

Shuibuya rockfill dam

BOMAG compaction technology in use on world's highest rockfill dam



Job report by H.-J. Kloubert



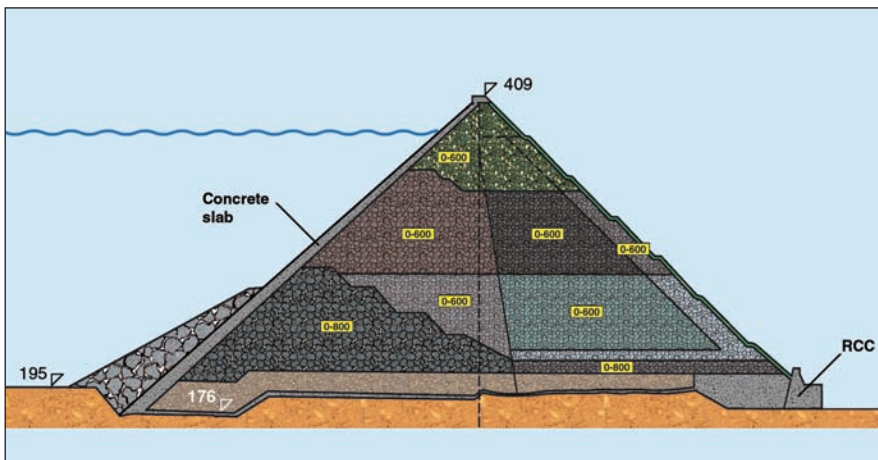
Shuibuya rockfill dam

Using the latest compaction technology on the world's highest rockfill dam

The Shuibuya concrete face rockfill dam (CFRD) which presently is under construction, is the highest of its kind in the world. The project construction started in 2002. The total dam height of 233 m will be reached in 2006. The Shuibuya dam is located near Yichang City on the Qing Jiang river, a Yangtse tributary river downstream from the famous Three Gorges dam in Hubei province, China. The dam will serve as a multi-purpose hydro-development project producing benefits mainly in power generation and flood control. The whole project includes construction of rockfill dam, concrete face, underground powerhouse with the installation of 4 generator units of 400 MW each. The first generation unit will be put into operation in 2006 and all four units will be completed in 2008.



Shuibuya rockfill dam and hydro power plant.



Crossview of Shuibuya dam.



Compaction of 1000 mm rockfill layers of lower dam body.

Rockfill dam design

The Shuibuya CFRD is designed with dam height of 233 m, 610 m length of dam axis and dam slopes ratio 1:1,4. On the upstream slope a concrete face slab forms the impermeable membrane of the dam. The concrete slab is 1,10 m thick at the bottom and 0,30 m thick at the top. The huge scale of the dam body needs more than 15 Mio m³ of rockfill material.

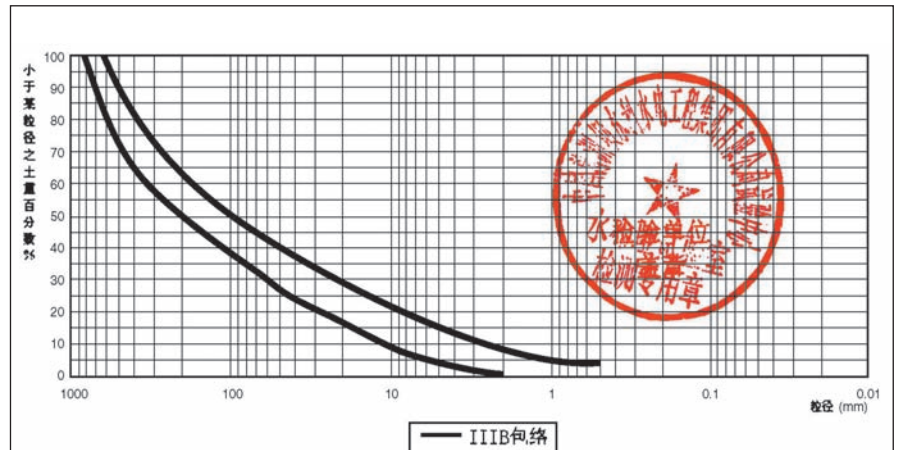
According to the working schedule and workforce distribution proper zoning of dam filling materials is carried out for the best utilisation of the material from excavation and to reduce costs.

