Quality Control Aspects for Casing Material and Coarse Filter for Earth Core Rockfill dam

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Abstract: Blasted prototype rockfill material from a multipurpose Irrigation Project which is under construction in India is considered for its quality control / assurance for this paper. The maximum particle size (d_{max}) of blasted rockfill material used in construction of the above project is 600 mm and the maximum particle size of inclined and horizontal coarse filters is 20 mm & 80 mm respectively. Following tests were conducted at site to check the quality and determine the field density, moisture content, grain size distribution and permeability as per relevant standards and field experiences:

(i) In-situ (Field) Density [3,4]
(ii) Moisture Content [1]
(iii) Prototype Grain Size Distribution for Casing and Filter Materials [2]
(iv) Permeability [5]

All the above mentioned tests were conducted at different stages / frequency of construction and determined material parameters. The results are presented and necessary preventive action was also highlighted. From the testing, the test results were collected i.e., field density, moisture content, field permeability, gradation, Coefficient of uniformity (C_u), Coefficient of curvature (C_c), finer percentage (> 75 µ) and compared with design values. From the comparison, it is observed that the parameters determined from field tests almost match with design values. Highlighted all the observed deviations and provided the corrective measures based on the field conditions. Therefore, the quality control measures are very much essential to ensure the safety of the structure.

Keywords: Rockfill, Quality control, Quality Assurance, Field Density, Gradation Curve, Permeability.

1 Introduction

All over the world, generally rockfill materials are being applied in the construction of earth core rockfill dam (ECRD) and concrete faced rockfill dam (CFRD) as a casing / shell material because of their natural flexibility, ability to absorb large seismic energy and flexibility to various foundation circumstances. The use of modern construction equipments and available construction materials in the vicinity, construct such dams cost-effective. The main purpose of the casing material is used to provide the stability to the structure.

This paper deals with the field testing, study of relative density [4,3], gradation analysis of casing / shell and filter materials [2] and also study the behavior of casing / shell material in aspect of permeability [5] for two mainly projects viz., Polavaram Project, Andhra Pradesh and Kanhar Dam Project, Uttar Pradesh. The maximum particle size (d_{max}) of the prototype gradation casing/ shell material as per approved construction is 600 mm. Overall performances of a rockfill dam depends upon the control exercised during construction, supervision and inspection stage. Proper quality control during construction is as important phenomenon as same as the design and it helps to sustain the structure up to its design period. Quality does not mean to implement very rigid procedures to be laid down for during the construction stage. As every work has its own problems & limitations and therefore, procedures should suit with the conditions. Sequence of works for each zone is an essential activity to construct resilient structure. Fig.1 shows Cross section view of Kanhar Dam Project

Permeability, shear strength and gradation are the prime considerations in case of pervious fills. The general consideration for control of permeability should be that the permeability of the material increases towards the outer slopes of the dam embankment. The control of compaction is generally determined by relative density test which is a measure of the compactness of a pervious material with respect to the loosest and most compact states at which it can be placed.

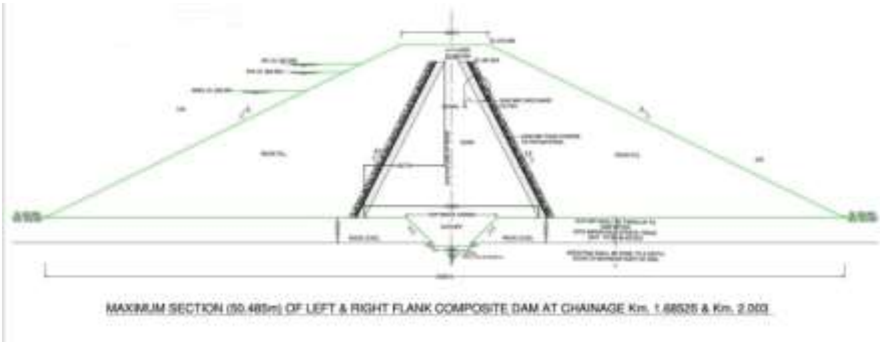

Fig 1: Cross section of Right section of Kanhar Dam Project

2 Testing Frequency

For pervious (Rockfill & fillter) materials, the testing frequency generally considerate as per IS 14690 and same has been shown in tabulated form in Table 1 [8]:

