NEEDED RESEARCH PERTAINING TO FROST ACTION AND RELATED PHENOMENA

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The Committee on Frost Heave and Frost Action in Soil is operating under a long-range plan consisting of three main steps. The first is to summarize the available knowledge on the subject. That consists in reviewing and summarizing the published literature on frost action and related phenomena, and in keeping abreast with current developments. The review of published literature has been completed, and is ready for publication this year. This symposium is the result of the committee's efforts to learn of current developments which result from investigations and experience. The second step is to analyze the available knowledge in the light of recurring damage which may be attributed to frost action and state the phases on which information is lacking or on which available information may not be reliable. This will then be followed by the third step which will consist in planning, in some detail, the investigations which can be expected to help fill in present gaps in knowledge or verify that which is believed to be unreliable. The three steps are believed to constitute a sound and orderly approach toward increasing the knowledge of the effects of frost action so that knowledge can be put to the best use.

The highway problems associated with frost action, like the phenomenon itself are not simple ones. The elements of climate, soil, soil water, pavement, and traffic individually and collectively, are factors which determine just how detrimental frost action can be. The overall problem involves proper road maintenance; regulation of loads on existing roads during and following the frost-melting period; and design to prevent detrimental action in new roads. Any action resulting from freezing or thawing of the base or subgrade which stresses the road surface, base or subgrade, changes the water content, porosity or structure of the base or subgrade, or changes their capacity to support loads is within the scope of the problem. Thus it includes both the primary effects of freezing as well as the secondary effects of thawing road foundations.

The complexity of the problem and the probable involvements of investigations needed make it impossible to state all the details in need of study. Some of the more important gaps in present knowledge are listed here.

A statement of needed research can be divided into four parts. First, there is need for a better understanding of the extent and nature of damage caused by frost action. Second, there is need for more precise information on the technological aspects of the process of freezing and thawing and of the influence of the elements which are involved in the process. Third, in order here but of prime importance, is the development of means for predicting the load-carrying capacity of existing pavements and their foundations and protecting them from load damage during the frost-melting period. Fourth, and this is the ultimate goal of frost studies is the inclusion in designs for new roads, means for minimizing the detrimental effect of freezing and thawing of road foundations.

Extent and Nature of Damage Due to Frost Action

The reports of damage to pavements and small structures due to frost action indicate that only a few of those reports are based on a comprehensive appraisal of the extent of the damage. There is need for more specific information on the following items: (1) The extent of damage geographically so that the damage can be related to traffic, pavement designs or soils or geologic parent materials on an area basis; (2) The nature of the damage, its severity and whether the damage can be attributed justly to frost action; and (3) The frequency at which the different degrees of damage reoccur.

Freeze damage has a habit of differing from year to year, little or no damage occurring some years while severe damage occurs at other times. That habit tends to over emphasize frost effects at one time and underemphasize it at other times. A persistent annual appraisal of road conditions should indicate not only the extent and degree of damage but should show those areas which are most susceptible to damage.

The records could then make possible a better correlation with climatic conditions which set the stage for the damage. When correlated among the states they could help define the limits of soil or geologic regions most susceptible to detrimental frost action.

Data on freeze damage can be obtained by means of extensive condition surveys by trained crews. A good appraisal of frost damage can also be made by maintenance supervisory personnel as a regular and routine duty if each is trained to detect the telltale evidence of frost effects, and, if a systematic effort is made to obtain the desired information.

Observations on the Fundamentals of Frost Action

Without doubt some progress could be made in designing for protection against frost action by cut and try methods. However, an understanding of the basic processes of soil freezing and thawing, how they affect load-carrying capacity, and an understanding of the factors which influence frost action should speed the progress.

Perhaps there are more unanswered questions concerning the role of soil moisture in frost action than for other factors which influence it. There is a need for an explanation of the accumulation of moisture directly under the pavement or in the upper part of subgrades. Is it the result of movements due to temperature differences? Or is it solely to the "suction" from below as water is being drawn into growing ice crystals? How much is attributed to surface infiltration at pavement edges? Are surfaces sufficiently permeable to permit entrance by that means?

There is no doubt that water accumulates when the soil freezes and causes a reduction in bearing capacity when the water is released suddenly on thawing. However, there is some lack of agreement on whether or not the small increases in soil moisture sometimes observed can account for the large reductions in bearing capacity. Is the reduction in bearing capacity caused substantially by increase in porosity or is it caused largely by the released water being in a "more free state" than it was prior to freezing? What is the nature of the distribution of the melt water which accompanies a regain in bearing capacity? What is the real effect of the water table on the movement of water? Is it necessary to have ice lens formation to segregate enough water to cause critical reduction in bearing capacity or can that result from development of ice crystals not segregated into lenses?

Those questions may appear academic, yet if answered adequately they could point the way to betterment of designs. They do point to one practical question which is not yet satisfactorily answered. That is, what minimum moisture contents cause detrimental reduction in bearing capacity on freezing and thawing of various soils?

