1. Several engineering and technical difficulties have been resolved succesfully by applying bold innovations in the project.

(1) Using soft rock in the dam rockfill: Rocks in the damsite area are composed of hard/rigid greywacke (saturated uniaxial compressive strength of 100MPa ~ 250MPa) and soft/weak mudstone (saturated uniaxial compressive strength of 10MPa ~ 30MPa), of which mudstone exists mostly in the formation of interlayers and greywacke/mudstone interbeds that can hardly be removed. Hence, how to make use of mudstone constituted a key technical issue related to the dam safety and cost. Considering the aforesaid factors, many field and laboratory tests as well as calculations were performed thereafter. It was proposed that the mudstone content in zone 3B rockfill should not exceed 10%, and that in zone 3C rockfill should not exceed 35%. Making good use of soft rock reduced exploitation from the quarry and disposal volume, saved cost for the project, and minimized impact on the environment. Utilization of rockfill with soft rock content as high as 35% in a 200m-scale CFRD set a new precedent in the world dam building history.

(2) Application of wide compressive vertical joints between face slabs successfully solved the problem of spalling damage of face slab of high CFRD: Learning of the spalling damage experiences of the concrete face slabs for a number of high CFRDs in the world, based on study and research of their damage causes and mechanisms, for the first time, the Designer came up with a technical solution to set wider joints (60mm in width) between face slabs, put Pulai corkboards of corresponding thickness into joints, and thicken the riverbed face slabs above EL.121.00m plus two layers of reinforcement, which upgraded the face slabs' ability against spalling damage and attained good performance.

(3) Innovative design for the upstream and downstream dam slopes: With the gradients of 1V:1.3H, 1V:1.3H and 1V:1.25H respectively designed for the upstream dam slope above EL.210.8m, the downstream dam slope below and above EL.200m, dam filling has been saved a lot in volume. Introduction of such steep dam slopes for a 200m high CFRD is really an initiative move.

(4) Drainage measures for the dam during the construction period took full advantage of local topographic features: The annual mean rainfall volume at the damsite area amounts to 4500mm, and rainfall is frequent with great intensity during rainy seasons, so uplifting of the face slabs during the construction period would be an outstanding issue. In consideration of the topography of ridges alternating with gullies, the design scheme was characterized in making the ridge at the dam foundation area as the divide,

so that water catchment of the upstream area could be drained to upstream, and water catchment of the downstream area would be drained to downstream. Such arrangement wisely solved the uplifting problem of face slabs during the construction period.

(5) Successfully solved the energy dissipation and cavitation problems of the water release outlet (with the function to release an ecological flow for downstream riparian users during the reservoir impoundment period, and to be plugged when the spillway is ready to overflow) under high head: The water release outlet for this project features high operating head (design head of 182m), fast flow velocity (maximum flow velocity of 58m/s), and great difficulties in energy dissipation and cavitation mitigation, which is fairly rare in the worldwide engineering field, and there is no successful experience that can be learned from. After numerous model studies and comparison of different alternatives, it was determined to adopt the scheme of setting a Howell Bunger (conic) valve plus an energy dissipating chamber at the butterfly valve downstream. The energy dissipation rate can reach 70%, so that the maximum flow velocity downstream of the energy dissipating chamber can be reduced to 30m/s or so. The performance of the water release outlet has proven that this scheme is a great success.

(6) A water training stoplog structure at the power intake successfully solved the problem for taking surface water: To assure that the water environment on which downstream living creatures rely would not change significantly with and without the dam, the Owner raised specific requirements for the generation flow in terms of temperature and oxygen content. Based on extensive investigations, applying a water training stoplog structure at the power intake could achieve the goal of taking reservoir surface water for power generation. This is a model scheme not only satisfying the project purpose but also taking care of environmental concerns.

2. Excellence in both engineering and construction quality

(1) The drainage measures for the dam during the construction period functioned well and caused no damage to the face slabs, which warranted the smooth ongoing and good quality of the face slab concreting works.