The main rockfill is blasted by deep hole micro differential blasting methods from soft and hard lime stone formations near the job site. The material is then excavated and transported to the dam by trucks and placed and levelled by bulldozers. Compaction is carried out with 25 t BOMAG BW 225 VARIOCONTROL rollers with 6–8 passes. Water tankers continuously spray water on the rockfill layers to support the compaction process.

Strict Compaction Requirements

Compaction

Due to the enormous loads which the stored water will exert on the dam, the rockfill material has to meet high specifications with regard to density, strength, compressibility and resistance to deformation. Based on tests carried out before construction process, theoretical calculations and on the experience on similar projects, the density specification is set up to 2,15 t/m³. The lift thickness is specified at 800 mm after compaction. The rockfill material has to meet a limited grading envelope. Oversized blocks are removed by excavators.



Grading specification of rockfill material.



Rockfill grading and density control.

and vertical direction. It provides compaction amplitudes of up to 2,5 mm and centrifugal forces of up to 500 kN. VARIOCONTROL rollers offer exceptional performance in terms of uniformity of compaction and depth effect. When operating the rollers in automatic mode the VARIOCONTROL system automatically adjusts the energy required for compaction without the drum commencing the undesirable bounce mode.

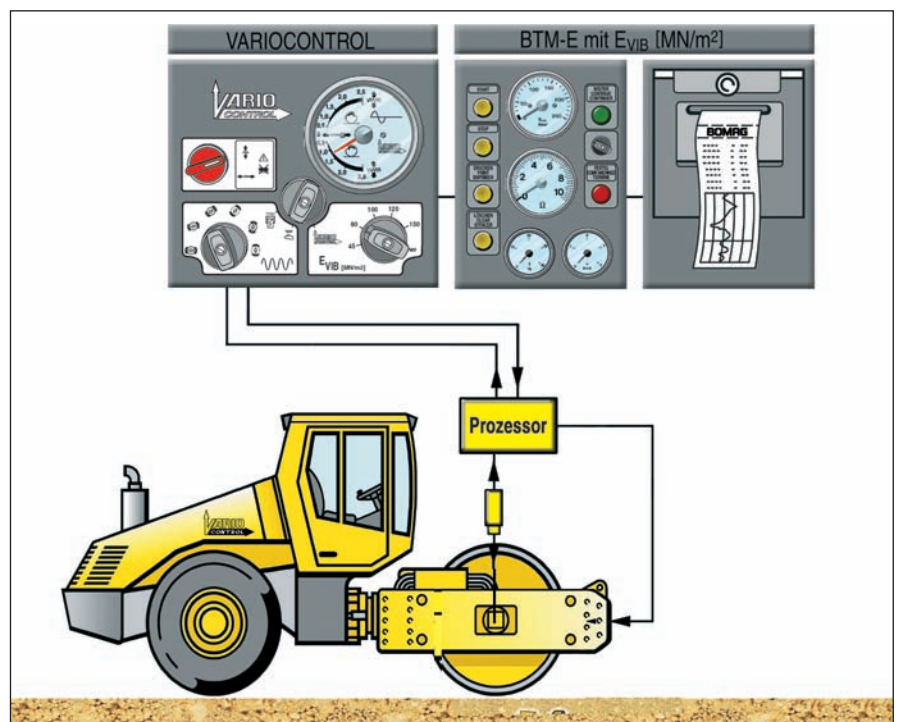
In addition to automatic mode, where the system controls itself, it is also possible to preselect the direction of vibration. Here the

operator can select from a choice of 6 vibration directions between horizontal and vertical. VARIOCONTROL rollers are also equipped with a new method of roller-integrated measurement to provide an assessment of compaction during the process by determining the dynamic stiffness of the soil. The measurement principle is based on the plate bearing test in the German DIN 18134 standard, during which a circular plate is loaded and unloaded and the deformation modulus E_V [MN/m²] itself is obtained from the force-displacement cycles. The soil is considered as linear, elastic and isotropic.

