Grouting the foundation of Evinos dam in Greece

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Abstract
Extensive grouting works involving curtain grouting and consolidation grouting were carried out beneath the core foundation of Evinos dam in order to reduce the permeability of the rockmass. The effectiveness of grouting was examined by closely monitoring the grout takes as well as by comparing permeability values before and after its application.

Introduction
The Evinos dam in western Greece is part of a scheme intended to divert water, through a 29Km long tunnel, to the Mornos reservoir, which is the main water supply source of Athens. The construction of Evinos dam is completed, and the filling of its reservoir is scheduled for 2001. The 126m high earthfill dam consists of a central core made of slightly weathered mudstone, transitional filter zones and shoulders made of rockfill and river gravel. It is founded on the flysch formation of Pindos zone, consisting mainly of sandstones with siltstone / mudstone intercalations with varying degree of folding, faulting and weathering.

The geological characteristics of the site affected greatly the design of the dam (Marinos et.al. 1997). The necessity of grouting for the purpose of sealing was mainly derived from the results of water pressure tests (Fig.1).

Grouting scheme
The grouting works implicated curtain grouting and consolidation grouting (Fig.2). Curtain grouting involved the construction of a vertical thin barrier, 70m in depth, from a grouting gallery located at the bottom of the valley up to the left abutment, and from foundation level and two specially constructed tunnels at the right abutment. The grout injected boreholes were drilled by successive split spacing from primary up to quarternary holes.

Consolidation grouting involved the injection of grout at a 12m deep zone along the axis of the dam. The width of this zone varied from 10m at the top of the abutments to 54m at the central part of the river valley. The grouting operations were performed i) directly from foundation level at the central part of dam's axis and ii) after placing 10m of core at the abutments.

Sealing – Closure criteria
At places along the curtain where the grout take within primary (A) and secondary (B) holes was less than 25lt/m for their total length, the rockmass was considered ungroutable an no further grout injections were required. If that was not the case, further split spacing was required with two tertiaries (C_u, C_d) and a quarternary (D) borehole. The sealing criteria that were then used for the assessment of the effectiveness of curtain grouting were: i) grout take at each stage of injection within the quarternaries less than 50Kg cement/m and ii) equivalent coefficient of permeability (k) lower than $5x10^{-5}$ cm/sec. Similar criteria were specified for consolidation grouting: i) grout take less than 50Kg cement/m and ii) permeability (k) lower than $10x10^{-5}$ cm/sec.

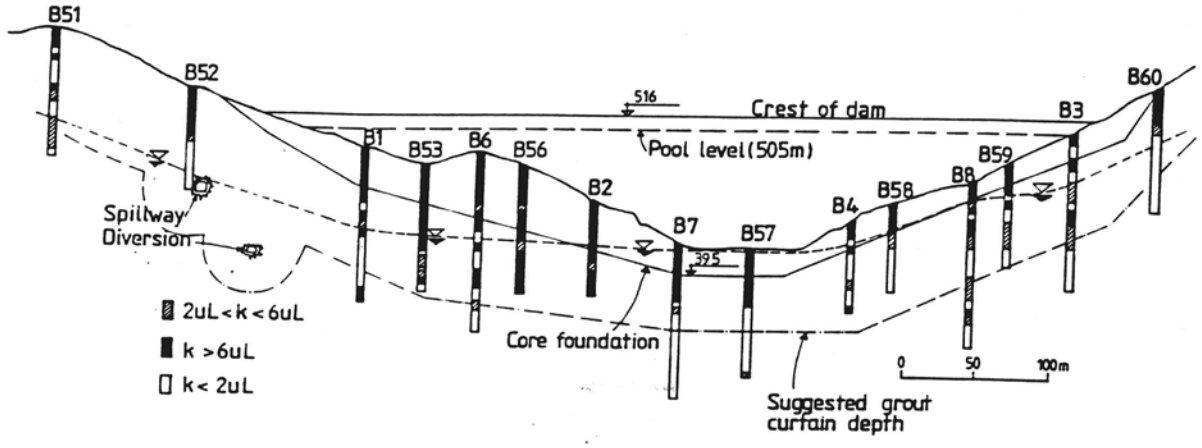

Figure 1 Longitudinal section of Evinos dam, with permeability data (Marinos 1997).

Curtain grouting

Grouting was carried out with ascending stages of 3m in length, after the boreholes were drilled to full depth and flushed with water. Water to cement (w/c) ratios of 2:1 and 1:1 by weight, with 2.5% bentonite on cement weight were used. The applied pressures, up to 16 bars, were such to avoid hydraulic fracturing. Every other primary (16m) spacing and every other quarternary (8m) spacing borehole was water tested before grouting. After the completion of the vertical grout curtain, inclined (45^o) control boreholes were executed in order to assess the effectiveness of the curtain.