Table 1: Testing frequency of Rockfill & filter material

Type of material	Test to be performed	Quantity	No. of test	Remarks
Casing / Shell material	Gradation	1000 m3	1 No.	During the initial placement
		10000 m3 or each shift whichever is more frequent	1 No.	After placement procedures have proved satisfactory and no significant changes in borrow area material
	Field Density	1000 m3	1 No.	During the initial placement
		10000 m3 or each shift whichever is more frequent	1 No.	After placement procedures have proved satisfactory and no significant changes in borrow area material
	Permeability	Monthly / 1000000	1 No.	
Coarse Filter	Gradation	1000 m3	1 No.	
	Field Density	1000 m3	1 No.	

3 Construction process for Earth Core Rockfill Dam

3.1 Placement and spreading

Usually placement and spreading works started with gradation analysis & shape factor of each dumping yard / borrow area where rockfill material to be collected. Acceptable materials to be transported from borrow area to working site by trucks or suitable conveying system. If the material are not fulfill the design requirement preciously not meet gradation criterion, grizzly screening (multi size boulder separators) to be installed and mix the materials as per their designed prototype gradation curve and transport by truck / conveyor system and spread by a bulldozer. During the dozing, the fines are moved onto the upper part of the layer, which creates a smoother working surface for the truck to place the next layer and the stratified permeability. Oversize rocks are often pushed into a specified zone in the outer part of the dam i.e., ‘rip rap’ or the rock may break by using of mechanical / pneumatic hammer. To meet the filter requirements is important to ensure that the contact between filters and rockfill material does not have an accumulation of large rocks [7].

3.2 Roller type and number of passes

Compressibility of rockfill material is dependent on the various factors viz., grading, degree of compaction (layer thickness, roller weight and number of passes), rock substance strength and the effect of wetting on the substance strength [6]. It is normal to specify smooth steel drum vibrating rollers to be used for compacting rockfill material. The roller is usually specified as having a static mass of between 10 and 15 tonnes. Roller trials are often specified to determine the number of passes. It is usual to require at least 4 passes of the roller. During site investigations, determine the degree of breakdown of rock under rollers may also be found which may influence the resulting density and particle size distribution, permeability and modulus of compressibility.

It was also study that any additional compaction achieved after, say, 4 or 6 passes may not great influence the density it only breaks the rock of the upper part of the layer. Therefore, it is common to limit the number of passes to 4 or 6, seldom more than 8 [7].

3.3 Addition of water

Water is regularly added to the rockfill material to aid compaction and to weaken the rock-to-rock contact points in rock-types which are weakened by wetting. The water should be added by spraying on to the dumped rockfill before spreading. Commonly the amount of water is specified as a percentage of the volume of the rockfill. If the rock forming the fill is strong, produces few fines and is not greatly weakened by wetting, water may not be needed. Rolling trials can assist in assessing whether watering is needed and the amount of rolling required to achieve good compaction.

3.4 Durability requirements

Rockfill is often required to be 'hard' and 'durable'. The means of measuring this are seldom specified and in many dams such a requirement will be unobtainable like where siltstone or sandstone is being used, which may breakdown on repeated exposure to wetting and drying. Breakdown only occurs on the surface of the rockfill, and is not detrimental to the shear strength or compressibility of the rockfill as a whole, provided the rockfill is well compacted and watered during compaction. Nevertheless, water should be used to control dust wherever necessary.

Hence, in general, there should be no requirements on durability for rockfill. The exception might be for some volcanic and altered granitic rocks which can deteriorate with. For rip-rap, or the outer layer of rockfill on the downstream slope, durability under wetting and drying is important and should be specified.

4 Inspection / Testing of Rockfill material & Filters

Testing of rockfill material is very difficult to its large size. During the construction process it is require determining the particle size distribution analysis, compacted field density and permeability. Particle size distribution (PSD) had a significant influence on the strength, permeability, and compaction behavior of rockfill materials.

