Reinforced earth trial structure for Dewsbury ring road

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This is an excellently illustrated Paper, but I was disappointed that the Authors did not address some key issues related to the use of pulverized fuel ash (PFA) as a fill material for reinforced earth construction. The key issues are the following

- (a) the effects of age hardening of PFA on soil-reinforcement interaction, on the design life of the structure, and on economics
- (b) the cost-benefits of using PFA.

The latter is particularly significant as it underlines Dr Jones's contention in reference 12 of the Paper that cost structures should be published. Also, the Authors in their introduction allude to cost savings, and in the conclusion state that cost savings in excess of 40% could be obtained by adopting reinforced earth structures, but they do not illustrate the cost structure for the scheme.

58. In fact, if the Hollinghurst and Murray¹³ cost structure is used, in conjunction with cost indices, the actual benefit of using PFA as fill for reinforced earth schemes would yield, in 1990, an overall cost benefit of 7.2% (see reference 14) with respect to granular material as fill. Therefore, the overall cost benefits of using PFA for reinforced earth construction could be estimated to be in the 35–40% range.

59. It would be interesting to hear the Authors' views on the above points and, if possible, to obtain the cost structure for the scheme so that a definitive figure can be arrived at for the monetary benefits.

Professor Jones, Mr Cripwell and Dr Bush

Mr Fernando raises a number of important points with regard to the use of pulverized fuel ash (PFA) as fill for reinforced soil structures. Unfortunately, these could not be given the treatment warranted in the space allocated to the Paper. The following information addresses some of the points raised.

Effects of age hardening of PFA

60. Although most PFA materials age harden, the rate and degree of hardening from different sources vary. A major study, aimed at determining the geo-technical engineering properties of PFA produced by the major power stations in Britain, is currently being undertaken at Newcastle University. The study has been commissioned by National Power in conjunction with Power Gen.

61. Table 7 provides an example of the effects of age hardening on Tilbury PFA. The increase in effective cohesion c' has significant implications with respect

DISCUSSION

Table 7. Effects of age hardening on Tilbury PFA

		Elapsed time		0	7	14	21	28	
		Unsoaked	C_d : kN/m2 ϕ_d : degrees	14.9 44	19.7 43.6	24 41		26.6 43	
Tilbury Power Station	Direct shear test (c-d)	Stockpiled	Soaked	C_d ϕ_d	1.7 39.5	2.7 40	5 42		7.8 40
			Unsoaked	C_d ϕ_d	28.2 43	29.7 41	29.7 43		38.2 44
		Conditioned	Soaked	C_d ϕ_d	2.4 41	8 41	8.7 42		28 43

to the economics of reinforced soil. Assuming that the soil–reinforcement interaction is dependent solely on friction ϕ' , the influence of cohesion on *reducing* the design tension of the reinforcement in a vertical structure, with no surcharge loading, is illustrated in Fig. 23. The effect of age hardening on soil–reinforcement interaction, particularly where anchors are used as the reinforcing elements—as in anchored earth—is equally significant.

62. It can be seen that the values of cohesion c' , associated with Fig. 23, are conservative when compared with the values of Table 7. Current Department of

$$T = (ka\sigma_v S_v - 2c' S_v \sqrt{ka})$$

$$\text{where } ka = (1 - \sin\phi') / (1 + \sin\phi')$$

$$S_v = \text{reinforcement spacing}$$

$$\sigma_v = \text{vertical stress}$$

Fig. 23

Transport (DTp) design criteria limit cohesion c' in fills to a value of 5 kN/m² for design. Table 7 provides a powerful argument for a revision of this limit.

Cost benefits of using PFA

63. The Dewsbury trial was designed to provide evidence for a number of structures designed to DTp requirements for a life of 120 years.

64. The benefits of using PFA as fill in the proposed structures were technical and economic. A major technical benefit was the light weight of PFA. Dewsbury ring road was constructed on predominantly soft alluvial soils, and a settlement period was required in the contract. The use of PFA reduced the total settlement.

65. The other main technical benefit gained from the use of PFA fill was the reduction in volume of reinforcement needed to provide stability (see Fig. 23).

66. The major influence on the economic benefit of using PFA as fill for reinforced soil is the cost of PFA delivered to site. At Dewsbury, the cost of the PFA was competitive with granular fill. However, the use of granular fill would have increased the volume of reinforcement and led to an increase in settlement.

67. The cost savings in excess of 40%, identified at Dewsbury Bypass, were calculated from two separate studies. The initial cost studies for Dewsbury Bypass were based on the use of the former West Yorkshire Metropolitan County Council Cost Index. This is a historical database started by the former West Riding County Council, which was updated with cost data from each winning tender obtained by those Authorities.

68. The initial design costings provided an indication of the potential savings offered by the use of reinforced soil and PFA fill, and were the initial incentive to undertake the Dewsbury trial. Confirmation of the savings was obtained by applying the billed rates for Dewsbury Bypass for conventional wall construction to alternative conventional design prepared in parallel with this reinforced soil design. These showed savings averaging 46%.

References

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