After the thaw the surface of this road returned to normal level with very little permanent damage. Traffic was not restricted during the thaw.

Measures Taken to Minimize Frost Damage

The type of frost damage which affects the surfacing only can largely be avoided by cooperation between the research worker and the engineer responsible for the road construction. Research in progress at the Road Research Laboratory into the laying and compaction of dry concrete mixes and into the stripping of the aggregates used in bituminous carpets should go a long way towards the prevention of purely surfacing damage. Research is also being undertaken into the stability of base materials, particularly low cost materials such as brick rubble and colliery shale.

The problem of frost heave, is however, a more difficult matter. In the case of new roads constructed on chalk subgrades, attention is now generally being paid to the frost question, and the depth of possible frost penetration is accepted as the design criterion rather than the normal high strength of the subgrade. The comparatively rare occurrence of serious frost in Great Britain precludes on economic grounds either the wholesale reconstruction of existing roads known to be affected by frost heave, or the construction of new roads, other than those falling in the Trunk and Class 1 categories, to completely non-frost susceptible standards. During the last few years, however, the counties and other authorities responsible for road construction and maintenance have become increasingly conscious of the frost problem. As soon as the thaw sets in after a bad frost, affected roads are, as far as possible, closed to traffic until subgrade moisture conditions have returned more nearly to normal. This frequently prevents any extensive breakup of the surface. It is usual too for authorities to keep plans of their areas on which stretches of road susceptible to frost heave are marked. In this way the lengths most liable to give trouble are located and the economies of remedial measures can be considered in relation to these sections only.

Acknowledgement

The work described in this paper was carried out at the Road Research Laboratory of the Department of Scientific and Industrial Research. The paper is submitted by permission of the Director of Road Research.

LOAD CARRYING CAPACITY OF ROADS AS AFFECTED BY FROST ACTION

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For a number of years, highway engineers have known that a general weakening of the road structure occurs during and after the spring thaw. This loss in supporting value manifests itself in two forms the most obvious of which is the notorious "frost boil" where complete breakdown of the pavement structure results in sections of the road becoming impassible or practically so. The soil conditions causing this type of failure are readily identifiable as to soil types and proper corrective treatments made during grading operations will eliminate their occurrence.

The correction of these localized failures, however, has not eliminated the less spectacular, but still serious progressive failure which accumulates over a period of years. This is the reduction in load-carrying ability of the road structure resulting from the detrimental effect of frost action. Field observations have consistently shown that the weakening occurs during and two or three months following the spring thaws. Recognition of this phenomenon has led to the practice in Minnesota of restricting axle loads to values below the legal 9-ton axle load limit on all types of pavement structure, excepting concrete pavements. In Minnesota the degree of restriction has, in the past, been based on the considered opinion of the District Maintenance

Engineer arrived at by observations of performance of each road in question. This program has proven quite effective in the reduction of road damage which would otherwise result during and following the spring thaw. Maintenance repair costs have been reduced proportionately.

However, it was recognized that the load restrictions adopted in this practice were not always consistent with the actual load-carrying capacity of the road. The amount of loss in load-carrying ability was not known, nor was it known whether such losses occurred in all soil types and all classes of pavement structure design. In 1946 a field-testing program was initiated in Minnesota in an attempt to evaluate the losses using "full-scale" plate field bearing tests employing loads and bearing contact areas

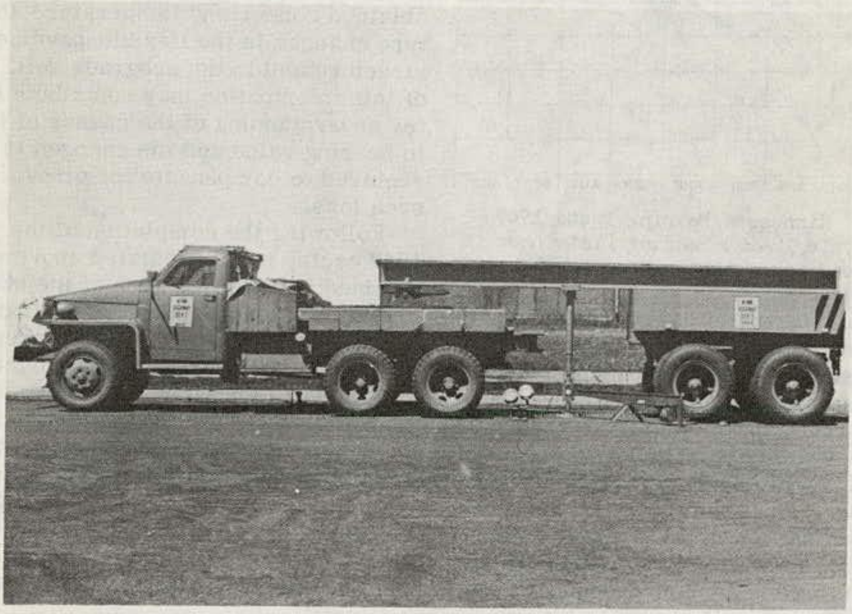

Figure 1.

approximating those of actual traffic. Figure 1 illustrates the present equipment.