A large proportion of past studies of frost effects has attempted to relate the nature of the soil, that is, the grain size and grading, to the effect of freezing. It is now generally accepted that free draining soils do not permit the occurrence of detrimental differential frost heave. However, granular soils do suffer a reduction in load carrying capacity following thawing. Much work has been done to relate the fraction finer than the No. 200 sieve and the fraction finer than 0.02 mm. diameter to susceptibility of soils to damage by frost. The results obtained to date are useful but are not yet adequate. The proportion of fines does not alone govern the stability of granular base materials. More needs to be known concerning the nature of the fines as well as the amount. Also, more needs to be known concerning the effects of grading in the sand fraction and the coarse aggregate fraction for it affects not only the heave but also the bearing capacity.

The influence of climate in bringing about detrimental frost action has long been recognized. It has been accepted generally that wet fall seasons followed by severe winters cause serious heaving and spring breakup. More recently it has been brought out that spring breakup has occurred in areas where cold winters do not occur and that damage does not necessarily depend on the severity of the winter cold but rather on the nature of the temperature fluctuations and moisture conditions as they are related to traffic.

There is need for knowledge of the effect of cycles of freezing and thawing, rate of

frost penetration, and rate of thawing, particularly for areas where light freezing is followed by a reduction in bearing capacity on thawing. A study of climatic conditions with respect to reduction in bearing capacity could well be extended over a period which would include spring seasons showing a wide range of frost damage. Data on maximum and average depths of frost penetration are not yet completely reliable. Also, the thermal properties of soils need to be studied in connection with climate to determine whether or not those thermal properties will markedly affect designs.

Protection from Damage Following Frost-Melting Period

Investigations have been made by several state highway departments and one federal agency to measure the reduction in load carrying capacity of pavements from the so-called normal period in summer and early fall to the frost-melting period. That has been done by plate bearing tests, penetration tests, and accelerated traffic tests. Those efforts have been directed towards determining the traffic which different types and thicknesses of pavement will carry during the critical period. There is lack of agreement as to the adequacy of a plate bearing test as now used in measuring the reduction in bearing capacity of flexible pavements. That is believed to be due to the slow loading of the plates, allowing some buildup of strength in the pavement foundation, and its inability to evaluate the effect of repeated loadings in disturbing the soil. Methods of measuring the load-carrying capacity of pavements needs further study.

Efforts should be made to use data on traffic and relate them with pavement performance during the critical period. That is true also in determining interrelationships between traffic and climate.

Many existing roads will deteriorate rapidly if maximum legal loadings are permitted to operate during the critical period. The problem of determining the most satisfactory basis for setting up adequate local load restrictions is in need of study. How should those restrictions be specified to be most effective in preventing damage to existing roads? The measurement of load-bearing capacity of pavements is being carried on by the Committee on Load Carrying Capacity of Roads as Affected by Frost Action. The work and its need are mentioned here to bring out the interrelationships of parts of the frost problem.

Designs to Prevent Damage to New Roads

Development of information on the items suggested will make possible a better understanding of the basic laws which govern frost action and of the various elements which influence the magnitude, severity or rate at which the different phases of frost action take place. That is essential if designs are to be improved.

Engineers are now well acquainted with severe differential frost heave and can predict with reasonable accuracy where such heaves will occur. Also they can set up designs including drainage, excavation and replacement or other means to prevent detrimental heaving. The problem then is, in the main, one of designing to prevent detrimental reduction in load-carrying capacity of roads.

The quality of base and subgrade materials as determined by its composition, grain size and grading characteristics, and its susceptibility to breaking down (degradation) during construction or weathering in service and its relation to frost action have been mentioned. There remains the problem of determining the appropriate cross section design for the road. Here is need for methods of design for determining the thickness and width of base for specific soil and traffic conditions. Many organizations how have design methods which take into account frost conditions. However, there are few, if any, who feel their methods cannot be improved.

Difference in the degree of spring breakup damage brings out the question of economics of pavement design. Should designs be made with sufficient factors of safety that they are adequate to prevent spring season damage under the severe conditions which might happen at intervals of from 3 or 4 to 10 or 15 years or should they be designed on the premise that load restrictions will be imposed to prevent damage at those times?

What should be the relative difference in the factors of safety for a lightly traveled secondary highway compared to that of a trunk highway?

There continues to be a difference in opinion as to the efficiency of full width bases compared to bases slightly wider than pavement surfaces. The types of materials best suited for each and the conditions where each is most effective deserve study. There have been too few field investigations to determine the shape of the frost layer as affected by pavement type, snow removal and storage practices, and climatic conditions. The practicability of drainage of bases with relation to their permeability and cross section designs is questioned by some engineers. This is in need of clarification.

Summary

Advances and improvements beyond the present state may be slow but they will be brought about most quickly by an orderly program of study. As soon as the review of literature and this symposium are available to all, there should follow a critical analysis of available information. There can then follow the preparation of a set of recommended practices adaptable to local conditions. Concurrently there can be prepared outlines of investigations pointed toward filling gaps in present knowledge. These can be done best by coordinated efforts of all who wish to participate in the studies. The staff of the Highway Research Board will continue to work with the committee in these activities.