particularly where flood or rainy season restraints are of major significance. These sequences also played a major role in determining the construction methods and equipment required both for RCC conveyance to the dam and its conveyance on the dam itself. Thus integrated planning of these items at an early stage of the dam design was required.

In the case of Yeywa HPP particular efforts required to be made since the civil works construction was foreseen to be very largely made without any construction contractors being involved. Whereas construction by direct labour is rather the normal practice of the government agencies in Myanmar, the scale and urgency of the Yeywa project obviously would severely stretch local resources, there also being many other projects under construction at the same time

## 2. Project Design

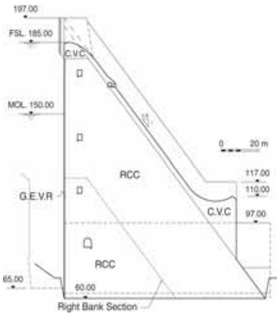
### 2.1 River Diversion

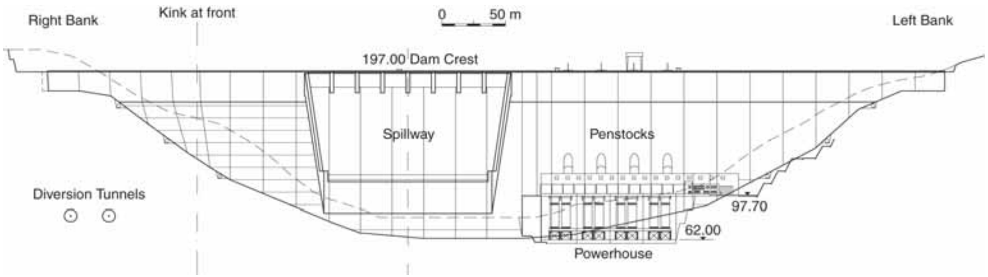
Taking advantage of the over-topping capability of an RCC dams, and arrangement of its construction sequences such that the left bank construction works, including the powerhouse could be kept safe against major damages, even with a 1:1000 year flood passing via the two diversion tunnels and over the river / right bank section of the RCC dam, the two concrete lined diversion tunnels could be maintained at 10 m diameter accepting that only a 1: 2 year wet season flood (1:50 year dry season flood) could be diverted during the early construction stages.

The last two dry seasons of the construction require the conversion of Diversion Tunnel No. 1 into a Bottom Outlet facility and finally the permanent plugging of Diversion Tunnel No. 2

### 2.2 RCC Dam Design

The design of the RCC dam had to be carried out prior to any experience being available in the actual use of Myanmar’s natural pozzolans. Additionally the possibilities of an experienced contractor actually carrying out the RCC works, rather than the use of direct labour employed by the Department of Hydropower (DHP) seemed very remote. Thus a relatively conservative downstream slope was selected and has been maintained for the dam construction, since the conditions prevailing in Myanmar are certainly very challenging for DHP to maintain material and construction qualities, in spite of extensive QC training activities being carried out..



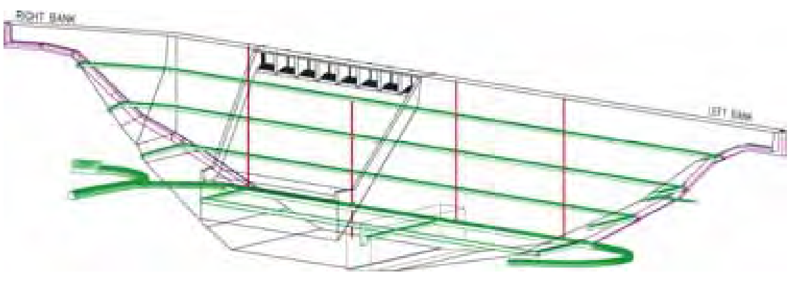



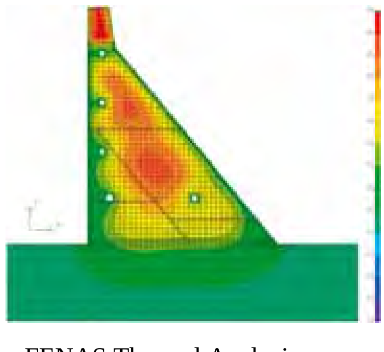

Section through Dam & Spillway

Dam Longitudinal Elevation from Downstream

Particular aspects of the dam design include the following:

- Advantage of the RCC dam selection was also taken to use an integrated RCC cofferdam arrangement, as used for example in Beni Haroun in Algeria, this then providing a cofferdam of up to 60m high to protect the later stage downstream works in the river section, against floods with return periods of 1:50 years. Finally this is being used both on the river/ right bank section and also on left bank. Any possible preferential crack or joint at the interface between the integrated cofferdam and the downstream section of the dam is being provided with pressure relief /drainage facilities, as a precautionary measure.
- design of the Power Intake towers as conventional reinforced concrete structures abutting onto the upstream face of the RCC dam itself. This was not only preferred in order to minimise affects on RCC construction activities, but it has enabled DHP to construct these up to above the actual inlet bellmouths and closed gate positions in advance of the starting of RCC construction. At the rates of progress possible for the construction of such structures under direct labour and resources conditions in Myanmar, there is no doubt that significant delays have been avoided by adopting this solution.
- inclined grouting galleries at the abutment foundations rather than sub-horizontal grouting tunnels were adopted in view of the limited tunneling experience available to DHL and severe limitations on types of explosives and shotcreting capabilities. It was then decided to try to remove such galleries from interfering with and delaying RCC construction and affecting the critical path of the project by constructing the galleries in trenches in the foundations.

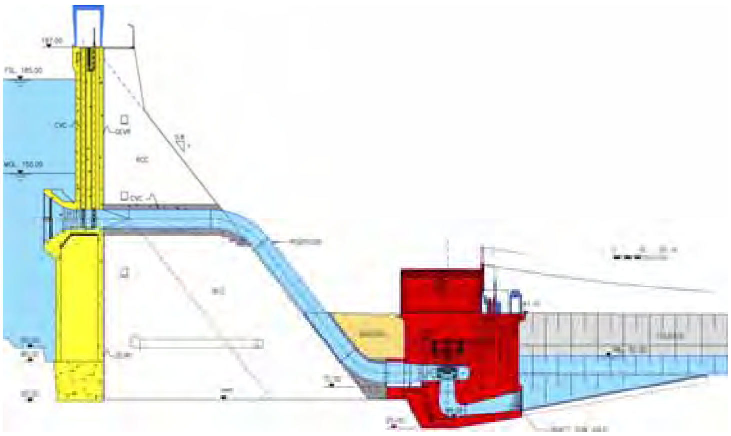


Dam Isometric with Grouting & Drainage Galleries

FENAS Thermal Analysis
Typical Cross-Section

With regard to Finite Element Stress Analyses and Thermal Analyses, CPE has used the FENAS finite element programme, further developed for these particular uses by CPE in association with Swiss owner and designer of the FENAS system. The relatively easy use of this software is facilitating follow up temperature analyses according to the actual construction sequences and measured temperature changes during construction.



Section through Dam & Powerhouse

An extensive network of copper-constantan “thermal couple” wiring is being installed in two main sections of the dam, in order to monitor in detail temperature changes. It is noted that the natural pozzolan combined with the particular cements being used on the project so far show rather good thermal characteristics (low temperature rises).

### 2.3 Power Generation Facilities

A section through the dam and power generation system indicates the Power Intake set in front of the dam with emergency closure gates and maintenance gates operated from the dam crest. The steel penstocks pass through the dam in a CVC surround with the inclined steel penstock on the downstream face of the dam leading to the spiral casings of the 200 MW turbines in the open-air powerhouse just beyond the toe of the dam.

For early security against flooding, the intake gates will be temporarily installed early, immediately following completion of the concrete surround to the horizontal sections of the penstocks and prior to erection of the upper sections of the towers following the RCC dam construction. The intake towers are foreseen to be anchored to the dam within the conventional concrete surround to the penstocks.

## 3. Natural Pozzolan Search, Investigations and Exploitation

Consideration of the use of natural pozzolan from indigenous sources, instead of importing fly ash from Mae Moh thermal power station in Thailand, as proposed in the Feasibility Study by the previous consultant, was included in the present consultant’s tender for the further engineering services required for the project. This was based on examples of such on other RCC projects, reviewing of the geological maps of Myanmar and consideration of supply uncertainties from Mae Moh and the extremely long road and sea transport routes which would be involved.