Rockfill material generally covers a range of particle sizes between 0.001 mm and 1,000 mm, and it is well known for containing wide-ranging grain composition. Therefore, the scaling distribution for grain composition is an essential index for studying the physical and mechanical properties. When the gradation of a rockfill material is changed, its permeability, deformation, strength, and other properties are altered. During the compaction process of an earth core rockfill dam, the void reduction between grains is caused by natural settlement and artificial rolling.

4.1 Particle size distribution (PSD):

The PSD likely to replicate the complexity and irregularity in structural properties of rockfill materials and can be used to study the physical behaviors between the whole and the parts of the materials. By using graphical representation (Fig 2) and statistical analysis of prototype material, described a set of parameters like shape factors; Coefficient of Uniformity (C_u) and Coefficient of Curvature (C_c); and also find the maximum particle size and percentage fine (0.075 mm). That was obtained any of the above projects is 600 mm and 0.49% (i.e. <5%) respectively.

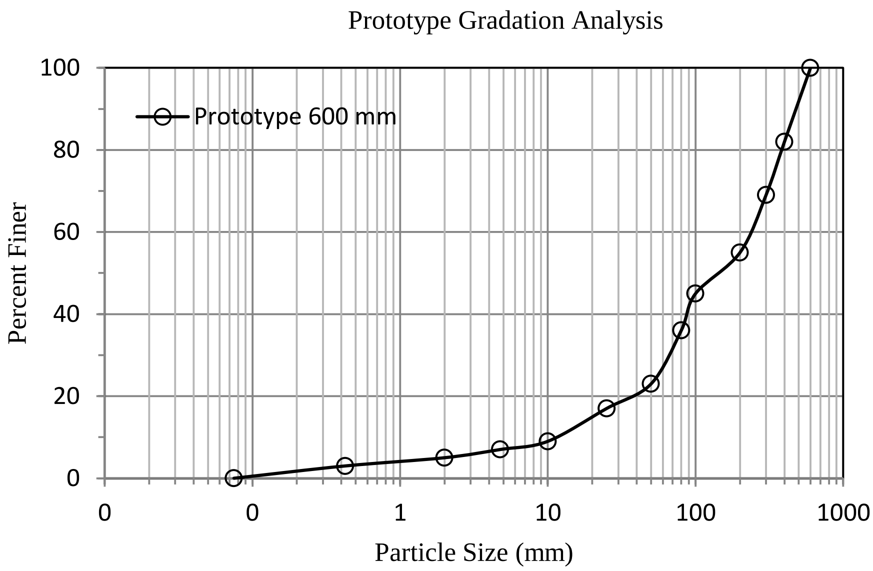

Fig 2. Prototype Grain Size Distribution Curves

4.2 Field Density:

The degree of compaction of the rockfill materials a key index for controlling the construction of earth core rockfill dams. The degree of compaction has an important consequence on the stability and seepage prevention of the dam. After rolling the materials to be dense and in the prototype gradation curve, it reflects that the void has been reducing steadily. Relative density is used as an indicator of compaction by comparing the porosity during the loosest situation and the densest state. At site the degree of compaction is measured by in-situ density.

Determining the in-situ density of casing material by the water replacement method as per IS 2720 part 33, using a circular ring on the surface and a plastics film (0·1 mm thick, 2 to 4 m square (for small diameter rings); and 0.2 mm thick, 4 to 8 m square (for large diameter rings) to retain the water. The ring diameter shall be at least 3 to 4 times the size of the largest particle. The diameter usually ranges between 0.5 and 2.5 m in multiples of 0.5 m. The rings may be made of 4 to 8 rnrn mild steel sheet and height of vertical flange will 10 to 20 cm. Pointer Gauge Assembly and Supports - Horizontal bar with supports resting on or outside the ring, fitted with an adjustable vertical pointer and lock nut and IS Sieves - 100-mm, 80-mm, 40-mm, 25-mm, 20-rnm, 10-mm and 4.75-mm, 30 cm in diameter, was used as required. Platform weighing machine of capacity upto 100 kg (digital type) also used for rockfill material measurement. Photo 1 shows the procedure to determine the field density using water replacement method and gradation analysis for rockfill material

Photo 1: Determination of In-situ density of rockfill material using water replacement method

