Studies of Frost Problems in a Northern State

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The paper reviewed the history in one state, namely Minnesota, of frost studies on highways, design of highways for frost conditions, and research studies which have been made at a university. The intent of the presentation was thus to give examples of attacks which are being made on frost problems without trying to cover the very broad subject of frost studies in the entire country. The information and most of the slides used were drawn from papers previously published.

The paper reviewed information on the winter climate in the United States and the manner of making soil surveys and designs for frost treatments in Minnesota *(Ref. 1)*. The findings of the Highway Research Board Committee on Load-Carrying Capacity of Roads as Affected by Frost Action concerning the loss of strength during the frost melt period were described, and the design thickness of flexible pavements in Minnesota was shown to indicate requirements in a frost area *(Ref. 2)*.

The laboratory studies for determination of thermal properties of soils made in Minnesota were described in some detail *(Ref. 3)*. Methods for calculating frost penetration in highways *(Ref. 4)* and field measurements for comparison with calculations made in Minnesota, were presented. *(Refs. 5, 6)*.

It was the intent of the paper to present short description of several phases of frost problems, and thus to suggest a variety of questions in the discussion. This was accomplished at the two seminars at which the paper and slides were presented.

REFERENCES

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4. University of Minnesota, Bulletin 128. "Thermal Properties of Soils."
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Soil Stabilization

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At the seminars at Moscow and at Kiev, the writer gave a short description of some of the recent research conducted at the Massachusetts Institute of Technology on additives to improve the properties of soil. Presented were the results of work on additives to modify the frost susceptibility of soils and on additives to increase the effectiveness of portland cement as a primary stabilizer.

On the basis of laboratory tests the most promising additives for the modification of the frost heaving characteristics of soils were ferric chloride (an aggregant) and the polyphosphates (dispersants). A group of 11 dirty gravels were treated with 0.3 per

cent of tetrasodium pyrophosphate and subjected to controlled laboratory freezing tests. The results of the tests showed that the phosphate reduced the rate of frost heave for all 11 gravels. The minimum reduction was to half of the untreated value, the maximum to essentially zero, and the average reduction was to 0.2 of the untreated value.

The material on frost additives presented at Moscow and Kiev came from a paper, "Modification of Frost-Heaving of Soils with Additives," by the writer published in Bulletin No. 135 of the Highway Research Board.

Research on the use of chemical additives to reduce the effectiveness of portland cement as a soil stabilizer was described. In general, the tests showed that, with virtually all soils studied, cement stabilization can be substantially improved (two to 10 fold) by the incorporation of relatively small quantities of sodium compounds which form insoluble compounds with calcium. The most beneficial additives were caustic soda, soda ash, sodium sulphite, sodium sulphate, sodium metasilicate and sodium aluminate. Optimum additive concentration was found to correspond very nearly to a sodium ion concentration in the molding water of 1.0 normal, i.e., between 0.5 and 2.5 per cent of the soil dry weight, depending upon soil and additive.

The soil cement work described in the Soviet Union came from two papers by the author (and associates) presented before the Highway Research Board Annual Meetings of 1957 and 1959.

SOIL STRUCTURE

In answer to requests by the Soviet soil engineers, the writer gave extemporary talks on soil structure at Kiev and at Leningrad. The nature of electrical and externally applied forces transmitted between adjacent soil particles was discussed. The variation of these forces with environmental conditions was next considered. Shear strength as dependent upon environmental factors and applied pressures was finally discussed.

Much of the material came from the writer's two papers on soil structure published in the May 1958 Journal of the Soil Mechanics and Foundation Engineering Division of the American Society of Civil Engineers.

Analysis and Design of Concrete Slabs on Ground

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Conventional methods of analysis (utilizing Winkler's assumption, or an elastic half-space) were reviewed briefly. Reference was made to observations that for lightly loaded slabs (homes), or where the loads are temporary (pavements, industrial slabs on ground), warping caused by moisture and temperature gradients was sufficient to leave a portion of the slab entirely unsupported.

A new theory *(Ref. 1)* was outlined for calculating stresses and deflections in partly supported slabs of finite size. The significance of this theory in the analysis of concrete pavements was treated *(Ref. 2)*. Finally, the results of full-scale measurements *(Ref. 3)* for both upward and downward warping that confirms the validity of the new theory were presented.

REFERENCES

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