Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 60 (1990)

Artikel: Retaining walls containing reinforced fly ash

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DOI: https://doi.org/10.5169/seals-46562

Retaining Walls containing Reinforced Fly Ash

Terre armée aux cendres volantes pour murs de soutènement

Stützmauern aus bewehrter Erde mit Flugasche

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SUMMARY
The Author was responsible for monitoring the performance of two retaining walls which contain Fly Ash reinforced with plastic grids. Further research work is being conducted by erecting and testing full-size "model" walls. The most important findings to date are presented in this paper.

RÉSUMÉ
L'auteur avait la responsabilité du contrôle du comportement de deux murs de soutènement composés de cendres volantes renforcées par des grillages en matière plastique. Une étude plus poussée se poursuit par la construction de murs grandeur nature soumis à une série d'essais. Les résultats essentiels obtenus jusqu'à présent figurent dans cet article.

ZUSAMMENFASSUNG
Der Autor hat das Verhalten von Stützmauern aus Flugasche mit einer Plastikbewehrung untersucht. Versuche wurden an Wänden im Massstab 1:1 weitergeführt. Die Resultate werden hier vorgestellt.

1 INTRODUCTION

The Reinforced Soil Technique is a well-established method of construction for retaining walls and bridge abutments. The traditional form of Reinforced Soil utilises good quality free-draining fill in association with Tensile reinforcement (usually metallic). Because of the large volume of fill utilised the cost of this method of construction can be significantly reduced by the use of cheaper fills such as the waste ash obtained from coal-fired electricity generating stations, i.e. Pulverised Fuel Ash (PFA). Most industrialised countries have large stockpiles of this material which is particularly useful because of its low bulk density, effective cohesion and self-hardening properties. Until recently PFA was specifically classified in the United Kingdom as being suitable for use in Department of Transport Reinforced Soil structures [1] because of concern over corrosion of metallic reinforcement when buried in PFA. However with the advent of strong, chemically-inert, non-metallic reinforcing elements, e.g. Tensar, Paraweb, Fibretain, etc., this situation has changed.

In 1983 a trial retaining wall incorporating reinforced PFA was erected and test loaded successfully by West Yorkshire County Council [2] and subsequently the first commercial use was made of this composite construction in retaining walls which formed part of the Dewsbury Ring Road in Yorkshire. The walls, which were erected between 1985 and 1987, are used to support elevated sections of the ring road and because of the novelty of this form of construction sections of the walls were extensively instrumented. As a result of the successful use of this form of Reinforced Soil many retaining walls and abutments incorporating reinforced-PFA have been built in the United Kingdom. Monitoring of the walls at Dewsbury is still being undertaken and further research work into the behaviour of reinforced fly ash is being undertaken in the large scale test facility at Bolton Institute.

2 EXPERIMENTATION

2.1 Field Work

Field work consisted of the instrumentation and monitoring of retaining walls which form part of the Dewsbury Ring Road. The walls have the usual constituent components of Reinforced Soil structures, i.e. facing, bulk fill and reinforcement. The facing is composed of 'I'-section columns with precast concrete planks fitted into the vertical slots formed by the flanges of the columns. At the start of construction temporary props and walings were used to hold the columns upright and the walls were built up by progressively inserting concrete planks and laying and compacting the fly ash in layers behind the facing. A vertical sand drain was interposed between the facing and the PFA and this was gradually raised with the wall. At the appropriate elevations contiguous sheets of grid reinforcement were laid horizontally on top of the compacted PFA and one end of each sheet was passed in between vertically-adjacent concrete planks and anchored to the steel columns. The grid was then tensioned by pulling the free end and further PFA was placed and compacted. The process was repeated until the wall was built to full height. The temporary props were removed when the fill was approximately two-thirds of its final height and after completion of the filling a false masonry face was erected in front of the facing.

As the walls were constructed a large number of monitoring instruments (earth pressure cells, inclinometer tubes, magnetic extensometers, etc.) were installed to measure pressures and deformations both on the boundaries of the reinforced PFA block and inside the block [3]. The scope of the monitoring programme was enhanced by the Transport and Road Research Laboratory (TRRL) who arranged a variation to the design so that two different types of reinforcement, i.e. Paraweb and Fibretain, were utilised in two sections of one retaining wall.

2.2 Laboratory Work

The Laboratory Work is being undertaken in the Large Scale Test Facility at Bolton. This 'laboratory' is dedicated to experimental research into the behaviour of engineering 'structures' and forms of construction using large and full-scale 'models'. The grid-reinforced PFA research work is undertaken using the 'model' retaining wall which is 12m long, and which retains a 3.5m height of fill which extends for 6m back from the wall facing. The facing is identical to that used on the Dewsbury Ring Road and during wall erection the facing is rigidly supported by props and horizontal jacks (in a similar manner to the restraint at Dewsbury. The fill and reinforcement are placed in layers and when the full height of PFA has been placed the props are removed and the jacks are released - the jacks are mounted as a safety frame which is bolted to the ground beams and which is present to prevent extensive movement or catastrophic collapse of the facing. Discrete loads and uniformly-distributed loading is then applied to the surface of the fly ash using large concrete blocks. Instrumentation, of the same type as used at Dewsbury, is used to measure boundary pressures and displacements.

