One Day Course on Design and Construction of Modern Concrete Face Rockfill Dam (CFRD)

by Mr. Steven Toh Chin Kok, Grad. IEM

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The one day course on "Design and Construction of Modern Concrete Face Rockfill Dam (CFRD)" was organised by IEM's Geotechnical Engineering Technical Division (GETD) on 26th November 2015. It is one of its kind for this course to be held in IEM and also quite specific in geotechnical engineering of dams. We are honoured to have this course conducted by Prof. Xu Zeping at the Tan Sri Prof. Chin Fung Kee Auditorium, Wisma IEM. It was attended by 47 participants.

Prof. Xu Zeping is a member of International Commission on Large Dam (ICOLD) and chairman of Technical Committee on Embankment and Dams (TC210) of International Society for Soil Mechanics & Geotechnical Engineering (ISSMGE). He has been keynote speaker of several international conferences and symposiums. He is also the general reporter of Question 98 of the 25th ICOLD Conference in Stavanger, Norway, in June 2015.

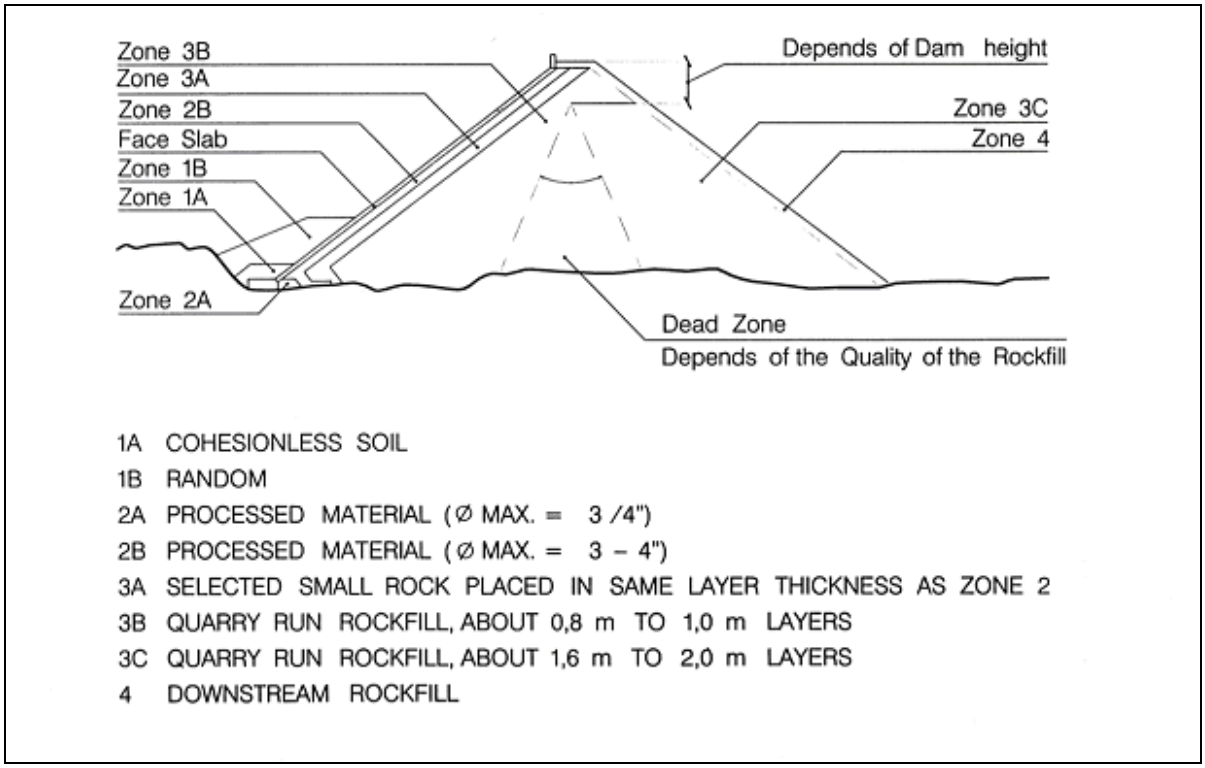
Prof. Xu conducted the course which include the contents of introduction of CFRD as a of the rockfill dams, developing history of the CFRD, design of CFRD, construction technologies, performance of CFRD upon earthquake, challenges of tall CFRD construction and innovations and trends for the future CFRD.