4.3 Field Permeability:

Excavated the pit of size 60 cm diameter and height equal to the thickness of the compacted layer (around 80 cm) on the compacted surface of rockfill. Trimm the vertical sides and fix the perforated circular cylinder as shown in Photo 2. From the water tank, allowed the water into the pit. Let the water flow freely into the cylinder till the surrounding area gets fully saturated. Once the surrounding area of the cylinder got saturated, the inflow to the pit slowed down. Once it was confirmed that the inflow is equal to the out flow (constant flow = Q lit/sec) of the cylinder, noted down the flow rate from the measuring water meter fitted to the inflow pipe. Constant head permeability test was performed. Then knowing the radius of pit (r cm), Height of water head or pit (H cm)and rate of constant flow (Q), the permeability (K) has been calculated using the following equation:

$$K = \frac{Q}{5.5rH}$$

Photo 2: Field Permeability test to determine field permeability of rockfill material

4.4 Filters

For carrying out in-situ density test for bottom layer of horizontal filter. Cylinder of size 30 cm diameter and height equal to a layer thickness is used for determining in-situ density of bottom layer horizontal filter. Hollow cylinder was fixed on the filter and removed the filter material from inside using hand tool. The cylinder was kept on lowering as the material from inside removed till the layer thickness. The removed material was collected and weighed (W). In-situ density was calculated dividing the weight of material (W) by volume of cylinder (V). The excavated horizontal filter material from the cylinder was collected and sieved using following sieves: 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.0 mm, 0.425 mm and 0.075 mm

Knowing the weight retained on each sieve, percentage weight retained on each sieve is calculated. Based on the percentage weight retained, cumulative percent finer is calculated and plotted the curve between sieve size v/s percent finer on a semi log graph sheet (Fig.3) for above of the one project. Compared the designed and observed gradation curves of bottom layer of horizontal filter. From the comparison, it is seen that the observed gradation curves deviate marginally and does not fit exactly into the designed gradation range (Fig.4). This problem can be sorted out by stacking the stock pile of different sizes, mixing them properly and then placing in its zone so as to achieve the required gradation of Type-1 filter.

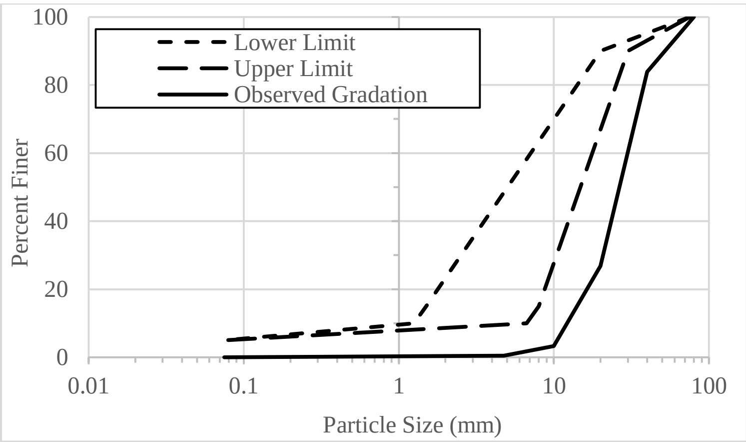

Fig. 3: Comparison of designed and observed gradation curves for Type -1 (bottom layer) horizontal filter

5 Conclusion

Ideal rockfill material is well graded, so it has a high density, strength and modulus after compaction and has a high permeability. This is not always practicable, if the available rock tends to break down during the rolling. Therefore, rockfill material forms a gap-graded material with a high percentage of sand. There is tendency that the rockfill will segregate during on placement, with the coarser particles being more predominant in the lower half of the lift and the finer in the top half.

Gradations apply to the Rockfill material below the upper surface of each layer which is usually finer because of breakdown under rolling action. The grading would be checked by a limited number of tests. Routine acceptance or rejection would be by inspection and only measured if it became necessary from a contractual viewpoint to confirm the percentage of finer particles was excessive. A guide to excessive finer fraction can be if the fill moves excessively as it is being rolled, or trucks bog on the fill. This also indicates the fill does not have a high permeability.

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