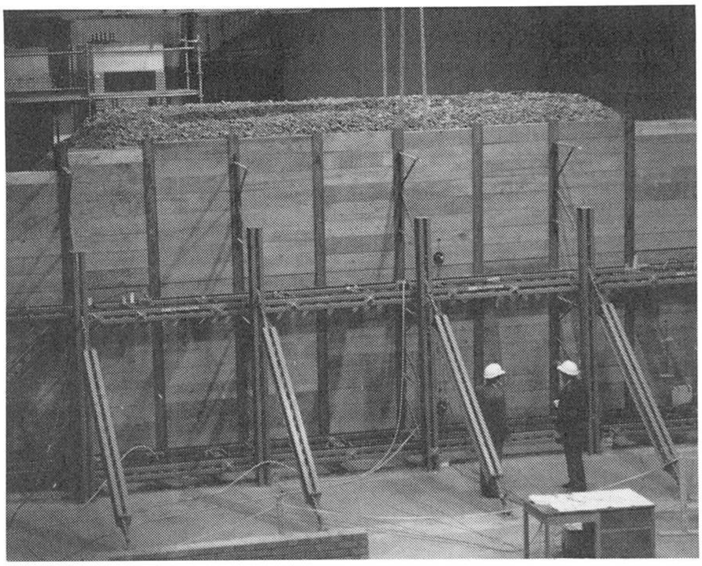

Fig. 1. 'Model' Retaining Wall Apparatus

The first series of tests is concerned with the influence of reinforcement length (relative to wall height) on wall strength and stiffness and the dispersion of applied surface loads within the reinforced mass. Walls containing unreinforced fly ash and PFA with very short reinforcement (0.25 x height) have been tested and further walls with reinforcement lengths in the range 0.5 to 1.0 times the height are currently being built. Future test series will investigate the influence of reinforcement extensibility, foundation soil compressibility and cyclic loading on the behaviour of reinforced fly ash.

3 DATA

Only those trends which have been observed in both the field and laboratory investigations are outlined herein.

3.1 Vertical pressure beneath the reinforced block

The data in figure 2 relates to six different instrumented test sections and three different reinforcement types. There is a random variation of pressure about a value equal to the calculated overburden. However adjacent to the facing there is consistently a reduction in vertical stress - this is believed to be due to friction between the facing and the fill which helps to support the fill in this vicinity. At Dewsbury earth pressure cells were also cast into the concrete strip below the facing so that they were in contact with the underlying ground. The high values of pressure indicated by certain of these cells may result from 'downdrag' on the facing from the fill. Once the filling was completed the pressure cells indicated virtually no change in either the magnitude or the distribution of pressure with time - removal of the props, erection of the false masonry facing, and opening of the road to traffic had no significant effect.

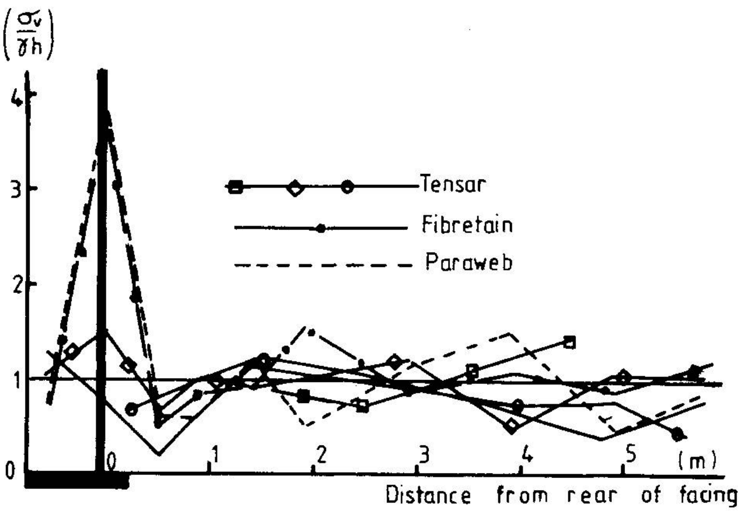

Fig. 2. Vertical pressure on base of PFA

3.2 Lateral pressures on the wall facing

At the end of construction the compaction process determined the pressure acting on the facing for a depth of approximately 3m down from the top of the fill. These compaction-induced stresses masked the influence of the shear strength properties and self-weight of the fill. The maximum pressure on the facing occurred in the vicinity of the upper propping position. However this method of wall erection is beneficial as removal of the props permits virtually complete dissipation of the compaction stresses, despite the presence of tensile reinforcement in the fill, as indicated in figure 3. At the same time there was a slight increase in the pressures acting on the lower half of the facing. The resultant pressure distribution approximates that predicted by earth pressure theory for a cohesive-frictional soil, i.e. zero stress in the upper zone and a linear increase with depth in the lower part - figure 3. To finish the retaining walls at Dewsbury a substantial concrete footing was cast along the

