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DISCUSSION

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## Downdrag on Bitumen Coated Piles[a]

Discussion by Bengt H. Fellenius,[4] M. ASCE

The writer has studied the paper by Baligh, Vivatrat, and Figi and offers a few related results and some criticism. The authors describe in Appendix I results from creep tests on bitumen coated steel plates in contact with a granular soil. About 10 yr ago, the writer carried out similar laboratory tests using strips of clay sheared against concrete blocks (29). The shear reducing effect of a thin bitumen coat on the concrete was studied and compared to the results when no clay was used (i.e., bitumen sandwiched between the concrete block and a dummy "clay" strip made of concrete).

The clay strips were 157 mm (6.2 in.) in length, 45 mm (1.8 in.) in width, and 5 mm (0.2 in.), thick, carefully trimmed from undisturbed piston samples

[a]November, 1978, by Mohsen M. Baligh, Vitoon Vivatrat, and Heinrich Figi (Proc. Paper 14141).

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obtained from the Backebol test field in Southwestern Sweden at a depth of 20 m (65 ft).

The properties of the clay are summarized as follows: (1) Undrained shear strength—0.36 kg/cm$^2$; (2) sensitivity—15; (3) natural water content—80%; (4) liquid limit—75%; (5) plastic limit—34%; (6) amount of particles smaller than 0.002 mm—72%; (7) organic content—6%; and (8) preconsolidation pressure—1.24 kg/cm$^2$.

The concrete blocks were made from ordinary ready-mix concrete and cast against a machined steel plate to ensure a plane and smooth finish. The bitumen, penetration 120, was carefully heated and brushed onto the concrete aiming to a thickness of 1.0 mm (0.04 in.). The thickness was measured after cooling and found to vary by 0.1 mm over the concrete surface and by 0.4 mm between different tests.

All the testing was carried out in a temperature controlled room at a temperature of 4° C. The test apparatus, the trimming method, the assembly of the test, and the test procedure are described in a report by the Swedish Geotechnical Institute (29).

The four shearing tests presented in this discussion were carried out as follows: (1) Shearing the clay strip directly on the concrete block; (2) shearing the clay strip on the concrete block coated with a 1-mm layer of bitumen; (3) shearing a dummy "clay" strip made of concrete on the concrete block coated with the bitumen; and (4) basically a repeat of No. 3.

The test apparatus was placed so that the shearing surfaces were horizontal. The test specimen was first subjected to a vertical force of 1.24 kg/cm$^2$ (Test No. 4 had a force of 0.42 kg/cm$^2$, only). This force gave a small vertical deformation. Twenty-four hours later, the apparatus was locked so that no further vertical deformation could occur (constant volume test) and a constant shear velocity was applied. The shear force developing as a result of the induced strain was measured. Three different velocities were applied. The lowest velocity was 0.01 mm/hr (shear strain rate of about $3 \times 10^{-8}$ sec$^{-1}$). Therefore, a relative movement of 10 mm required 40 days of testing.

The results of the four tests are shown in Fig. 4 giving the induced shear stresses as a function of the applied rates of strain. The plot of data from test No. 1 shows that the shear stress in the clay was basically uninfluenced by the strain rate. A shear stress of 0.45 kg/cm$^2$–0.50 kg/cm$^2$ (920 psf–1,020 psf) developed, which is higher than the original undrained shear strength of 0.36 kg/cm$^2$ (740 psf). However, the two values are not compatible. Test No. 1 served as a reference to test No. 2, having the bitumen layer placed between the clay and the concrete. A comparison of the two curves indicates that the bitumen coat reduced the induced shear stresses considerably, in particular at the lowest rate of strain, where the reduction was about 90%. As evidenced by the results of Test Nos. 3 and 4, the shear took place in the bitumen layer and it was the bitumen that governed the shear stress values, despite the soft and sensitive highly plastic clay that was used.

Test Nos. 2, 3, and 4 all show that the induced stress, $\tau$, about doubled, when the rate of strain $\dot{\gamma}$ increased by an order of magnitude. Mathematically, this relation is expressed as

$$\tau = \text{constant}\ 2^{\log \dot{\gamma}} \qquad (12)$$

However, the number of tests is too limited for this relation to have much practical significance.

The results are plotted in a lin-log scale, which the writer considers to give the best visual picture, when comparing the curves with each other. A log-log scale indicates easily a too high degree of precision and could lead to erroneous extrapolations not warranted by the data. However, for purposes of comparison with the authors' Fig. 2, the results have also been plotted in log-log scale in Fig. 5. The bitumen parameters "$m$" and "$n$" evaluated from a mean straight line are 0.16 and 0.36, respectively.