(2) Though the dam is filled with partial soft rock, the operation performance monitoring for the last four years suggests that maximum settlement of the dam embankment be 2.67m, maximum deformations of peripheral joints between face slabs be 45.9mm in opening, 20.5mm in shear and 26.8mm in settlement. Comparing the measured values with the designed values, there are great safety margins in the design.

(3) Thanks to the rational and reliable design for the dam foundation treatment, face slabs and waterstops for joints in between face slabs, the concrete face performs well in seepage control, and the maximum seepage volume from the dam body as well as its foundation measured by the measuring weir in the dam downstream is less than 100L/s.

(4) Over the last four years since its commissioning, the spillway has experienced the real tests of long-term flood releases many times. The flood release monitoring data and after-flood inspections have demonstrated that all the civil structures and hydromechanical equipments operate normally and are in best state.

(5) Support design for the cut slopes is rational and reliable. The cut slopes resulted from the structure foundation excavation are quite large in scale and great in height, of which the maximum heights of both the spillway slope and the powerhouse slope have exceeded 200m. Latest monitoring data prove that the slope deformation tends to be stable.

Since its commissioning in October 2010, all the major structures have been working normally and in good conditions, and their performances fall in the anticipated ranges of the design parameters. The whole project fully manifests its excellence in both engineering and construction quality. In 2011, Bakun Hydroelectric Project was awarded the "2010-2011 National Excellent Project Gold Prize" by the National Engineering Construction Quality Appraisal Committee of China. In 2013, the project also won the honour of an "International Milestone Project", jointly granted by the ICOLD, Chinese National Committee on Large Dams and Brazilian National Committee on Large Dams.

3. Transparency and integrity

(1) The Project Owner is Sarawak Hidro Sdn Bhd of Malaysia. During the project execution stage, the Project Directorate set up by the Owner has presided over major issues related to the construction schedule and the project investment.

(2) With a standard international project management system established and the Owner’s leadership, the engineering consultation service, project construction and equipment purchase had been procured in a transparent and efficient international competitive bidding manner, many renowned companies across the world had participated in the bidding processes which were based on technological priority.

(3) To assure the project could have satisfactory safety and reliability, the Owner employed a number of world famous consultancy agencies and technical experts from Canada, USA, Australia and Brazil, to review and assess our major technical studies

and achievements. Transparency and disclosure have been observed in the engineering process.

4. Sustainability and respect for the environment

(1) Thanks to the soft rock dam-filling technology, making full use of excavated materials in the rockfill zones reduced exploiting the quarry and disposal volume, and therefore, minimized damage to the natural environment.

(2) Applying a water training stoplog structure at the power intake successfully solved the problem for taking the reservoir surface water with rich oxygen, which can effectively mitigate the reservoir's impact on the downstream ecology.

(3) The earth slopes resulted from the structure foundation excavation have been environmental-friendly protected by sodding.

(4) Providing a water release outlet to release an ecological flow for downstream riparian users during the reservoir impoundment period, greatly mitigated effect on the downstream ecosystem.

(5) The power plant can generate 15.517TWh electricity yearly on average, and can replace a coal-fired power plant of the equivalent capacity. Every year, the power plant can save standard coal of 4,960,000 tons, and spare CO_2 emission by 14,940,000 tons, NO2 emission by 57,000 tons, SO_2 emission by 56,000 tons and soot emission by 67,000 tons.

(6) Completion of the project has made improvements to the natural environment surrounding the reservoir area and local transport conditions, brought along tourism development in the reservoir area, and promoted local economic development.

What services did the member firm provide to the project? Please describe briefly.

In this project, our company mainly undertook the civil engineering and instrumentation design for the main dam, spillway, power intake, power tunnel, powerhouse, water release outlet and the cut slopes, as well as the design review of the steel structures such as the hydraulic gates and valves. (Engineering of civil works)

Please use additional pages as needed. Maximum 5 pages per project.