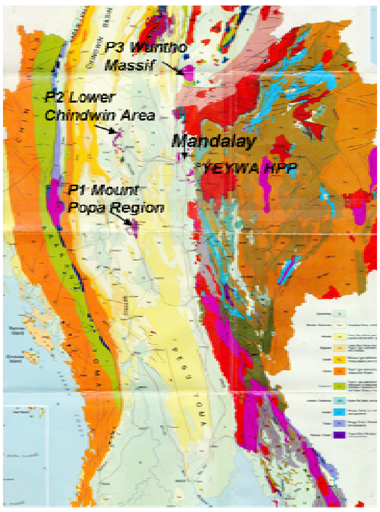
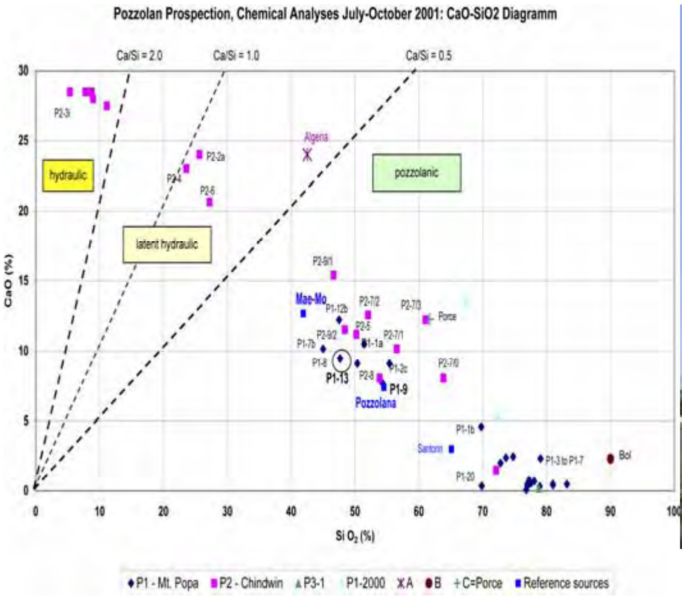



*Fig. Locations of Pozzolan Sources*

First confirmation of actual signs in the field of likely pozzolanic materials in the Mount Popa region could be made during an initial engineering visit together with the client’s geologists to two volcanic regions between Yangon and Mandalay prior to the award of contract. The subsequent reconnaissance, investigation and testing campaign lead CPE’s own senior geologist were concentrated on the Mount Popa and Lower Chindwin areas and included identification and sampling at potential sources, chemical and physical testing for screening of material sources for grinding to 4’000 Blaine and subsequent carrying out of both compressive and tensile testing on trial mixes. The locations of the main areas targeted as potential sources of natural pozzolan are indicated in the map.

The results of the analyses of chemical testing were evaluated using charts similar to the example one shown below. This indicated that some of the sources both near Mount Popa (P1-9 & P1-13) and at Lower Chindwin (P2-5, 2-7 and 2-9) have very significant deposits of very good natural pozzolans for use as partial cement replacement in the cementitious materials required in RCC dams and other mass concrete uses. Exploitation of the resources at Mount Popo area was decided upon for the Yeywa HPP, it being more easily accessible also to areas south of Mandalay, and the milling facilities now installed at Mount Popa are presently providing the natural pozzolan being used in the Yeywa dam (see figure below).




Example Chart from Pozzolan Testing Analyses

Pozzolan Mill at Mount Popa

## 4. Trial Mix Testing & Full Scale Trials

The first trial mix testing was carried out at the Asian Institute of Technology in Bangkok, with technical staff of DHP participating for training, particularly in the carrying out of direct tensile strength testing, this being a very sensitive test requiring accurate preparation of samples and equipment stiff enough to avoid exaggeration of the affect of even small eccentricities. These first tests required the organising of milling of the pozzolan at small mills in the Mandalay area and obtaining of crushed limestone aggregates all for transport by road to Bangkok.. The test results at AIT were very positive.

A subsequent series of tests carried out at the site laboratory at the Paung Laung hydropower project proved less successful, its remote location away from the Yeywa site and Yangon prevented the close following of these tests, which could only be contemplated since the site possessed a rigid 200 ton compression and tensile testing machine. This testing machine could then be transferred to Yeywa site where the laboratory staff's now routinely carries out direct tensile testing of cylinders and cores.

By this stage new limestone quarries and crushing facilities had been installed by three private Myanmar contractors some 20km downstream from the dam axis. It took almost a year until also the impact crushers, required to produce both coarse and fine aggregates with satisfactory shapes, were installed and operational at all three quarries. Following the improvements in fineness and flakiness indices of the aggregates, produced by the combined use of both cone and impact crushers, RCC trial mix testing results greatly improved until savings in cement quantities in the order of 30kg / $m^3$ could be achieved

Direct Tensile Testing at Yeywa HPP Site Laboratory

Three trial embankments were carried out to test RCC materials, placing and equipment and also for training prior to placing RCC in the dam itself.