The test results published by the authors, the writer, and others, particularly field test results as referenced by the authors, indicate that bitumen coating is very efficient in reducing skin friction on piles. However, the authors' and the writer's laboratory tests provide mainly qualitative information, only. The

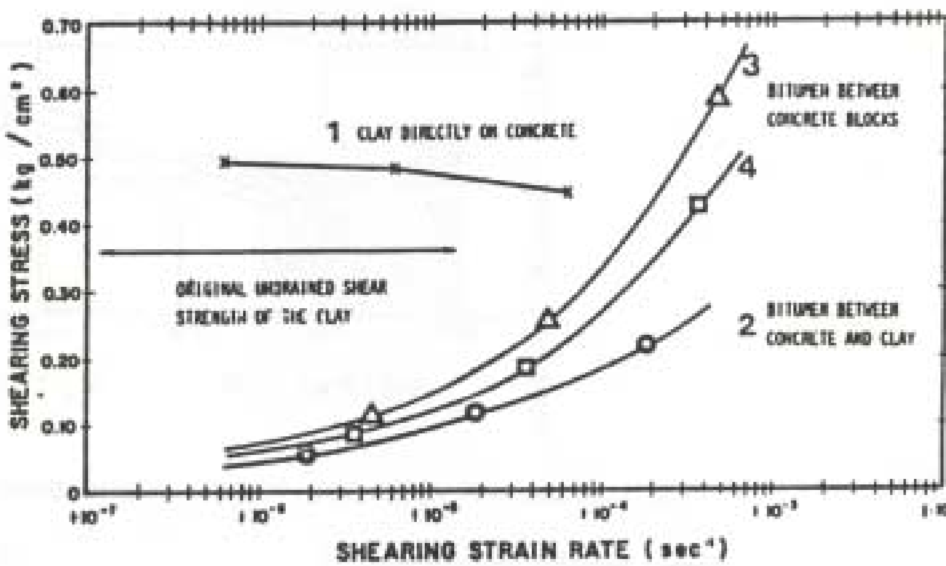


FIG. 4.—Induced Shear Stress as Function of Shear Strain Rate (Lin-Log Scale)

quantitative value of the information for use in practical design work is limited. In practice, the average settlement rates are often about 0.1 m/yr. Even when using bitumen coats of 1 mm–2 mm, which also is advisable for practical reasons, the shearing strain rate is on the order of magnitude of $1 \times 10^{-8}$ sec$^{-1}$. That is to say that the actual strain rates encountered in practice are about 100 times smaller than those studied by the authors and the writer.

Until test results are available from tests with strain rates in the range of $1 \times 10^{-8}$–$1 \times 10^{-7}$, which would be extremely time consuming to run, the writer has taken the approach in practical design to, either rely on actual field tests if justified by time and economical considerations, or to use the conservative assumption that a properly applied bitumen coat can reduce the negative skin friction to a value of about 0.1 kg/cm$^2$ (200 psf). This value will in most cases give an adequate reduction of the drag load and allow a rational treatment of the problem in the pile load design.

The most difficult problem associated with coating piles with bitumen is not really the choice of bitumen type, nor of determining the thickness of the bitumen layer, but the practical difficulties in getting it onto the pile in a layer sufficiently thin, yet not too thin, making it stay on the pile in storage considering cold and wet weather as well as hot and sunny weather, and preventing it from peeling off or being scraped off during driving, etc., while trying to avoid cost excalations and contractor claims that only too easily appear in piling projects involving bitumen coated piles. Recently, an excellent paper was published discussing practical problems in connection with the coating of piles in a hot climate (28).

The writer takes issue with the design example given by the authors. Understandably, the authors have wanted to illustrate their approach to the design calculations. However, in the writer's opinion, the chosen example is oversimplified and could lead less experienced designers to choose an unnecessarily costly

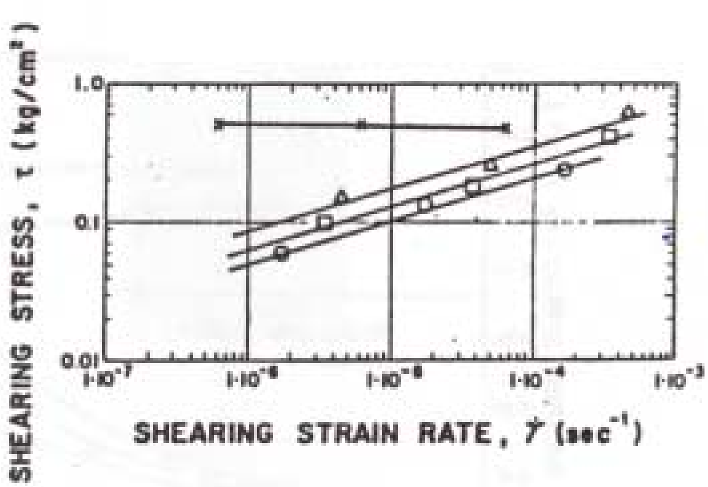


**FIG. 5.—Induced Shear Stress as Function of Shear Strain Rate (Log-Log Scale)**

design solution to their drag load problem. The "1 ft diameter concrete-filled pipe piles driven to bedrock" are probably 12.75-in. closed-end pipe piles filled with concrete after the driving. With the soil conditions described by the authors and an adequate choice of wall thickness and driving procedure, these piles can be allowed to carry both the structural load of 70 tons and the drag load of 56 tons without using bitumen or any other method to reduce the drag load.

Appendix.—References

28. Clemente F. M., 1979, "Downdrag. A Comparative Study of Bitumen Coated and Uncoated Prestressed Piles," *Proceedings*, Associated Pipe and Fittings 7th Pile Talk Seminar, New York, N.Y., pp. 49–71.

29. Fellenius, B. H., 1970, "Study of Shear Forces in Clay during Slow Rate of Deformation," *Grant No. C 230*, Report to BFR, Swedish Geotechnical Institute, Nat. Sw. Build. Res., (in Swedish).