## CONCRETE HIGHWAYS SUBJECTED TO EX-TREMES OF TEMPERATURE.

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HIS paper is based on observations made by the writer in every province of Canada, except British Columbia. Pavements under construction have been observed, and in some cases have been inspected year after year with a knowledge of materials and methods used in their construction. Temperature ranges of 120° F. are not unusual and in some cases reach <sup>150°</sup> F. In some sections below-zero weather occurs for several weeks at a time, so that the depth of frost is greater than in most parts of the United States. The effects of these conditions on concrete roadways can be discussed in three groups:

(1) A breaking up of the surface due to mechanical frost action.

(2) Expansion and contraction due to temperature changes with the formation of transverse cracks.

(3) The upheaval of slabs or parts of slabs with the likelihood of longitudinal cracks occurring.

Mechanical Frost Action .- While it is possible that a Porous concrete, weak in cement, might tend to break up on account of expansion caused by freezing, there is small likelihood of this trouble occurring if a satisfactory quality of concrete is secured. No actual case of this kind has ever come to the writer's attention. This must not be confused with the damage that results when concrete is laid in freezing weather or is frozen before it has had sufficient time to set up properly. This is a real danger and is one difficult to remedy after it has taken place. In addition to rutting or picking up under traffic concrete roadways laid in freezing weather may lack sufficient strength to withstand the stresses that the succeeding winter and spring induce.

Expansion and Contraction Due to Temperature Changes.—The first thought with regard to the effect of Such such ranges of temperature on expansion and contraction is that it would prove serious. When it is realized, however, that most paving is laid at a temperature of at least  $60^{\circ}$  p  $60^{\circ}$  F and that the thermometer will rarely rise above  $90^{\circ}$  F. , the amount of expansion to be provided for on account of temperature change is not large.

The drop in temperature in winter produces a contraction which to a considerable extent provides for expansion during the hot weather. Contraction is very evident during Canadian winters. In 1914, the Canada Comment during Canadian winters. Cement Company, Limited, laid a concrete road about one-half mile in length at their Point Aux Trembles plant, near Montreal. It was constructed to serve as an outlet for heavy traffic from the plant, but was to some extent an experimental road. About 1,000 feet was one-course work reinforced, a second thousand feet was two-course work reinforced, a second thousand feet was two standard one-courses and the remaining section was standard onecourse work without reinforcing. Hydrated lime equal to to per cent. of the cement by weight was added to about one hold one-half of each section. In both of the reinforced sections an attempt was made to have the new concrete bond <sup>special</sup> care being taken to have the new concrete bond with the with the work of the preceding day, the reinforcing in all cases of the preceding day. cases overlapping. For several weeks after the concrete was laid in apparently all was laid the weather was quite warm and apparently all of the weather was quite warm and apparently all of the sections had bonded, for no transverse cracks were noticeable, although a close watch was kept from day to  $d_{ay}$ . day. A sudden change in temperature, of about 50°, oc-

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curred, and over night a noticeable transverse crack appeared between successive days' work except in one instance where less than 50 feet of concrete had been laid during a day owing to a mixer break-down. During the winter some of these joints opened to a width of more than half an inch. Other instances could be cited showing very noticeable contraction. At present the writer cannot recall a single instance, however, where there has been creeping of one slab on the other or evidences of buckling where transverse joints 1/4 inch wide have been provided at intervals not greater than 35 feet and have been properly maintained.

It is during the winter and very early spring that the contraction is most marked, and there does not seem to be the lag due to moisture change that has been reported from localities further south.

While some transverse cracks are undoubtedly due to improper filling over pipe or box culverts, the writer believes that many of them represent carelessness in stopping work other than at a vertical joint.

Heaving .- Concrete pavements in Canada have shown evidences of heaving. During the winter of 1913 a street at Steelton, Ont., adjoining the Canadian "Soo," raised by frost two inches from actual levels taken by the town engineer. It returned to place with no damage except a longitudinal crack. In a street in Truro, N.S., laid in 1913, one slab raised about two inches, as was shown by its elevation above the combined curb and gutter adjoining. It settled back into place in the spring without even developing a crack.

Station Street, Oakville, was paved in 1914. In a length of about a mile there is only one spot where cracks have developed and there is known to have been an underground spring there that was not properly taken care of.

This work is reinforced and the crack has not opened to any noticeable extent. It has been given no repairs to date.

An exceptional spell of warm weather in January of this year took all of the frost out of the ground along the Toronto and Hamilton highway. The completed portion, about 17 miles in length, was carefully inspected. In only one spot had longitudinal cracks developed, and there only three slabs were affected. At this particular spot the side ditches were not taken down to their full depth until after the concrete had been laid. In digging the ditches, quicksand was encountered and it is now very evident that when the thaw saturated the ground there was a lateral movement of the subgrade material into the open ditch on the north side of the road, leaving the slab on that side unsupported. It settled and a longitudinal crack developed. The slab is noticeably lower on the north side of the crack than it is on the south side.

During the summers of 1911 and 1912 there was laid near Winnipeg, Man., several miles of what has sometimes been spoken of as a concrete road. It was actually constructed as a base for an asphalt pavement, but in an endeavor to reduce the initial cost it was not covered. The mixture was about 1:3:6, and no transverse joints were made. It was laid on the natural soil, gumbo, a very retentive clay, and was given only the attention that subbase work usually gets. It developed transverse cracks approximately every 30 feet, and during the first winter developed a number of narrow longitudinal cracks. It received no maintenance. The second winter opened up the longitudinal joints until many of them were more than an inch wide. By another spring some of them looked like gullies.

Less than a mile from this location there was laid in 1913 a road under much more satisfactory conditions,