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Discussion of a Paper
by Charles M. Noble

EXPERIENCE WITH AIR-ENTRAINING CONCRETE IN NEW JERSEY

by C. C. Rhodes

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EXPERIENCE WITH AIR-ENTRAINING CONCRETE

IN NEW JERSEY

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In these days of widespread concern over the durability of modern concrete it is becoming increasingly evident that all practical means of securing a reasonable service life of pavements and structures must be utilized and the search for fundamental knowledge of the causes and mechanics of premature breakdown tirelessly carried on if concrete is to retain its present high place as a construction material. Mr. Noble has put his finger on many of the known essential requirements for durable concrete, namely, the use of sound, clean and properly graded aggregates, and rigid control of all steps in the manufacture and placement of the finished product. However, with dwindling sources of quality materials and the modern accent on speed of construction as subversive influences, some of these precepts are difficult indeed to translate into actual practice. Although air entrainment is by no means to be considered a cure-all for inferior materials and workmanship, its use in concrete offsets many minor deficiencies and, in most cases, provides assurance of much greater durability than would otherwise be obtained.

The Michigan State Highway Department was one of the first to recognize the potentialities of air-entraining concrete and adopt it for highway construction after thorough investigation in the durability project of the Michigan Test Road which was built in 1940. As the result of these studies, air-entraining concrete has been required in all pavements constructed since May, 1942, and there are now more than 800 miles of such pavements in the State. The increased resistance to scaling attained in these pavements by air-entrainment has amply justified its use.

The experience of the Department parallels that of others with regard to the proportioning, use and properties of air-entraining concrete. Our records show a reduction in compressive and flexural strength of 3.2 per cent and 4.1 per cent respectively for each percentage increase in air content for concrete containing 5.5 sacks of cement per cubic yard, which is in line with average practice. Except for a few early projects where the air-entraining agent was added at the mixer, it has been the policy of the Department to use Type IA cement which contains the air-entraining agent interground at the mill. Air requirements are 3 to 6 per cent and tests are made periodically on each project with an Iowa aircoter by experienced engineers. When air contents drop below 3 per cent, neutralized Vinsol resin solution (NVR) is added to the batch at the mixer in amounts necessary to produce the required volume of air; when air contents are too high, which rarely happens, the air-entraining cement is blended with standard Type I cement to reduce the amount of entrained air to specification limits.

Greater workability and less segregation are valuable assets, and, combined with the known greater durability, make air-entraining concrete an attractive material for structures as well as pavements. There may be a slight loss in compressive strength and bond to steel, but these deficiencies may be offset to a great extent by slight modifications in the design of either the concrete mixture or the structure itself. The advantages were considered sufficiently great to warrant the adoption of air-entraining concrete by the Department for all bridge construction in 1947.

Mr. Noble has brought out a point of particular interest to us in his brief discussion of early transverse cracking in concrete pavements. In Michigan we have made a rather extensive study of this phenomenon in connection with a general appraisal of the membrane method of curing concrete, the results of which are now in the process of publication as a Bulletin of the Engineering Experiment Station at Michigan State College.[1] In this study it was concluded that the effects of temperature during the early hardening period on hot summer days are critical, but the occurrence of temperature cracking in a pavement of given design depends not only on the rate and extent of temperature change but also on the character of the subgrade, the physical and chemical properties of cement and aggregates, and the proportioning, mixing, placing and finishing of the concrete.

Through a survey of earlier concrete pavements in Michigan constructed with 100-ft. slabs and reinforcing steel it was revealed that about 10 per cent of all slabs were cracked within a few weeks of their completion dates. Of this 10 per cent, approximately three times as many cracked slabs were found in the morning pours as in the afternoon pours for the entire seasonal range of construction conditions in 1947. Although cracking to such an extent is not excessive, the facts lead inevitably to the conclusion that half of the total early cracking could have been prevented by effective temperature control during the early hardening period. Moreover, it is quite possible that small variations in tensile and flexural strength may significantly influence crack occurrence at early ages, in view of the close balance that exists between the tensile forces acting on the slab

1 "An Appraisal of the Membrane Method of Curing Concrete Pavements", by C. E. Rhodes and J. R. Evans, Bulletin No. 109, Engineering Experiment Station, Michigan State College, East Lansing, Michigan.

and its ability to resist them at this stage. Thus it is conceivable that a reduction of, say, 10 per cent in flexural strength at ages up to 24 hours due to air entrainment, or any other cause, may be disproportionately reflected in the crack pattern. After 24 hours, strength gain outstrips the induced temperature stresses and danger of premature cracking from this cause is much reduced.

It would be a mistake, however, to put too much emphasis on the loss in flexural strength through air-entrainment as a major cause of temperature cracking. There are too many other factors of equal or greater significance in the problem, some of which were mentioned earlier. For example, we have found concrete pavements with more than two thirds of all slabs cracked at the end of the first year, in spite of the fact that no air-entraining agent was used. These pavements were built about 20 years ago, contained 100-ft. slabs, but were without reinforcing steel. At that time, too, present refinements in sub-base preparation were unknown.

One way of controlling temperature cracking obviously is to control the rate and extent of temperature change in the pavement. At the present time, the Michigan State Highway Department is experimenting with the use of white-pigmented membrane curing compounds for this purpose. Pilot tests have been made on experimental sections of pavement to determine visual effects and weathering characteristics, and a full-scale trial of these compounds on several projects is contemplated for the coming construction season.