## 5. Construction & Implementation Activities

In parallel with the above mentioned design, pozzolan investigations RCC trial mixes and full scale trials undertaken, the construction activities were continuing. Following the first year of construction by the Department of Hydropower (DHP) using its own direct labour, as is the tradition in Myanmar (the use of international tendering not usually being an option open to Myanmar) progress on the diversion tunnels was suffering some delays. In order to minimise the effect of delays in excavation of these diversion tunnels on the right bank, the staged execution of the works on the left bank were commenced in the second dry season and additional cofferdam works carried out to enable commencement of construction of the permanent separation wall between the tailrace channel and the main river. This accelerated its use as a cofferdam to protect the powerhouse and dam construction works on the left bank, it also provides an optimum location for the RCC conveyance system supporting towers for RCC conveyance by conveyor belt both the left bank and the river and right bank sections of the dam.

View from left bank shortly after major flooding Oct 06

Additionally construction of the power intake towers, which are located immediately upstream of the dam to facilitate unhindered RCC placing in the dam, could also commence without waiting for the delayed main diversion of the river. Additionally a long awaited approval could be obtained to construct an important bridge across the river, just downstream of the project, to replace the ferry system, which had provided up to then the only means for transport and plant to cross the river.

The diversion tunnel lining works were carried out using a 10m diameter telescopic lining carried out after the invert sections were previously concreted. This was Myanmar's first ever use of such a hydraulically operated formwork and, following erection with the support of a CFA operator and training in the use of the formwork, all but the first few sections of Diversion Tunnel No. 1 could be satisfactorily executed by DHP's direct labour teams.

Other major steps achieved in the project execution have included the following:

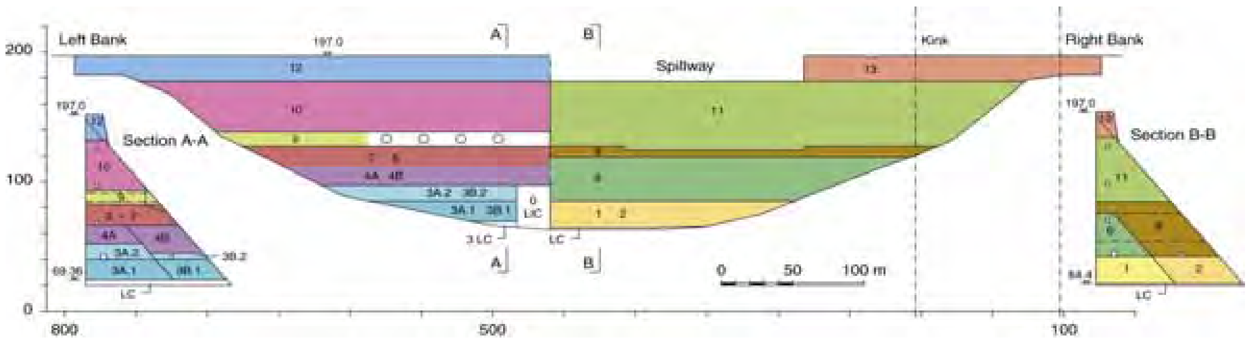
- arrangements could be made, during the ongoing construction works, between the Government of Myanmar and the Government of China for a loan to finance contracts for RCC Conveyance and Placing (Lot CW2), Supply erection and commissioning of Hydraulic Steel Structures -Penstocks and Gates etc- (Lots HSS1 and HSS2) and Electro-mechanical Equipment (Lot EM1) and Associated Substations and Transmission Line Equipment supply contracts (Lots SS1 and TL1-4). These have now commence with Lot CW2 contractor CCGC (Gezhouba) having already completed several stages of the RCC placement.
- 1000 ton / day pozzolan mill facilities have been supplied and installed at Popa by the Hi-tech company of Myanmar and are being operated by them for sale to DHP of 4'000 Blaine milled natural pozzolan
- 480m$^3$/hr RCC and 150m$^3$/hr conventional concrete batching plant facilities, complete with wet belts and ice plant, storage silos etc have been supplied and installed by Hi-Tech and operated for supply to Lot CW2 (sale to DHP) of RCC and of conventional concrete direct to DHP's direct labour construction of all civil works apart from RCC placing.

RCC & CVC Batching Plants

Subsequently the project implementation is quite well advanced, the river having been diverted in December 2004, the four Power Intake towers completed for installation of trash racks and gates once the RCC dam reaches elevation 127.4 to enable the horizontal sections of the penstocks to be installed, prior to continuing with RCC up to the dam crest on the left bank.

