CORRESPONDENCE

The Secretary,
The Institution of Civil Engineers.

DEAR SIR,

EXPERIENCES WITH SOME SHEET-PILE COFFERDAMS AT TILBURY

In the course of a visit to the Tilbury Generating Station in the Thames Estuary with Dr Bjerrum and his colleagues from the Norwegian Geotechnical Institute, and with Mr Svennar of the Municipality of Oslo, some very useful data on the critical depths of sheet-pile cofferdams was obtained. The Writer is indebted to Mr I. H. Ogilvie of Messrs Holloway Brothers (London) Ltd., the contractors, for the information.

The soil conditions at Tilbury Generating Station were recorded by Skempton (1953). The conditions are similar to those at Shellhaven, some 7 miles downstream, where Skempton and Ward (1952), observed the loads in the bracing of a deep cofferdam. At Tilbury some 50 ft of soft clay (interspersed with three layers of peat) overlies about 20 ft of sandy gravel that lies directly on the chalk.

The sheet-pile cofferdams at Tilbury were constructed for various purposes and they vary in dimensions. The relevant details of their construction and performance are grouped below under four headings :

(1) *Ash-plant cofferdam.*—The intention here was to drive the steel sheet piles down to the chalk. A high driving resistance in the gravel and the chalk being rather deeper in places than anticipated, prevented all the piles reaching the chalk and some finished in the gravel. The tops of the piles were driven down in a narrow trench about 4 ft below ground level.

In the course of bulk surface excavation to permit placing the uppermost frame of struts, the tops of the sheet-piles moved in about 12 in. (more in places) and the central excavated area lifted. A sketch of the cofferdam cross-section at this stage is given in Fig. 1. The cofferdam is 61 ft $\times$ 42 ft in plan, and the maximum depth at the centre when failure occurred was about 6 to 7 ft.

An estimate of the stability number at which the movement occurred may be made on the basis of Skempton's shear strength records. The average undrained shear strength(s) of the soft clay just below the dried crust is about 350 lb/sq.ft and the unit weight (γ) of the clay is about 115 lb/cu. ft. Hence the stability number :

$$\frac{\gamma H}{s} = \frac{115 \times 6}{350} = 2{\cdot}0$$

which is the theoretical stability number for an unsupported face or slope in a deep bed of clay of constant shear strength. The long sheet piles had not contributed to the stability and according to Mr Ogilvie they showed no visible sign of bending.

(2) *Cofferdams for internal culverts.*—The steel sheet piles for these cofferdams and those mentioned subsequently were originally 22 ft long, but on account of the heads being

damaged from time to time their lengths became reduced to about 20–21 ft, and some were eventually as short as 18 ft. The sheet piles were driven down to ground level, the width between the piles varied from 7 to 10 ft and the depth of excavation varied from 11 to 15 ft. A frame of struts was placed at the surface and, in the early stages, bulk excavation proceeded without any further strutting. After one or two unfortunate experiences—when the the piling started to come in—it was found advisable to put in a bottom frame of struts. This prevented the piles from moving inwards, but it did not always prevent the bottom

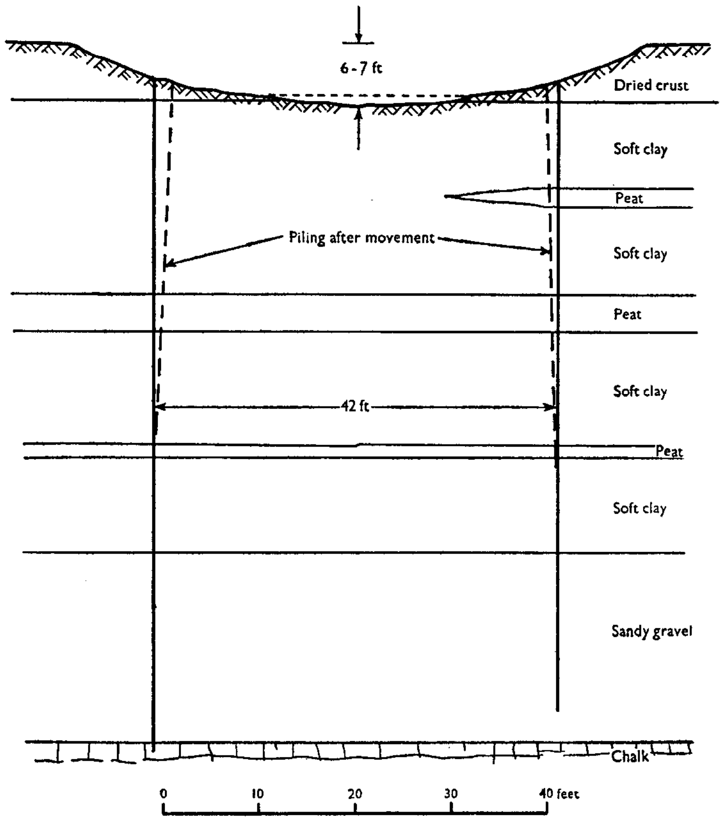

Fig. 1

from rising. In one instance the bottom rose 18 in. In these cofferdams the sheet-piles were left in the ground after culvert construction and the piles were driven to the exact size of the culvert. Thus it was necessary to prevent the piles moving inwards.

