Prefabricated sand filter drains used at Tarbela Dam

Drains filtrants en sable préfabriqués utilisés au barrage de Tarbela

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SYNOPSIS The left bank rocks of Tarbela Dam are highly fractured and contain solution channels, fissured zones and erodible gouge material. Seepage through the bed rock was controlled by grout curtain and drainage system from the galleries. Problem arose when substantial amount of fines were passed by some of the drain holes. Different types of drains such as polymer bonded filters, epoxy bonded filters and sand filtered drains were tried and finally the latter were selected.The concept of the sand filtered drain consists of two concentric slotted PVC pipes prefabricated with filter sand in the annulus.The latest design has been the result of a thorough re-appraisal of the filtered drain concept. These drains have been successfully used at Tarbela Dam.

INTRODUCTION

Seepage through bedrocks under the spillway structures and from the abutments of the Main Embankment of Tarbela Dam Project is controlled by the conventional grout curtain and drainage system. Pervious rocks extend to great depth and it was not economical to make a positive cutoff with the grout curtains. The limestone beds contain granulated lenses which will not accept portland cement grout but which will pass appreciable quantities of water. In the original design the drainholes were lined with 50 mm dia PVC pipe having 0.5 mm wide longitudinal slots. It was expected that natural filter would quickly develope around the slots and after an initial passing of some fines, further piping would stop. This did not happen and instead very heavy flows and discharge of fines were experienced. The situation especially under the auxiliary spillway and the left abutment, deteriorated fast.This paper describes the problem, the design and construction of prefabricated sand filter drains. This innovation is expected to prove very satisfactory and may be used elsewhere on similar sites.

GEOLOGY

Tarbela left bank rocks consist of low grade metamorphic limestones interbedded with phyllites and occasional layers of quartzizites and basic igneous dolerites.The limestones are dolomitic, ferruginous or marly with lenses of granulated material locally called sugary limestone.The beds strike northeast and dip steeply to the southwest.Local folding of beds is common.The rocks are generally moderately to highly weathered.Fractured rock with crushed zones is frequently present.There are many shear zones containing erodible gouge material of very low shear strength.

DESIGN AND PERFORMANCE OF DRAINAGE SYSTEM

It was assumed in the original design that grouting would fill majority of the open joints, cavities and solution channels thus reducing permeabilities.The hydraulic head on the drainage curtains would thus reduce to less than 1 on 1 and will not cause piping.Migration of fines was to be prevented by use of slotted PVC pipe drains.At the left abutment,the core of the main embankment was wrapped around its u/s face and on the spillways,special u/s impervious blankets were provided under the approach slab adjacent to the headworks structure.The use of the u/s blanket would reduce the hydraulic gradient on the drains and little potential would thus exist for piping of fines.Experience showed the presence of much higher percentage of erodible material in the rock,the low effectiveness of grout curtain and inadequacy of slotted pipes to retain the migrated rock fines.

Effective angle of shearing resistance of the gouge material was found as low as 18°.Stability analysis indicated that piezometric pressures especially under the auxiliary spillway must not be allowed to rise above specified limits.Fig.1 shows schematic sketch of auxiliary spillway. Longitudinal drainage adits ASDA-2 and ASDA-3 are located in the left and right abutment rocks respectively.Both adits connect with the transverse Adit ASDA-1 under the headworks.During the initial impounding in 1974, the seepage into the drainage adits of left abutment reached 10 cusecs (0.283 cms)against the estimated value of 1.5 cusecs (0.042 cms).A number of drains discharged fines.The performance of drainage system of Auxiliary Spillway from 1975 to 78 was satisfactory.However during 1978 impounding deterioration was indicated with the discharge of significant amounts of fines from 10 drains under the headworks structure.These drains were plugged and replacement drains were installed by lowering a coaxial 50 and 75 mm diameter slotted PVC pipes down the holes from the drainage adits in 1.3 m segments.Sand filter was installed between the