The first cycle of tests consisted of a series of tests in the fall of 1946 and during the spring of 1947. These were exploratory in nature and covered a number of projects. The results indicated that a measurable loss in load-carrying capacity of roads did occur during and after the spring thaw. This loss was very nearly fifty percent of the fall bearing values, the latter being the optimum condition for load-carrying capacity.

As a result of these preliminary tests, a Committee on Load Carrying Capacity of Roads as Affected by Frost Action, Project Committee No. 7 of the Department of Maintenance, was established by the Highway Research Board. The assigned objective of the committee was the determination of the loss in carrying capacity of completed roads, road bases, subbases and subgrades during the spring of the year because of frost action and the determination of subsequent recovery. It is the aim to determine, as well as possible, the percentage loss in road strength and not to determine proper design values, although such may to some extent be a by-product of the study. A number of states are actively participating in the study and interesting information is being obtained. The reader is referred to the reports of the committee, of which two have already been published, for the more detailed data being obtained. The following describes briefly some of the results obtained in the Minnesota tests.

The program of investigation in Minnesota has followed the plan to accomplish the committee's objective while at the same time attempting to obtain information bearing on the cause or causes of the weakening action.

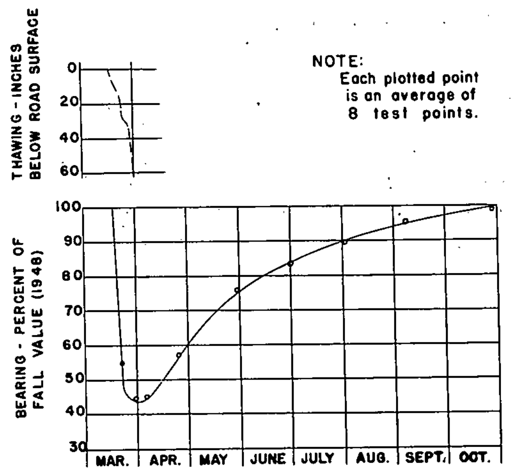

Figure 2. Minnesota Bearing Tests 1949 Loading Cycle, 12-in. Bearing Plate Loss of Road Strength and Recovery.

The test cycles from 1947 through the summer of 1949 were limited to a relatively small areas of the state to provide the detail necessary for mapping the complete cycle of loss and recovery of load-carrying capacity. A graph illustrating this cycle is shown in Figure 2. The bearing tests have been made for the most part with a 12-in. diameter plate, the present equipment permitting a total reaction load on the plate of 28,000 lb. Data has also been obtained concerning temperature and moisture changes in the flexible-pavement structure and in the subgrade soil. Analysis of this information may contribute to a better understanding of the causes of the loss in bearing value and the changes in design required to compensate for or overcome such loss.

Following the completion of the 1948-1949 cycle, which as stated above was confined to a limited area of the state, a series was started to cover the full length of the state to establish as a fact that the loss in carrying capacity occurred on all soil types and flexible-pavement structures all over the state. Because of the serious flood conditions this spring in the northern part of the state, it was not possible to obtain bearing tests in that area. Data was accumulated for 126 test points and the results have substantiated the previous observations.

The test points have included granular and cohesive soils and all types of surface and base design with the exception of concrete pavement. The tests were made on the surface of the road structure. The average loss in bearing value for the 126 test points was 42 percent of the fall bearing value. As is apparent from the tabulation below the percentage loss, within experimental error, was substantially the same for all soil types and flexible pavement design. The average bearing value in psi is also shown.

B. P. R. Classification	Number of Test Points	Average Spring Bearing Value (P. S. I. at 0. 2-in. Defl.)	Average Loss in Percent
A-2	16	205	40
A-4	9	222	46
A-4-7	14	145	45
A-7	71	96	42
A-6	13	85	40
A-5-7	3	62	41

The details of test procedure and data will be found in a future report of the Committee on Load Carrying Capacity of Roads as Affected by Frost Action.

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