(3) *Cofferdams for external culverts.*—These cofferdams were similar to the above, but the sheet-piles were extracted after construction of the culverts. The piles were therefore spaced 4 ft wider than the finished width of the culvert; hence it was not of much consequence if the piles moved in a little during construction. The width between piles varied from 14 to $22\frac{1}{2}$ ft, and the depth of excavation was 15 ft. One frame of struts was placed at ground level and the contractors' policy was to have timber ready to put in a bottom frame

if movement started. Experience showed that a depth of 15 ft was just about critical, sometimes the sides came in a little and the bottom came up, and a bottom frame was put in immediately. Sometimes the cofferdam was stable without a bottom frame. The Writer and his colleagues witnessed one such case where a cofferdam was excavated to 15 ft. Only in one part had it been necessary to place a second frame of struts.

Mr Ogilvie described another case, where movement took place more rapidly than usual and happened overnight. A cross-section indicating the mode of failure is shown in Fig. 2. The piling remained quite straight, it moved outwards and away from the top frame of struts and *rose* above its original level. A gap was formed between the clay and the back of the piling at the ground surface. The clay heaved up in the bottom of the excavation.

(4) *Valve-pit cofferdam.*—This cofferdam is about 41 ft × 36 ft in plan and was constructed subsequent to our visit, and after the contractors had had considerable experience of this site. Sheet piles all 22 ft long were selected for this cofferdam and they were driven down 1 ft below the ground surface. The depth of excavation was as much as 18 ft in places and, in addition to a surface frame of struts, a second frame was placed about 10 ft below the surface. The bottom excavation was taken out in strips and immediately replaced by a heavy concrete mat. No movement whatever was encountered in the construction of this cofferdam.

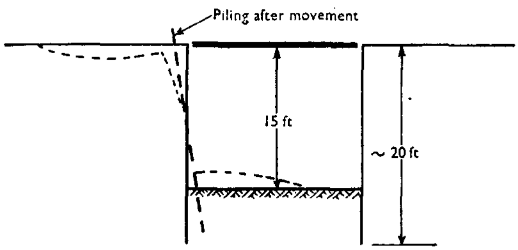

Fig. 2

As a result of his experiences with the latter three groups of cofferdams, Mr Ogilvie had demonstrated that the critical depth for excavation with one frame of struts at the surface was about 15 ft, irrespective of the depth of penetration of the piles below excavated level (which varied from 5 to 8 ft) and of the width of the cofferdams (which varied from 7 to $22\frac{1}{2}$ ft).

The critical stability number for this condition with one surface frame of struts in position may also be estimated on the basis of Skempton's shear strength measurements. The representative average shear strength of the soft clay for this case is about 390 lb/sq. ft and the unit weight about 103 lb/cu. ft. Hence the critical stability number:

$$\frac{\gamma H}{s} = \frac{103 \times 15}{390} = 4{\cdot}0$$

This value is precisely that estimated on the basis of the Bell equations by Skempton (1946), for the anchored sheet-pile wall in a deep bed of clay of constant strength and with which our case is strictly comparable. At this same stability number the Writer has pointed out (Ward, 1955), that there was a significant change in the distribution of loads in the struts of the deep Chicago Cofferdam Contract D-8 (Wu and Berman, 1953).

The practical value of these experiences may be stated in two rules as follows :—(*a*) In a deep deposit of normally consolidated clay the uppermost frame of struts should be placed across a cofferdam before the depth of excavation (H_1) reaches a value given by $H_1 = \frac{2s}{\gamma}$; and (*b*) the second frame of struts should be placed before the depth of excavation reaches a depth H_2 given by $H_2 = \frac{4s}{\gamma}$.

Both the above rules hold, irrespective of the length and strength of the piling. though on account of weak piling it may be necessary to insert frames of struts between (*a*) and (*b*). The use of rule (*b*) is no guarantee against bottom heave ; whether or not that occurs depends on the strength of the piling, its penetration, and on the uppermost strut being capable of taking tension.

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Yours faithfully,
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