25 t VARIOCONTROL rollers for main rockfill

Following the project schedule a daily output of at least 15.000 m³ for laying and compacting of the main rockfill material is necessary. Due to the strict compaction requirements and high performance demands Chingjiang Construction is using 3 BOMAG BW 225 D-3 VARIOCONTROL rollers. The 25 t heavy single drum rollers are equipped with variable compaction amplitudes which continuously adjust the compaction energy to the actual operating conditions and allow the maximum possible energy to be transferred at all times.

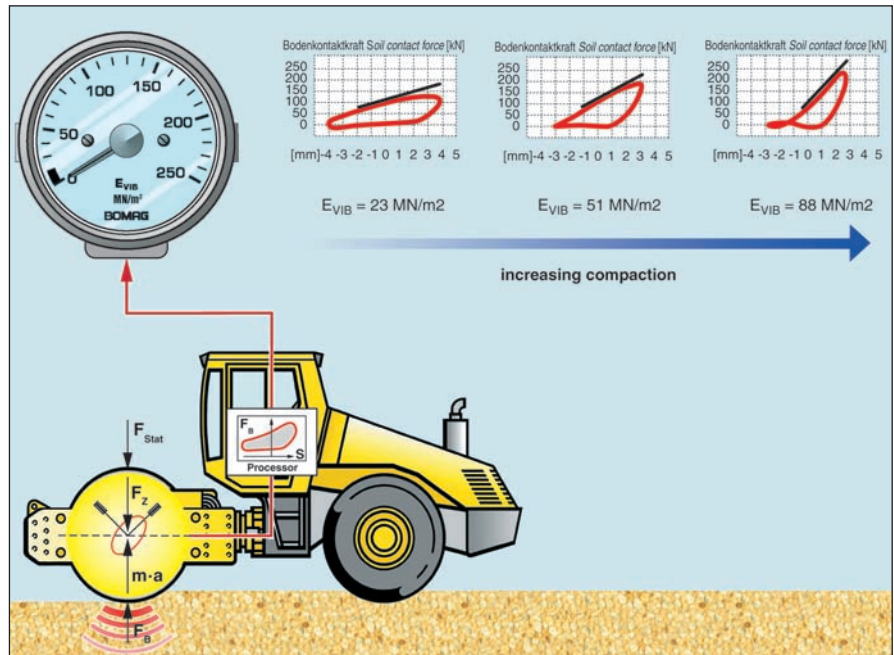
The VARIOCONTROL system uses the analysis of the interaction between the drum and the stiffness of the material to be compacted. The BVC exciter system generates directed vibrations at any angles between horizontal



VARIOCONTROL with integrated intelligent compaction system.

Intelligent Compaction System

The VARIOCONTROL system enables the determination of a value directly related to the deformation modulus E_V of the soil during each vibration movement and uses the inter-relationship between force and the penetration of the roller into the ground. The measuring value is called vibration modulus E_{VIB} [MN/m^2]. For this purpose the contact force between soil and roller drum is determined by integration of the acceleration measurements taken at the roller drum. When analysing the contact force over the vibration path of the drum each rotation of the eccentric produces a loading and unloading curve in which the enveloped area defines the compaction work done. As with the plate bearing test the vibration modulus E_{VIB} [MN/m^2] is calculated using the load curve. The cylindrical shape of the drum and the changing contact area of drum and soil is thereby taken into account. The system is able to measure E_{VIB} values in the range $20 MN/m^2$ to $250 MN/m^2$. The E_{VIB} values are displayed on the operator's control unit and can be printed for documentation and evaluation purposes.



E_{VIB} measurement system.