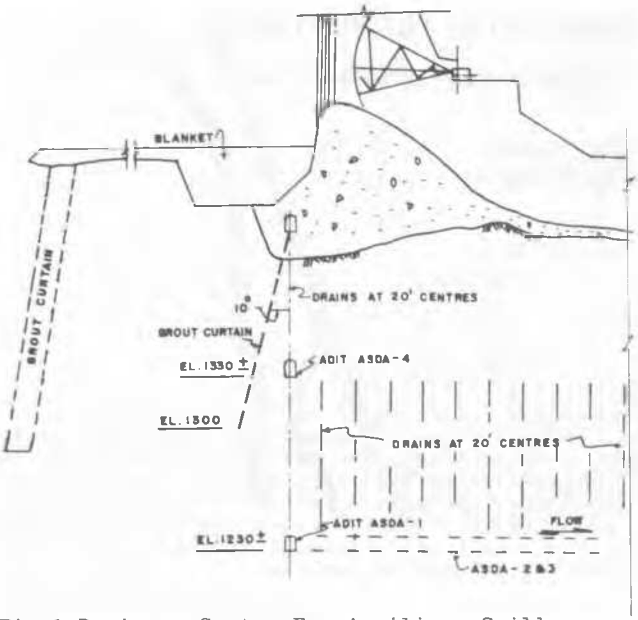

Fig.1 Drainage System For Auxiliary Spillway

PVC pipes under controlled conditions.A slighly coarser filter sand was placed in the annulus between the 75 mm PVC pipe and the wall of the hole.Performance of 1980 indicated discharge of fines from some additional drains.It was clear that the gradation of the fines was not suitable to form a natural filter pack behind the slots of the PVC pipes.The gradation of the silt sized fines is shown in Fig.2.

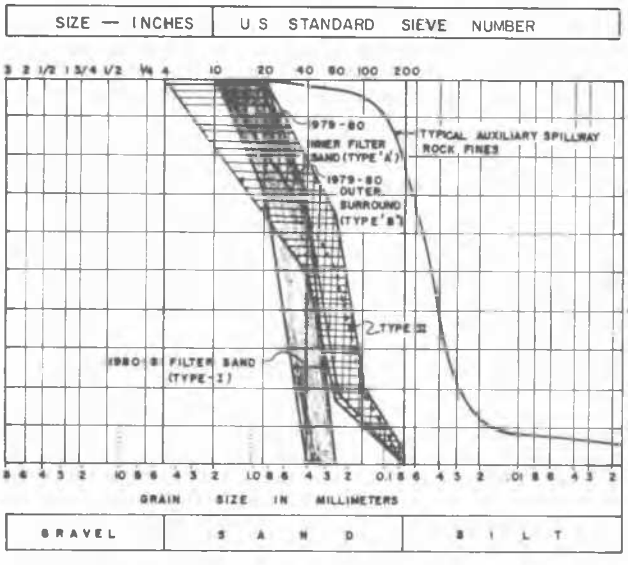

Fig.2 Gradation Of Rock Fines And Sands Tested For Use In Drains.

To prevent the movement of these fines a filter was required which would not only retain these fines but also transmit the seepage water so that pressures would not build up.Furthermore a large number of drain holes had been drilled upward from the galleries.Placement of filter sand around the slotted PVC pipes in these holes was not possible.The construction difficulties required a workable solution.

ALTERNATIVE FILTER DRAIN SYSTEMS

In 1978,drains had been fabricated at the site. The method consisted of placing the inner sand filter continuously as the pipes were extended down the drain hole.This meant that the filter sand extended in an unbroken column from the bottom to the top of the drain.The drawback to this arrangement is that it could result in a substantial loss of sand filter,should serious damage occur to the inner PVC pipe. For the updrains various proposals for prefabricated filter drains were investigated.Initially,both prefabricated proprietory system and site-fabricated systems utilizing filter cloth were looked into. The prefabricated proprietory system, in general, comprised of slotted PVC pipes coated with a 15 mm thick epoxy bonded sand layer.The samples tested in the site laboratory were either weak in retention of fines or weak in transmissibility. Laboratory tests were also run on various filter cloth drain samples for discharge capacity and fines retention capability.The results are summarised in Fig.3 & 4.All the cloth samples tested had desirably high discharge capacities but none retained rock fines of the grading found at the site.Eventually a sandwich type drain was prepared which proved practical, dependable and economical.

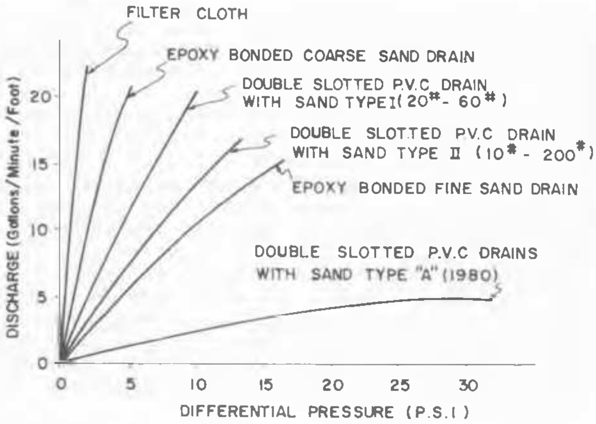

Fig.3 Flow Rates In Discharge Capacity Tests

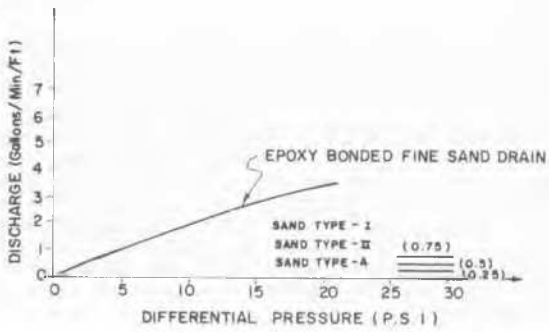

Fig.4 Flow Rates In Fines Retention Tests

FABRICATION OF SANDWICH FILTER DRAINS

Prefabricated sand filter drain consists of two concentric PVC pipes of outer dia 75 mm,inner dia 50 mm and 1.3 m length of the two pipes fabricated in the workshop Fig.5.