Stages 1, 2, 3A1, 3A2 & 4A of RCC placing have been completed using vacuum chutes during the design, fabrication, supply and erection of the main conveyor system by CGGC. Commissioning by the end of the year is foreseen.

RCC placing sequences have been adjusted several times to suit the anticipated river levels and flood risks in the wet season between May and October and have also required to be adjusted to take into account the actual progress with the excavations on both banks. This has thus required significant flexibility in the joint rearranging of RCC construction sequences to maintain continuity and good progress with the actual RCC works. The efforts made by all parties to successfully find solutions together has enabled together with the high capacity concrete plant and major efforts on the part of DHP to overcome any material shortages have enabled relatively high placement rates to have been already achieved on Myanmar's first RCC dam. The actual sequences now jointly planned are indicated below. The maximum monthly RCC placement now planned is 110'000 $m^3$/month, the highest to date already achieved was 91'667 $m^3$/month.




RCC Placing Sequences, Viewed from Upstream

The project has however suffered some relatively important, unforeseen set backs during its construction, the very recent occurrence of an over 1:50 year flood right at the end of rainy season 2006 (Oct with public roads flooded, bridges and transmission lines washed away) promises to be the most serious one. On the other hand the construction works themselves are relatively secure against major damage from such occurrences, although they inevitable cause significant delays. This has proved beyond doubt the major advantage of an RCC dam, as opposed to a CFRD or rock fill dam, since the foreseen overtopping of the RCC sections already constructed in the river section, is taking place at the same time as continuing with RCC construction on the left bank section. Such a very major flood security advantage is not to be underestimated, especially in countries where extreme power shortages combined with frequent shortages of fuel, pumping capacities etc are prevalent.

RCC Placing Stage 4a

The tasks ahead are major, somehow in spite of many adversities regarding lack of power supplies, fuel, appropriate explosives and now “no-lack of too much rain”, each of the problems are being overcome in their turn and DHP with the Chinese contactors and CPE’s support will still sooner, rather than later, successfully complete the project.

### The Authors

**U Win Kyaw** is Director General of the Department of Hydroelectric Power of the Ministry of Electric Power. He graduated from Moscow (USSR) and held Master Degree in Engineering (Civil). He worked as Designer, Investigation Engineer and Hydropower Project Planning Engineer for many years. He has implemented many Dams such as, Moe Pyae Dam Project, Small Hydropower Projects, Tat Kyee Hydropower Project, South Na Win Hydropower Project, Paung Laung Hydropower Project.
Department of Hydroelectric Power (DHP), Nay Pyi Taw City, Myanmar

**U Myint Zaw** is Project Director of the Yeywa Hydropower Project. After completing his studies in Myanmar he has been involved in the construction of numerous hydropower projects in Myanmar, being project manager and then project director on many of these before returning to the Yeywa project as its Project Director.

**Alan Dredge** is Vice-President, Manager Hydropower South East Asia for Colenco Power Engineering Ltd of Switzerland (ex-Motor Columbus Engineering). He graduated from Birmingham University and has over 30 years experience in the design and construction of hydropower projects and is presently leading CPE’s teams on Yeywa HPP, 2’400 MW Sonla HPP in Vietnam, 6’300 MW Longtan HPP in China, having recently completed procurement advisory services to the World Bank for the 1070 MW Nam Theun 2 HPP in Lao PDR.
**Colenco Power Engineering Ltd**, Täfernstrasse, 26, Baden, CH-5406 Switzerland

**Paul Fischer** is Colenco Power Engineering Ltd’s Chief Resident Engineer for the Yeywa HPP. He has almost 40 years experience in the design and construction of hydropower projects including being project manager for the design and construction of the 3 hydropower 1000 MW Saddam Dam Project, site manager for Singkarak HEPP in Indonesia and project manager of other hydropower projects in Switzerland, Liberia, Nigeria etc.
**Colenco Power Engineering Ltd,** Tamar Dan Street, Taguntaing Ward, Pyigyitagune Township, Mandalay, Myanmar

**Karl Steiger** is the leader of Colenco’s Geotechnics and Dams Section with over 30 years of experience in design of dams and hydraulic structures in South-East Asia, Africa, South America and USA. Since many years he also serves the Swiss Government as Federal Dam Safety Expert. As chief dam designer he was involved in the general layout, the diversion scheme and the dam design and calculations for Yeywa HPP.