HR-197 Fatigue Behavior of High Air Content Concrete

Key Words: Fatigue strength, Air content, Portland cement concrete PCC

ABSTRACT

The rigid pavement design procedures currently in use consider only the modulus of rupture strength of concrete in determining the fatigue life of concrete highway pavements. The effects of entrained air, water/cement ratio, and aggregate type are not considered. The purpose of this study was to determine the effects of various air contents, various water/cement ratios, and different aggregate types on the flexural fatigue strength of plain concrete and to develop fatigue curves that incorporate these effects and could be used for design.

Fifteen series of concrete were investigated in this study. The variables consisted of air content, water/cement ratios, coarse aggregate types, and fine aggregate types. The fatigue specimens consisted of 6 in. x 6 in. x 36 in. beams and were subjected to flexural one-third point loading. The bottom fiber stress varied from essentially zero to a maximum stress corresponding to 60, 70, 80, or 90% of the modulus of rupture. As the bottom fibers were in constant tension, there was no reversal of stress. All concrete was mixed and placed in the laboratory to assure proper control of the mix. The fatigue specimens were cured in water until testing which took place at a specimen age of 28 to 56 days.

Thirteen series were tested using an Instron Model 1211 dynamic cycler, and two series were tested using an MTS fatigue test machine. Both fatigue test machines were fitted with load fixtures which enabled loads to be applied at the same geometry as the modulus of rupture machine. Three hundred fifty one fatigue tests were conducted. Results of these tests (Phase II) are presented in graphic form in the text and in tabular form in Appendix B.

The S/N diagrams show a reduction in fatigue life as the air content increases and as the water/cement ratio is decreased to 0.32. However, these curves may not be used for design, as they allow no factor of safety against failure. These figures present repetitions of stress with a constant probability of 0.05. The constant probability of 0.05 means that for 100 specimens tested at given stress level, only five would exhibit a fatigue life less than that indicated by the curve.

The fatigue curves developed in this study were used in pavement de-signs following the Iowa DOT Pavement Design Procedure and compared to designs using the Portland Cement Association (PCA) fatigue curve for a given subgrade and traffic. The PCA curve generally yields a more conservative design. However, in some instances the PCA curve produced inadequate thicknesses.

The main fatigue test program was supplemented by additional investigations. The compressive strength, modulus of rupture, modulus of elasticity, and unit weight were determined for each series. Plastic air content determinations were compared with hardened air contents determined by high pressure air meter methods. Scanning electron microscope photographs were taken at various magnifications and various air contents, water/cement ratios, and aggregate combinations to determine characteristics of the air void system. A mercury penetration porosimeter was used to characterize the void properties of the various concretes at the various air contents.

The following conclusions can be made as a result of the tests per-formed in this investigation:

1. The fatigue behavior of plain concrete in flexure is affected by the air content of the concrete. The fatigue strength decreases as the air content increases. Fatigue curves obtained from this study (Figures 42-46) provide a basis for improved rigid pavement design
2. The fatigue behavior of plain concrete in flexure is affected by the water/cement ratio of the concrete. The fatigue strength is decreased for a low water/cement ratio (0.32). There did not seem to be a discernible difference in fatigue strength for concretes with a water/cement ratio in the range 0.40 to 0.60

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