Compaction Trials using model BW 225 D-3 BVC

Compaction trials were carried out with BW 225 D-3 VARIOCONTROL rollers at an early stage of placing III zone main rockfill to establish the number of passes to achieve the compaction specified. A $14\text{ m} \times 35\text{ m}$ trial area was integrated into the construction of the lower dam body.

The following method used:

- Compaction and proof rolling of test area using BW 225 to produce a stable and uniform subgrade
- Placing 900 – 1000 mm rockfill layer, $14\text{ m} \times 35\text{ m}$ size, removing oversized boulders $> 600\text{ mm}$
- Compaction of shoulders, 4 passes with BW 225, automatic mode
- 1 compaction pass with BW 225, automatic mode on first test track



25 t VARIOCONTROL roller in automatic mode on a 1000 mm rockfill layer.

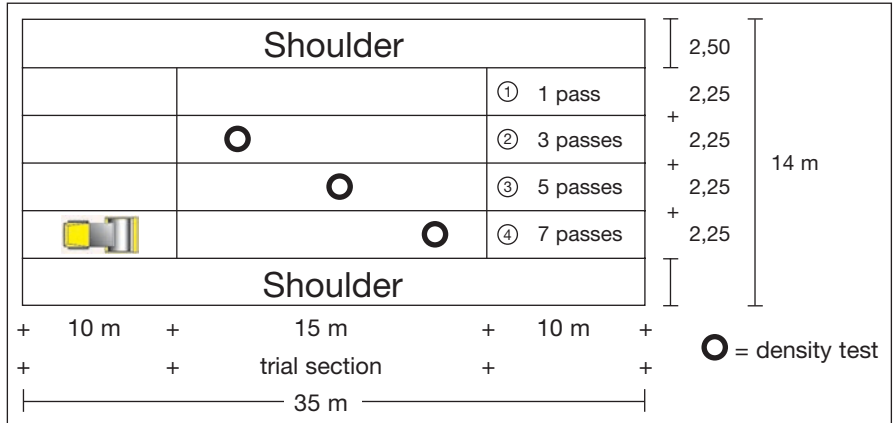
- 3 compaction passes with BW 225, automatic mode on second test track
- 5 compaction passes with BW 225, automatic mode on third test track
- 7 compaction passes with BW 225, automatic mode on fourth test track
- Density tests, water replacement method, on second, third and fourth test track

