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Flyash as Fill Material

Cendres Volantes Utilisées en Remblais

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SYNOPSIS At the Asnæs power station, the largest in Denmark based on coal, the flyash is placed hydraulically in basins surrounded by dykes of previously deposited flyash. In the years 1966-67, a 40,000 m³ steel tank for oil was erected on a bed of sand and gravel resting directly on about 5 m of this lagoon ash. In-situ and laboratory investigations are reported which proved that the flyash, in spite of being loosely deposited and having a large water content, has undergone a natural hardening process and therefore now has the properties with respect to bearing capacity and settlements that allow the use of shallow footings. Settlement observations were carried out.

On the basis of these results it was decided in 1978 to study the possibilities of using previously deposited lagoon ash as fill in a dam which was to carry a new coal conveyor for a large extension of the coal depot on a water-covered area at the power station. The length of the dam was about 400 m and its height 6 to 12 m, of which the height above water was about 3 m. According to the results of the investigations the dam could be constructed of excavated flyash. The paper also reports the experience gained during the period of construction, using end-tipping at full height.

1. General

In boilers for modern power stations, coal-dust stoking is used with the coal being ground to a very fine dust in grinding plants and blown into the furnace. Before the combustion products are let into the chimney, the solid particles of the smoke are withheld in filters which may be cyclone or electrostatic separators. This combustion product is called flyash.

At the Asnæs power station at Kalundborg, the largest in Denmark, this type of stoking is used. After separation the flyash is mixed with salt water from the inlet Kalundborg Fjord and then through pipelines led into sedimentation basins. With the nineteen seventies and the state of the oil market, the use of coal in the power stations has increased very much, and the amount of flyash, which is 12 to 14 pct. of that of the coal used, has now reached a considerable level. In 1975 in Denmark, about 250,000 tons were produced, and it is estimated that in 1980-81 the amount of flyash will have reached one million tons per year.

In the following two important building projects at the Asnæs power station are described, in which the waste product called flyash has had important uses. These projects are a 40,000 m³ oil tank in steel and a rather large dam across a water-covered area.

2. Foundation of oil tank

2.1 Project

In 1966 the Danish Geotechnical Institute was given an assignment from the consulting engineers A.J. Moe A/S, to cooperate in the prelimi-

nary investigations for the foundation of a 40,000 m³ fuel oil tank which the owner, the power station Isefjordværket I/S, required to be placed in an ash-sedimentation basin which was now dry. The ash had been deposited during a period of about 8 years, raising the ground level from about -0.8 to about +5.0 m.

2.2 Soil Conditions

Geotechnical borings with vane tests to determine the undrained shear strength c_u , showed very uniform soil conditions with the soil below level -0.8 being a heavily preconsolidated moraine clay with the following average properties:

	Above level -8.8	Below level -8.8
Water content, w (%)	12	11
Void ratio, e	0.32	0.30
Shear strength, c_u (kN/m ²)	310	610

The upmost about 0.5 m of the moraine, which had made up the sea bottom of the inlet, had a slightly larger water content of about 15 % and a slightly smaller strength of about 150 kN/m².

The flyash was markedly stratified in a mixture of regular flyash of the silt fraction and cinder material of the sand fraction. Average properties of the flyash are indicated as follows, with the extreme values in parenthesis.

Unit weight of grains (kN/m ³)	22.5 (20.8 -23.5)
Median grain size, d_{50} (mm)	0.046 (0.013-0.068)
Uniformity coefficient, $U = d_{60}/d_{10}$	7.0 (4.8 -9.8)
Void ratio, e	2.32 (1.68 -3.22)
Ignition loss, g_l (%)	18 (8 -32)

These values correspond to a water content of

103 % and a unit weight of 13.8 kN/m³ saturated material.

Thus the investigations confirmed the immediate impression of a very loose deposit.

It was, however, known already at that time that chemical reactions take place in flyash after the deposition, so that stable compounds are formed which are somewhat similar to cement. Tests on intact samples of the ash confirmed the occurrence of this process, as the hardening was observed partly as a preconsolidation, as determined by the Casagrande procedure, of 250 to 550 kN/m² in consolidation tests, and partly as an effective cohesion of 11 to 14 kN/m² (to be used together with a friction angle of 35° to 30°) in drained triaxial tests. This estimate was confirmed by load tests in a test pit on circular plates of 200 mm to 450 mm diameter - with one example shown in Fig. 1 -, and it was then decided to place the tank on shallow footings.

