Dynamic and Fatigue Response of Concrete

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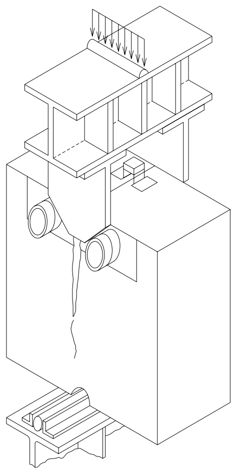
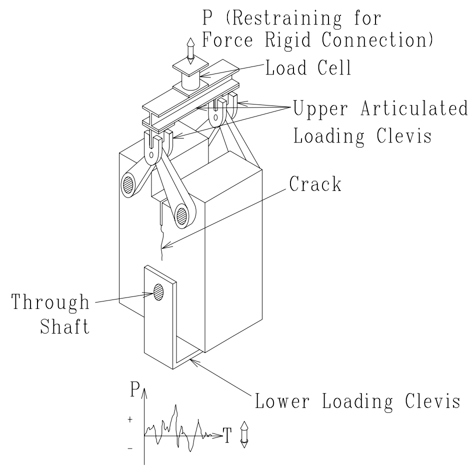
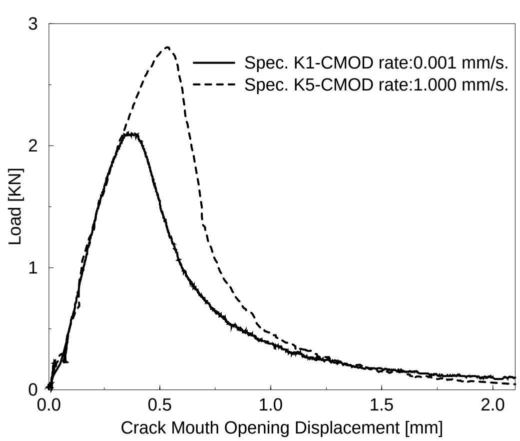
As part of an industry funded project (Electric Power Research Institute), the dynamic and low cycle fatigue of concrete was investigated. The objective was to improve our basic understanding of the phenomena which governs crack propagation under variable amplitude loading (such as those caused by earthquake, wind and wave repeated loads).

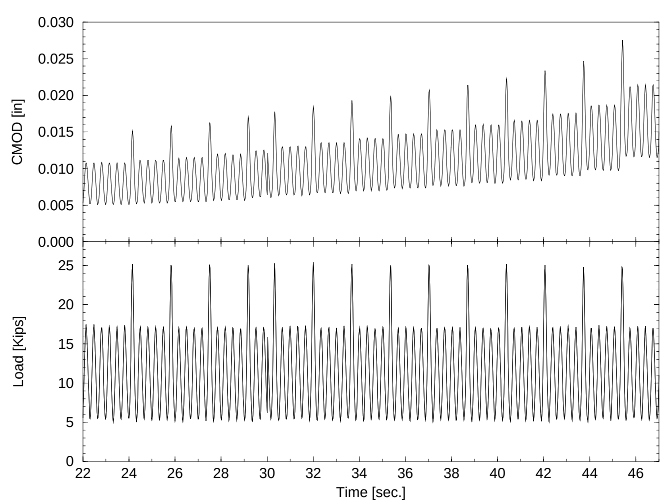




Tests conducted with impact loads, showed that the strength of the cracked specimen was about 20-30% higher than those obtained under static load.

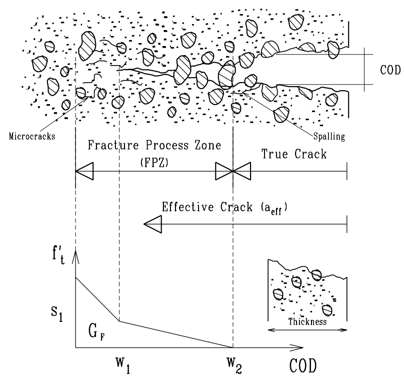
In the second phase, specimens were subjected to variable amplitude low cycle fatigue loading. Current practice is often based on emperical rules of thums which dictate that a crack will propagate when the maximum principal tensile stress has exceeded a number of times the tensile strength (this is often coupled with Engineering Judgment). This model is often used in conjunction with linear elastic dynamic analyses.

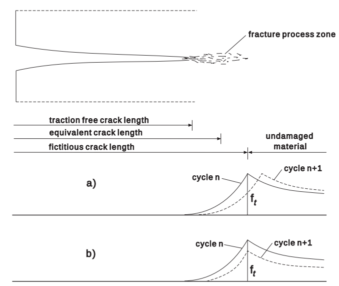




It was determined that crack growth can be explained in terms of the damage induced by the fracture process zone which is at the tip of a concrete crack.

Load history effects manifested themselves in aspecimen which was subjected to low cycle fatigue loading in the range of 25% to 75% of the maximum load. Following some minor crack length adjustment, the stiffness remained nearly constant for about 10^4 cycles. Hence, no low cycle fatigue crack propagation took place. The specimen was then loaded over the peak, under CMOD-control, resulting in the formation of a fracture process zone (FPZ) at the tip of the crack. The FPZ is a zone in which the matrix is intensively cracked. Along the FPZ there is a discontinuity in displacements, but not in stresses. The stresses are themselves a function of the crack opening displacement (COD). At the tip of the FPZ, the tensile stress is equal to the tensile strength f_t, and it is gradually reduced to zero at the tip of the true crack.

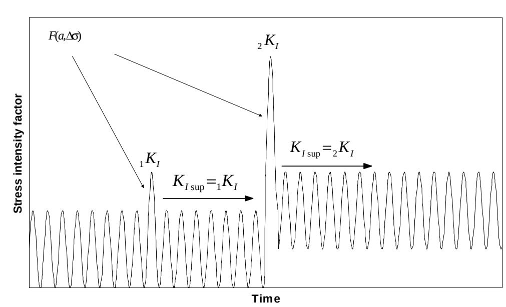




With a FPZ now present, the specimen was again loaded in low cycle fatigue between 25% to 75% of the maximum load (lower than before due to the crack extension). The stiffness then decreased much more rapidly than before and the specimen failed after 1458 cycles. On the basis of this observation, we conclude that the fatigue response of concrete is drastically different if we have a fully developed FPZ than otherwise.

Whereas a nonlinear dynamic analysis which accounts for the observed phenomena would be desirable (assuming that such a code exists) would be desirable, it may be prohibitively expensive.

Instead, a simple model based on linear elastic fracture mechanics is proposed. This model, which accounts for both size effect as well as the load history, provided a very good correlation not only with all the tests performed, but also with tests performed by other researchers.



From this, we conclude that load history is of paramount importance in the fatigue behavior of concrete, and only a nonlinear fracture mechanics model can rigorously explain it. This model has been implemented in our computer program MERLIN.

Slowik, V., Plizzari, G., and Saouma, V.E., **Fracture of Concrete Under Variable Amplitude Fatigue Loading**, In Print *ACI Materials Journal*, May, 1996.

Saouma, V. and Slowik, V. **Cyclic, Dynamic and Hydrodynamic Fracture Response of Concrete**, Report (in preparation)