Bakun Dam, Sarawak

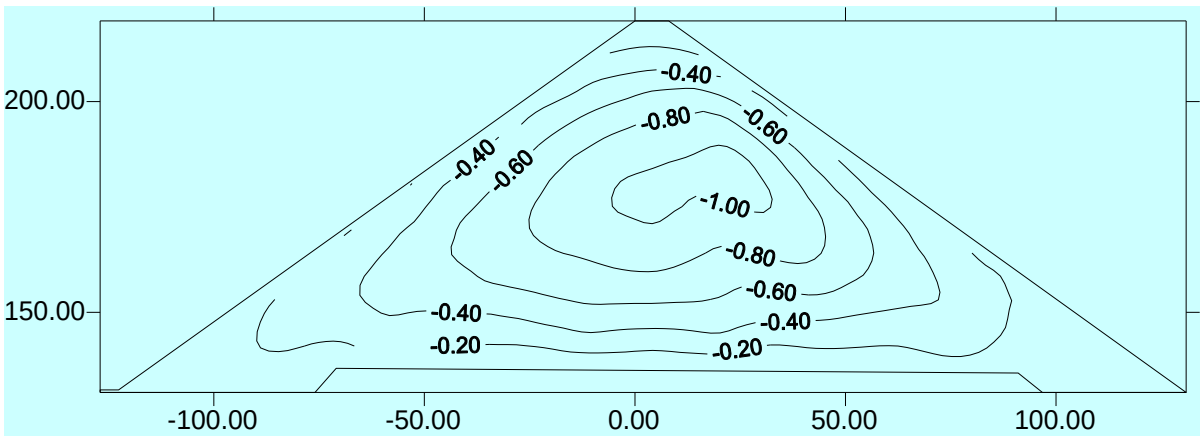
CFRD was rapidly developed after 1960s, with the application of vibratory roller and the technique of layered compaction. A local paradigm of this dam is the largest dam in Malaysia, Bakun Dam in Sarawak. The main features of modern CFRD consisted of concrete face slabs constructed using slipform, thin plinth, graded cushion layer, waterstop system for joints, apart from layered compaction by vibratory roller.

CFRD has a relatively low requirements and good adaptability on topographical and geological condition of dam site, compared with other dam types. The main concern of CFRD built on narrow valley is the arching effect and differential displacement in abutment areas. While for wide valley, the impacts of development of accumulated displacement should be considered. There is no special requirement on the strength of foundation, however, soil, peat and sand layer should be excavated. Geological considerations are focus on conditions of seepage barrier and the condition for plinth alignment on sound, non erodible and groutable foundation.

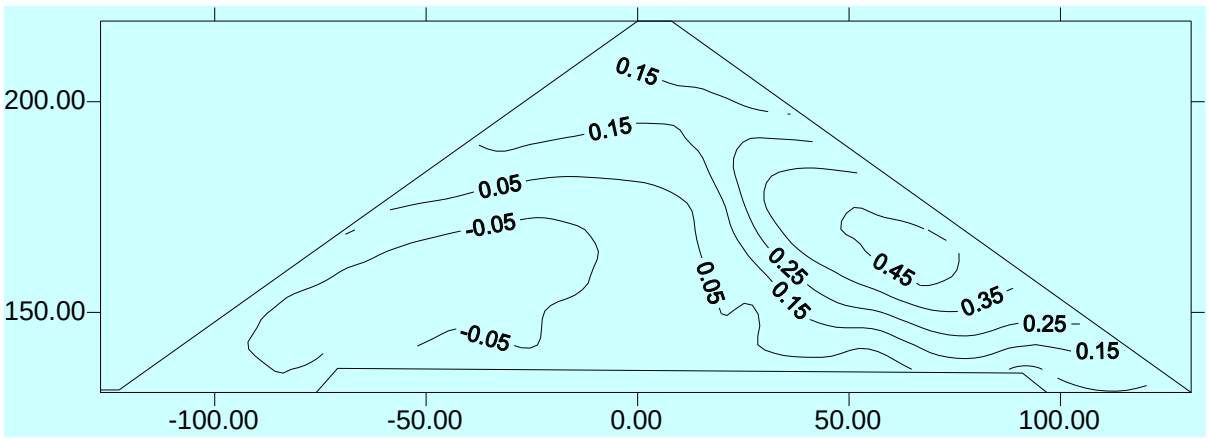
Prof. Xu stated that the best rockfill for CFRD shall be rock with uniaxial saturated compressive strength of 30 to 80 MPa, therefore having less issue on secondary breakage or settlement. In engineering design, the main principle for optimisation of section zoning of CFRD is to arrange rockfill materials with different properties, according to the stress and deformation distribution of dam body in different part.