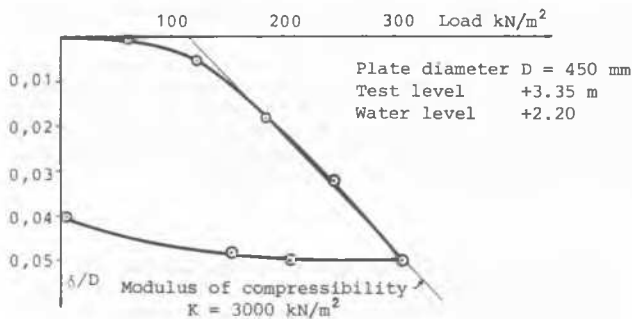


Fig.1: Plate loading test.

2.3 Foundation of tank

The foundation of the tank was carried out as shown in Fig. 2. The dimensions which were used were ample as compared with current Danish practice.

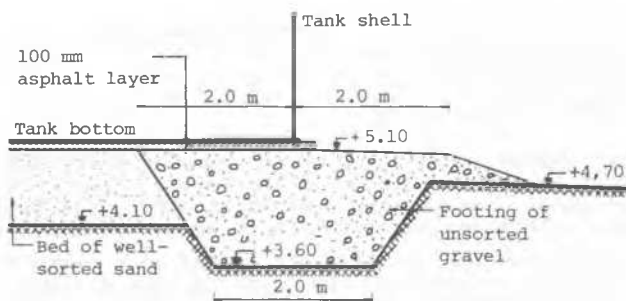


Fig.2: Foundation of tank on flyash.

For the sand bed, sand with a median grain size of about 0.3 mm was used. Standard Proctor tests were carried out and led to a requirement of a mean compaction of 98 %. For the gravel foot-

ing beneath the 16.0 m high shell of the tank, a median grain size of 3 to 5 mm was used and a mean compaction of 100 % was required.

2.4 Settlements of the tank

As a final control of the adequacy of the foundation, settlements were recorded during a water load testing, where settlements were to be completed in each load step before the subsequent load step. This happened in a few days per step.

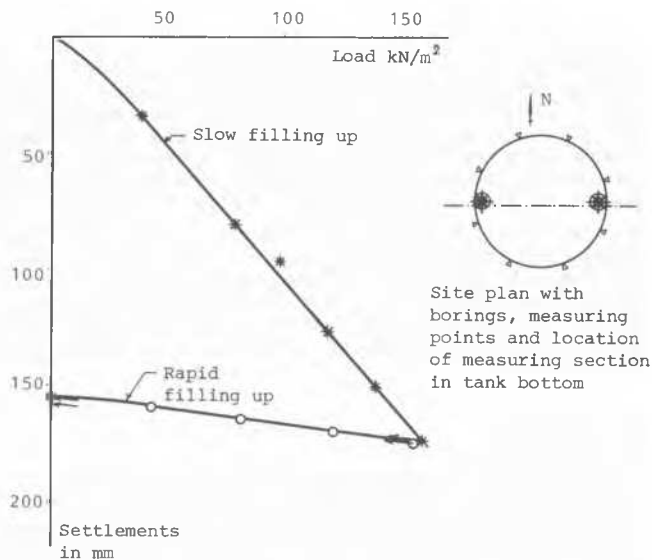


Fig.3: Settlements of tank shell.

The settlements of the tank shell were recorded at 8 points. It will appear from Fig. 3 that the mean settlement of the full tank amounted to 173 mm. Otherwise, the distribution of settlements was entirely plane between the values of 139 and 207 mm. By computations, strains in marine clay and gravel bed lead to a settlement of about 14 mm. The remaining 159 mm of mean settlement are therefore caused by the compression of flyash and correspond to a modulus of compression of 2100 kN/m².

Also the settlements of the tank bottom were measured. The results are shown in Fig. 4. The maximum settlement was about 380 mm and slightly more than was expected from the tank shell settlement at this point, which was about 200 mm.

The investigations were completed with a rapid filling up of the tank leading to an entirely unimportant increase of the tank shell mean settlement. The latter value was measured at about one year after the tank was taken into use at 184 mm, and about 8 years later it had increased to 200 mm.

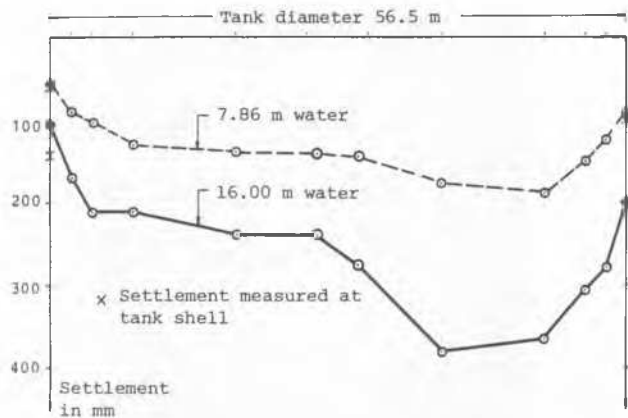


Fig. 4: Settlements of tank bottom.