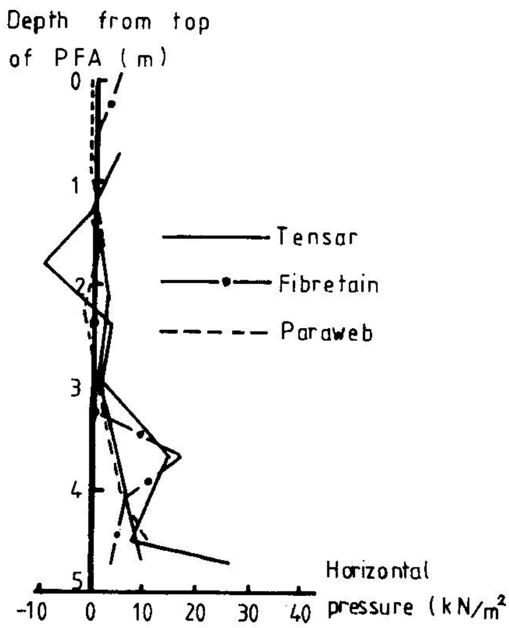

Fig. 3. Lateral pressures on facing

base of the facing and a masonry skin was erected on the footing. The gap (150mm) between the masonry and the facing was then filled with concrete. This had the effect of stiffening and restraining the facing considerably so that the earth pressures increased significantly, as shown in figure 4, and the forces in the soil reinforcement became very small. The rigidity of the final facing was such that it acting as a partial, gravity retaining wall. Nevertheless the upper 'zero-pressure' zone still remained, indicating that in the long-term the cohesion of the PFA was reliable and was not lost due to deformation of the block of fly ash.

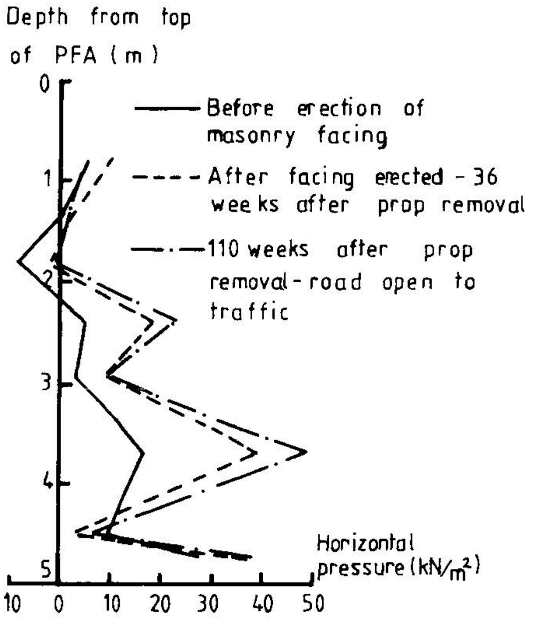

Fig. 4 Influence of facing stiffeness

3.3 <u>Horizontal movement of the facing</u>

Removal of the props resulted in immediate outward translation of the facing of up to 0.15% of wall height. For the Dewsbury walls the outwards displacements doubled over the next three months but the rate of movement decreased drastically. Figure 5 contains data recorded at three different elevations for various sections of walls at Dewsbury, after removal of the props.

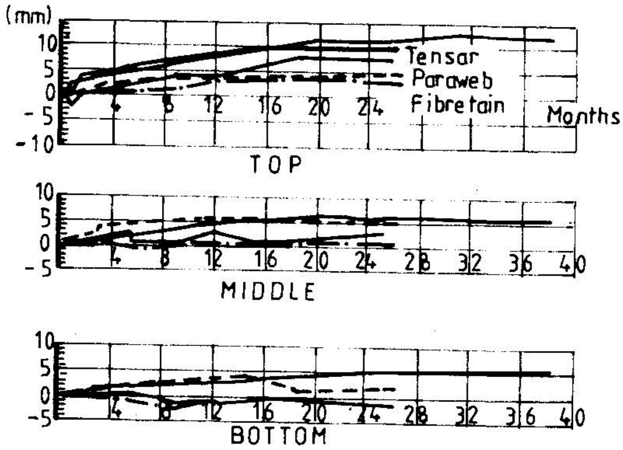

Fig. 5 Outward movement of the facing

4 CONCLUSIONS

The distribution of vertical pressure on the base of a reinforced soil block can be taken as uniform with the mean pressure equal to the overburden. PFA possess a reliable cohesion which exhibits no tendency to decrease with time or small movements of the compacted fly ash. Consequently there is no lateral pressure on the rear of the upper part of a facing which retains reinforced PFA.

5 REFERENCES

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