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DISCUSSION

REDUCING NEGATIVE SKIN FRICTION WITH BITUMEN SLIP LAYERS[a]

Discussion by Bengt H. Fellenius,[3] M. ASCE

Need for Reduction of Negative Skin Friction.—The authors' first requirement for a bitumen coat on a pile is that "the settlement of the soil must only result in a slight load on the pile." In the section on the desired properties of bitumen and later in the section on application with foundation of plants at Moerdijk site, the authors indicate that the acceptable "slight load" is 1.1×10^4 lbf (48 kN), i.e., 5.5 short tons.

The authors' example pile has a width of 20 in. × 20 in. (51 mm × 51 mm) a length of 130 ft (40 m). The mass of this pile is 26 short tons, i.e., almost five times greater than the drag load. Compared to this, the acceptance limit of the drag load is slight indeed.

The authors state that for the piles at the Moerdijk site, negative skin friction would occur in an upper layer of 16 ft to 20 ft (4.9 m to 6 m) of fill, clay, and peat. However, the authors do not mention the magnitude of the drag load, which would be obtained in this layer and which warranted the necessity of coating the piles. The writer feels that the case could be marginal and would like the authors to present the basis for the decision to eliminate the negative skin friction. Also, a discussion on alternative solutions would be of interest, e.g., increase of pile length to achieve an increase of bearing capacity or preboring through the upper 20-ft (6-m) layer.

The reduction of negative skin friction by means of a bitumen coat is reasonably simple. However, the cost of it is still on the order of 10% to 20% of the cost of the pile foundation, as mentioned by the authors, which is not negligible cost increase. Therefore, in each design case, a study of the necessity for the reduction of the negative skin friction to an acceptable level is needed including a cost comparison with alternative methods.

Often designers, who have established an allowable structural pile load as regulated in the various building codes, when aware of the existence of negative skin friction, simply substract the drag load from the allowable load. However, the code criteria for calculating allowable pile load generally are specified with some general consideration to tolerance of actual mispositioning of the piles, variations of the calculated structural pile loads, variations of deformation

[a]August, 1974, by Alphonus I. M. Claessen and Endre Horvat (Proc. Paper 10764).

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properties of the piles, past experience (with or without consideration of negative skin friction), and other miscellaneous factors. Normally, all of these somewhat unknown factors are supposed to be taken care of in a conservative factor of safety. Present state-of-the-art allows the engineer to better estimate the expected drag loads than was possible a few years ago. Using this new knowledge to simply substract the drag load from the allowable load to an extent would be to consider it twice: (1) Indirectly in the safety factor; and (2) again mathematically. Instead, the writer recommends that the better knowledge of the soil conditions, which in the first place made the engineer aware of the negative skin friction (and at the same time of other factors influencing the piles), should be used to evaluate the pile capacity from a soil mechanical point of view. One such method of design evaluation is presented and discussed by Fellenius (12). The principle of this method is that the *maximum* allowable load on the pile from the superstructure is stipulated by the existing practice and the pertinent building code, and measures to reduce or counteract the negative skin friction will be necessary only if a thorough soil mechanical study and structure analysis show that the otherwise allowed maximum load is too large.

Thickness of Bitumen Layer and Type of Bitumen.—The authors make reference to a paper by Bjerrum, et al. (1) who used a 0.04-in. (1 mm) layer of bitumen type penetration 80/100 to reduce negative skin friction. However, by mentioning that special measures were required to prevent this bitumen layer from being scraped off during driving and then recommending a layer of minimum 0.4 in. (10 mm), the authors infer that the thin layer is generally less suitable. In fact, the piles reported by Bjerrum, et al. were driven through an upper layer of granular soil that would have scraped off also a thicker bitumen coat. The thin coat proved to reduce the negative skin friction by more than 90%.

Walker and Darvall (13) present another case where a 0.06-in. (1.5-mm) thick bitumen coat of bitumen type 60/70 penetration virtually eliminated the drag load.

Thus, the writer concludes that unless the soil and settlement conditions are extreme, there is no need for the thick coat recommended by the authors, particularly if a bitumen softer than the one (penetration 40/50) recommended by them is used. Apart from requiring less volume of bitumen, a thin coat approx 1 mm to 2 mm thick is less likely to flow in storage and to peel off during driving.

Furthermore, from a practical point of view, it is of little significance whether approx 95% of the negative skin friction is eliminated or, e.g., only approx 80%. Thus, ordinary bitumen available in the market would suffice. The writer recommends the use of a bitumen of type penetration 85/100 specified in American Society for Testing and Materials D-946 to be applied to a thickness of 1 mm to 2 mm. This bitumen can be applied by brushing or by sprinkling (in the plant or in the field) after being heated to a liquid state, that is 350° F (175° C).

In the case of precast piles, a primer could be needed to achieve the proper adherence to the pile. The cheapest primer is obtained by dissolving the bitumen in ordinary gasoline to a liquid state and then to paint the pile surface with this solution.

Often, and particularly during cold weather conditions, the handling and application of hot bitumen is difficult and costly. Therefore, on occasions it may be necessary to mix the bitumen with a solvent, softening the bitumen

enough to limit the necessary heating to approx 170° F (75° C). However, the liquid bitumen must be able to cure rapidly to its original consistency to ensure that the coat stays on the pile in storage and during installation in the ground. In commercial terms such bitumen is denoted "RC, cut-back bitumen."

Appendix.—References

12. Fellenius, B. H., "Down-Drag on Piles in Clay due to Negative Skin Friction," *Canadian Geotechnical Journal*, Vol. 9, No. 4, Toronto, Ontario, Canada, 1972, pp. 323–337.
13. Walker, L. K., and Darvall, P., "Drag-Down on Coated and Uncoated Piles," *Proceedings*, 8th International Conference on Soil Mechanics and Foundations Engineering, Vol. 21, Moscow, U.S.S.R., 1973, pp. 257–262.