3. The dam

3.1 Details of the project

To the west of the present coalyard of the Asnæs power station was situated a water-covered area of the inlet which was reclaimed in 1977-78. The water depth on this area was between 3 m and 9 m before construction activities started in 1974 for a large expansion of the power station. The dyke to the side of the inlet was constructed by sandfill placed hydraulically and by bulldozers. The under side of the dam was located at about level -13, after about 4 m of marine silt (mud) had been removed.

Use of the reclaimed area for sedimentation of ash was started in the middle of 1978 immediately after completion of the dyke. The sedimentation of flyash has now stopped at about level +2.2.

It is now intended to use this area as a coalyard. While the flyash was placed there, a dam was constructed across the sedimentation basin. This dam is to carry a conveyor belt as well as tracks for a stacker and reclaimer for transport of the coal in the yard.

The dam was completed in the beginning of 1980 and is placed as shown on Fig. 5 which also shows the original water depths. The dam consists of flyash which has been excavated in sedimentation basins east of the Asnæs power station. The upper width of the dam is to be 15.0 m at level +4.0. The main features of the dam section as designed are shown in Fig. 6.

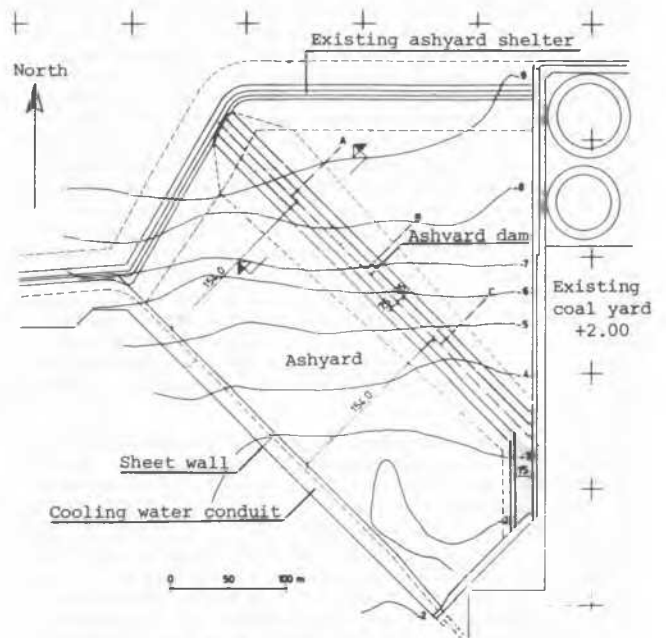


Fig. 5: Position of dam.

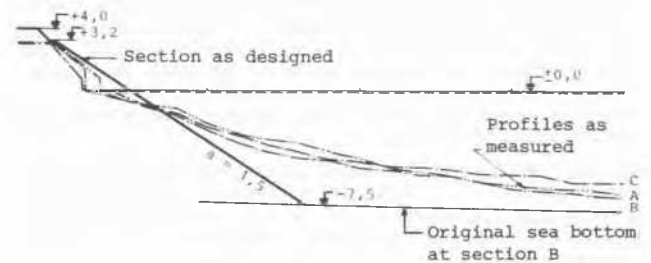


Fig. 6: Section of dam.

3.2 The fill

Before the above-mentioned dam was designed literature studies were carried out, as well as a large number of supplementary tests in-situ and in the laboratory. The investigations were carried out by the Danish Geotechnical Institute jointly with Messrs. Rambøll & Hannemann A/S (consulting engineers).

These investigations were, of course, started in the light of the positive results of the investigations carried out for the oil tank mentioned above. The particular purpose was to estimate the strength and deformation properties of flyash which after previous sedimentation is to be used as dam fill, particularly under water.

From the studies of literature on construction works using flyash as fill material it appeared that there were many papers on flyash which is placed in a dry state and then wetted and com-

pacted under ideal circumstances. In these cases flyash is reported to be placed on a dry formation. Few publications report on previously sedimented flyash being used as fill in a dam, and only in cases of well-drained basins where the water content in the sedimented ash was reduced to as low as about 20 %. Almost all the publications will mention the and the hardening in the sedimented ash which was also ascertained by the Institute in the investigations for the oil tank. The experience of the Institute on the use of previously sedimented flyash used as a fill material is limited to the embankments surrounding the above-mentioned oil tank. These embankments have been carried out above water level with slopes of 1:1.5, upper widths of about 3 m and a height of about 4 m. This cross section has ensured stable embankments for about 12 years.