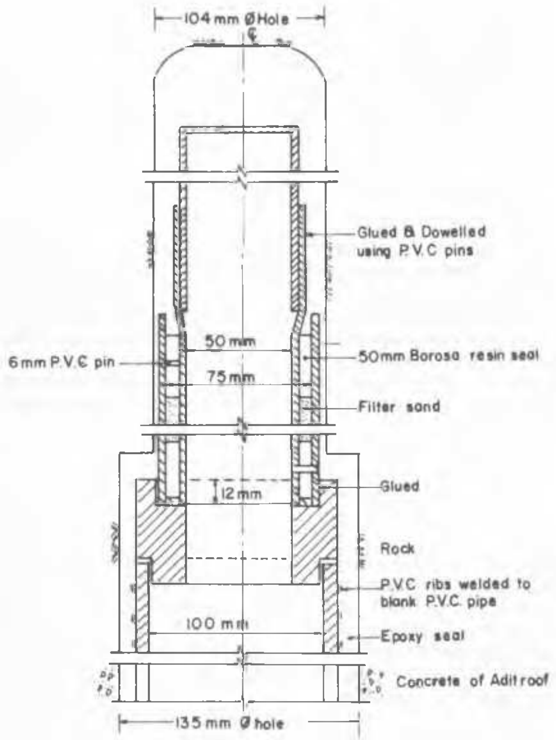

Fig.5 Sandwich Filter Drain Detail

The slots on both the pipes were 0.5 mm wide, 50 mm long and at 100 mm c/c vertically. After being filled with sand,the units were transferred to the vibrating table and were subjected to vibrations for 3 minuts obtaining final sand density of 1.84 gm/cc.After vibration,3 number 6 mm dia PVC dowel pins inserted into predrilled holes located close to the end of the pipe and at the mid points of the area to be filled with Barosa resin to seal the ends of the unit.The average production rate during 24 hours was 160 units with a crew of 12 men.Cost per foot was $ 10. Locally obtained river sand,oven dried and specially graded to conform to the requirement shown in Fig.2 was used in the annulus of the drains.

TESTS ON PREFABRICATED DRAIN

To check the flow capacity,a series of laboratory tests were conducted on the sandwich filter drains. The flow through the drain was measured and loss of filter sand through the slots was also monitored.Another series of tests with weights applied to the PVC pipe were conducted. This series checked whether the accumulated weight of the sand filter may cause the slots in the PVC pipe to open thus increasing flows and loss of filter sand.The loss of fines was small amounting to .05% of the filter weight.There was negligible change in flows with added weight on the filter. A series of tests were conducted witin a triaxial cell allowing pressure to be applied from the outside of the drain such as occurs in the field.The effective permeability dropped to 0.00022 cm/sec. The drain capacity was found to be 0.049 L/Sec/m/m head.

INSTALLATION OF SAND FILTERED DRAINS

In 1980,the drains were designed so that separate drain elements were formed by each pair of slotted PVC pipes.The elements could then be prefabricated with the filter sand sealed in at the ends with putty.By isolating the sand,the consequences of damage to the inner PVC pipe were limited to the loss of filter sand from only one drain element.The limited risk of drain defects and geological features coinciding was a major advantage of the prefabricated drains. In 1981,the use of putty for the end seals was discontinued;instead,a Barosa resin product was selected that formed a strong permanent seal after cooling.Other significant modifications in the drain arrangement were the improved bottom support and the strengthened junction with the upper adit.The uppermost unit of each drain was made unslotted connecting drain and capped temporarily during installation.

PERFORMANCE

After the replacement of all existing drains by sand filtered drains,the performance during the subsequent years was satisfactory.There has been a substantial reduction in seepage and an improved distribution of piezometric pressures. Since 1981 remedial works,there has not been any discharge of fines from the drains.

CONCLUSIONS

Prepacked sand filter drains have proved successful not only in retaining the migration of fine silt sized rock gouge material but also in transmitting the seepage water so that pressures do not build up.These drains have been prepared from indigenous material and are economical as compared to the patented filters.

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