The reduction in the takes through the series of grouting, showing the effectiveness of its application is shown in Figure 3.

Consolidation grouting

The grout injected boreholes were arranged in a 2.82 × 2.82 grid, rotated 45^o to the dam's axis. At both sides and parallel to the grouting gallery's excavated slopes two rows of inclined boreholes were also sunk and grout injected. A w/c ratio of 1:1 by weight with 2.5% bentonite on cement weight was chosen. Some additional grouting, named "contact grouting", was applied at two locations where consolidation grouting was performed from foundation surface, when 10m of core was placed. That was due to the local structure of flysch, which became more thin-bedded and multi-folded, creating installation difficulties for packers and reduced applied grout pressures. The effectiveness of consolidation grouting was checked by carrying out regular water pressure tests in a 8x8m grid.

The vast majority of both grout take and permeability test results fulfilled the specified sealing criteria. In a very few isolated areas some increased grout takes and permeability values were observed but were accepted because of surrounding tight rock.

Conclusions

By closely monitoring grout takes, injection rates, applied pressures as well as water pressure test results, before and after grouting, it was possible to assess the effectiveness of grouting beneath the core foundation of Evinos dam. In a few areas where sealing criteria were not satisfied and grout re-injection was required, further split spacing was applied up to quinary and along a section, 20m in length, up to sextary boreholes.

No relation exists between water permeability and grout take (fig.4). Therefore, the conception prevails in the literature that proportional relationships between permeability and grout take are not to be expected.

References

Marinos, P.G & Dounias, G.T & Karavokyris G. (1997). Flysch geological features and the design of Evinos dam, Greece. Proc. XI ECSMFE, Vol. 7 pp. 111-116.

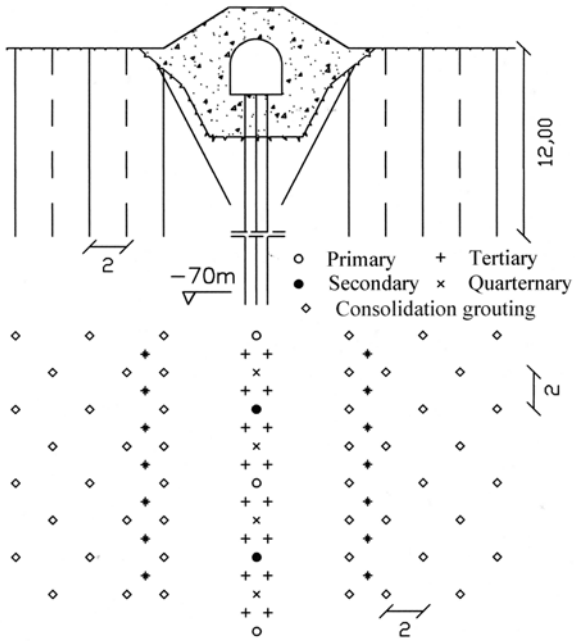

Figure 2 Layout of grouting works

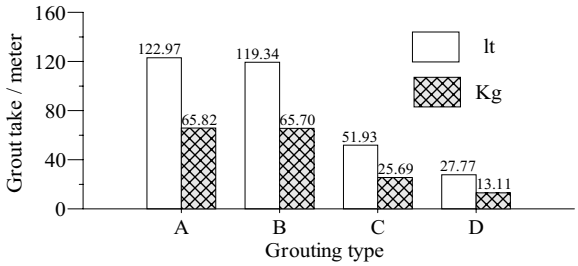

Figure 3 Curtain grouting: Mean values of grout take

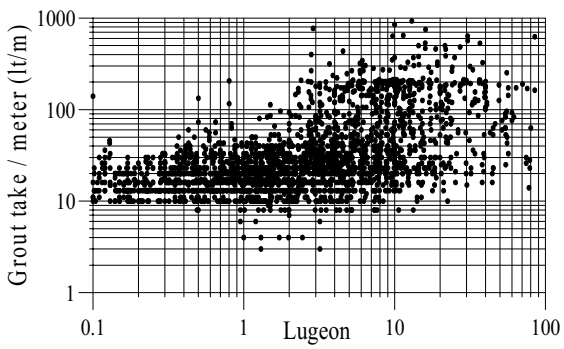

Figure 4 Grout take vs permeability values (2546 data)