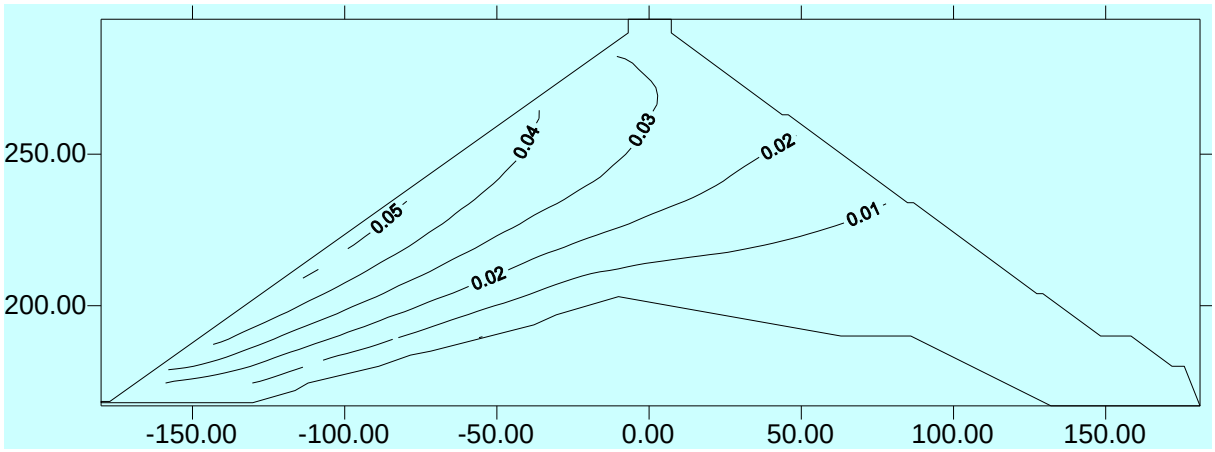
Standard Zoning Section of Modern CFRD



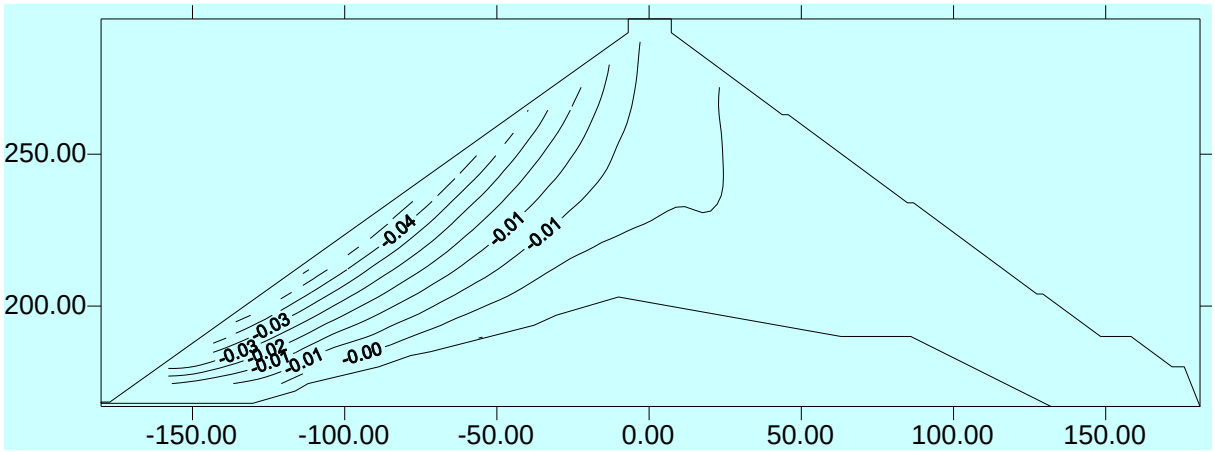
Horizontal Displacement (m)