Together with the supplementary investigations a test dam was constructed by previously sedimented flyash. In one of the existing basins a smaller basin of about 20 by 30 m, by a depth of about 3 m, was executed using a dragline excavator. The excavated ash was then placed in a test dam across the water-filled basin. In support of the estimate of possible increases in the strength of the dam material, dynamic soundings were carried out by Messrs. Rambøll & Hannemann. The results do seem to indicate a certain increase with time of the strength.

In the test dam, borings were carried out with tube sampling of intact fill material. Selected samples were used for classification tests. Also, on a number of samples both consolidation tests and triaxial tests were made. The latter tests - together with chemical analyses - showed that the chemical hardening which consists in hydroxides transforming into carbonates, was not nearly completed while the flyash stayed in the sedimentation basin.

On the basis of the laboratory tests which were carried out, the following classification parameters may be stated for the flyash in the sedimentation basins examined, with mean as well as extreme values.

Unit of weight of grains (kN/m ³)	22.9	(21.6 -24.9)
Median grain size, d_{50} (mm)	0.057	(0.032-0.150)
Uniformity coefficient, U	3.9	(1.1 -6.5)
Ignition loss, g_l (%)	9	(7 -12)

3.3 Construction

The dam as designed was constructed during the months from December 1978 to March 1979. The flyash was excavated from drained sedimentation basins east of the Asnæs power station, where it had been for some years (two to five years according to our information). The excavated flyash, which after the drainage was carried out had a water content of 30 % to 40 %, was transported in VOLVO dumpers (four in shuttle service, see Fig. 7) and finally placed by end-tipping. The photo also shows that flyash was still being sedimented while the dam was under construction.

The ash dam was constructed to its full height (i.e. about level +3.2) at once, and no compaction other than that caused by dumpers and bulldozers was used. At a few occasions it was necessary to reestablish and stabilize (e.g. with cinders or gravel) parts of the dam which were disturbed by the vehicles.



Fig.7: Construction of the dam.

The flyash was conveyed at a rate of 2000 m³ to 2500 m³ per working day, and the total volume used was about 150,000 m³.

The slopes of the dam were then reestablished above the water line, about 0.6 m gravel ballast was placed and compacted, and finally 0.2 to 0.3 m of gravel was added as a bed for the sleepers of the stacker-reclaimer tracks.

Soundings were made in three sections for the actual slope inclinations under water; the results appear from Fig. 6. They show a somewhat flatter slope than was assumed, but even so, the dam is fully acceptable, and it may be taken into account that the lowest about 2 m will probably consist of flyash which was sedimented on this location.

During control investigations four borings were carried through the height of the dam, and measurements in-situ of the void ratio were carried out in two test pits in the dam, at levels 0.2 m and 1.7 m respectively below the top of the dam. Laboratory tests show a mean void ratio for all intact tube samples taken of $e=1.45$ (variations are from 0.79 to 2.16); this is in reasonable agreement with the test dam's mean void ratio of $e=1.66$ (1.00 to 2.30). In-situ void ratios above water level indicate $e=1.16$ (0.88 to 1.31) and $w=33.6$ % (19.5 % to 46.4 %). Therefore, in this part of the dam there is a clear compaction effect from the traffic of dozers and dumpers. Also in this place oedometer tests confirm that the chemical hardening is not completed.

Remaining investigations, from autumn 1980 and onwards, include settlement estimates for the stacker-reclaimer track and measurements of dam

settlements in the years to come.

4. Conclusion

According to experience from the oil tank, undisturbed lagoon ash can be used to carry a construction of this type. It should be stressed, though, that the ash proved to be less hardened than was expected from the preliminary investigations, and that it will in any case give much larger settlements than would for instance hydraulically placed sand. Furthermore, the quality of the ash is indubitably dependent on the hardening process which will again depend on, for instance, the origin of the coal and the combustion. Therefore, flyash sedimented as lagoon ash is not a well-defined material.

It is known that flyash which is taken directly from the separators, can be used as fill in road dams and behind retaining walls if water is added and proper compaction is carried out. Experience from the embankments of the ash yards shows that also lagoon ash can be used in this way. It is, however, more interesting to note the successful use in constructing a stable ash fill dam with a reasonable cross section on a water-covered area, and the ensuing possibility of placing constructions on this dam, provided they are not too sensitive to settlements. Settlement observations are not yet available, but there are indications that the potentiality for hardening is not significantly reduced by the rebedding of the lagoon ash.

LITERATURE

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