Compaction trials with BW 225 D-3 VARIOCONTROL

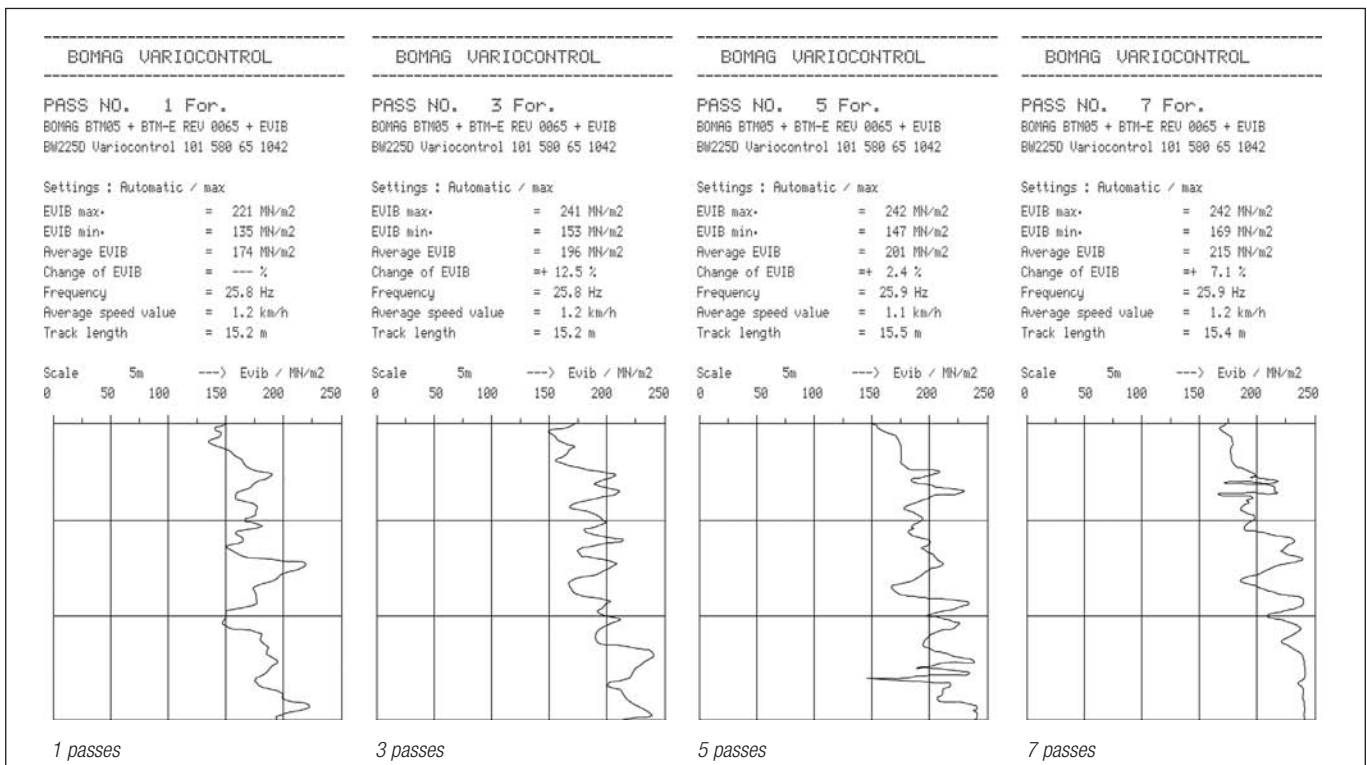
After 3 passes 2,00 t/m³, after 5 passes 2,15 t/m³ and after 8 passes 2,18 t/m³ were achieved. Using the density test results and

the EVIB curve evaluation the required number of passes for the main rockfill was specified at 6 and the operating speed 2,0 km/h with

the VARIOCONTROL rollers working in automatic mode.



Trial area to establish the optimum passes with BW 225 on rockfill layer ~ 800 mm after compaction.



EVIB measurement printouts showing increasing EVIB values with higher compaction.

The EVIB values show the increase in compaction, the uniformity of compaction and indicate refusal density after 5–7 passes.

EVIB [MN/m²] represents dynamic stiffness and is directly related to the compression modulus of the material and the bearing

capacity of the layer. EVIB also reveals weaknesses and faults caused by porosity or cracking in the rockfill material.

Project Data

- Project:** Shuibuya concrete face rockfill dam (CFRD), 233 m height
- Location:** Quingjiang river, 300 km west of Wuhan, Hubei province, China
- Project developer:** Quingjiang River Hydropower Development Co. Ltd.
- Client:** Quingjiang Shuibuya Project Engineering Company
- Contractor:** Quingjiang Construction Company of China Construction Group Corporation for Water Resource and Hydropower
- Construction time:** 2002 – 2008
- Hydropower:** 1600 MW, underground power house with 4 installed generating units of 400 MW each
- Dam parameter:** Dam height 233 m, crest width 12 m, dam axis 608 m, upstream dam slope ratio 1:1.4, downstream slope ratio 1.4 partial 1:1.125
- concrete slab area:** 138.000 m², concrete slab thickness: 1.10 m at the bottom, 0.30 m at the top
- Dam rockfill material:** 15.6 million m³, max. block size 600 mm
- Compaction specification:** 800 – 1000 mm layer thickness, 2.15 t/m³
- Compaction equipment:** 3 x BOMAG BW 225 VARIOCONTROL

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The machines illustrated may show optional equipment which can be supplied at additional cost. Specifications may change without notice.

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