Vertical Displacement (m)



Incremental Horizontal Displacement due to Impoundment (m)



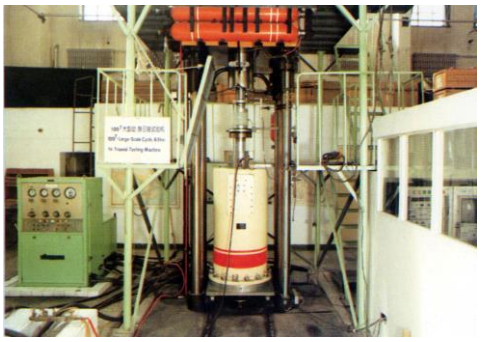
Incremental Vertical Displacement due to Impoundment (m)

Apart from some large scale tests being commonly used for investigation of rockfill properties, one of the interesting parts of the lecture is the usage of shaker in centrifuge modelling to analyse performance of CFRD in earthquake is available nowadays.

Shaker in Centrifuge Modelling

Description	Indice
Centrifuge acceleration	120 g
Maximum horizontal shaking acceleration	30 g
Maximum vertical shaking acceleration	20 g
Maximum shaking frequency	400 Hz
Maximum shaking duration	3 s
Maximum payload	400 kg
Shaking directions	H + V
Shaking wave forms	Sinusoidal, random, earthquake
Area of shaking table	1000 mm x 700 mm
Maximum shaking amplitude	± 4 mm
Shaker mass	< 700 kg

Large Scale Triaxial Testing Machine



Large Scale Dynamic Triaxial Testing Machine

Large Scale Creep Deformation Testing Machine

Construction of CFRD presented by Prof. Xu includes the aspects of foundation treatments, plinth construction, the extruded curb surface protection, quarry excavation and rockfill transportation, waterstop and joint installation, face slab construction and some latest technology development on CFRD construction.

Plinth Construction (Itapebi Dam)

Extruded Curb Construction

Waterstop Construction

Concrete Face Slab Construction using Slipform

Another aspect of CFRD behaviour foreseen, is their high resistance to earthquakes. Prof. Xu reported some cases of CFRD performances around the world and are found to be non catastrophic so far. In seismic area, attention and careful analysis must be given to the downstream slope. This will reduce the probabilities of failure if consequences are severe. The challenges of high CFRD construction were briefed, particularly on the face slab ruptures. The possible factors of slab rupture were discussed and its measures for avoiding it were presented.

Rupture of Wave Wall after Earthquake

Rupture of Face Slab after Earthquake

Towards the end of lecture, Prof. Xu presented about innovation and future development of CFRD. One of them is in controlling the rockfill deformation using Deformation Control and Integrated Deformation Coordination (DCIDC). This methodology combines the operation practices and theoretical analysis. With the increasing of dam height, the stress and

deformation properties and the operation status of CFRD will present some new features. Summarising the experiences and lessons of the previous tall CFRD construction, it could be noticed that the existing design criteria and conventional construction method will be adjusted for the construction of the future tall CFRD.

New Technology – Impact Compaction

Afterwards, Prof. Xu took on numerous questions from the participants who would like to know more about CFRD. The course ended with a big round of applause after presentation of a token of appreciation to Prof. Xu Zeping by Ir. Dr Ooi Teck Aun, President of the Southeast Asian Geotechnical Society.

Presentation of A Token of Appreciation to Prof. Xu Zeping by Ir. Dr Ooi Teck Aun