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FATIGUE FAILURE OF RC BEAMS UNDER A MOVING CONCENTRATED LOAD

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1. Introduction

Numerous studies on fatigue of reinforced concrete beams under a repeated load on a fixed point, which formed as the basis for fatigue considerations in the design of rc members, are reported in the literature. In these reports it was found that the fatigue life corresponding to the maximum stress in the extreme concrete fiber was consistently higher than that predicted by fatigue tests of concrete materials[1]. Hence an upper limit of concrete stress on reinforced concrete members is set based on the results of fatigue tests of materials.

Loading conditions in real structures like bridges are not fully simulated in laboratory tests of rc beams under fixed point repeated load since the stress history of each point on a beam is different for the case of moving load. The result of the present experiment showed fatigue failure of beams at a fatigue life of 10^5 cycles with extreme fiber stress as low as 32 percent of compressive strength of concrete cylinder. It is surmised that shear stress reversal at regions of high shear and low moments causes alternating tension and compression on certain planes at a point. This loading condition induced more damage hence resulting in lower fatigue life.

2. Experiment

Fig. 1 shows the dimensions of the test beam and the arrangement of the reinforcement. The material used was mortar which is a mixture of sand with maximum aggregate size of 2.5 mm and early strength portland cement. The compressive strength of the mortar was 379 kgf/cm^2 and the yield strength of the bar was 3920 kgf/cm^2. The steel ratio was 0.9 %. The dimensions were chosen so as to yield approximately the same strength in shear and in flexure.

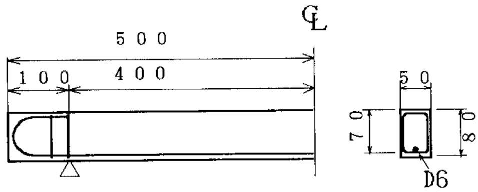

Fig. 1 Specimen dimensions unit: mm

3. Results

Table 1 shows the calculated stresses, fc, at the extreme compression fibers and the stresses on the reinforcement, fs, using cracked elastic analysis. In this table, fc'=compressive strength of concrete cylinder, fy=yield strength of bar, a, distance of the top of the rupture surface from the support. The stresses were calculated at the section corresponding to the top of the rupture surface. All beams failed in shear with the exception of beam M1-1 which failed in flexure by rupture of the longitudinal reinforcement.

Fig. 2 shows the growth of the critical diagonal crack (rupture surface) for each beam. It is can be seen from the figure that the crack propagated unstably at the first twenty percent of the fatigue life of the beam until it reached the neutral axis, grew stably up to about 80 to 90 percent of the life and then extended unstably up to failure.

Table 1 Summary of test results

specimen	a cm	Pmax kgf	Nfail	concrete fc/fc'	steel fs/fy
M1-1	30	313	391470	0.51	0.80
M1-2	20	313	198985	0.40	0.63
M1-3	20	313	160000	0.39	0.62
M2-1	15	325	160000	0.32	0.51
M2-2	23	325	73092	0.43	0.69
M2-3	16	325	66242	0.34	0.54
M3-1	28	350	23634	0.51	0.82
M3-2	19	350	11850	0.42	0.67
M3-3	18	350	55000	0.41	0.65
M4-1	31	400	574	0.62	0.98

Fig. 3 shows the variation of the normal stress on different planes on the compression zone of the concrete at the shear span. Each line correspond to the load applied at a particular position. The stresses were calculated from strain measurements assuming isotropic elastic behavior. It can be seen from the figure that on certain planes the normal stress alternates from tension to compression. This phenomena was observed when the crack tip was near the gage point but disappeared when the tip of the crack propagated away from the gage point.

4. Discussion

The experiment revealed that even for beams with very low stresses, fatigue failure due to concrete rupture like shear compression or diagonal tension failure is possible for the case of moving load.

For a moving load the normal and shear stress increase proportionally as the load approaches the point under consideration and then decrease proportionally as the load moves away from the point. However, when the load is immediately just to the left of the point and then move to the position immediately just to the right of the point, the shear stress reverses while the normal stress remains constant causing non-proportional loading and rotation of the principal axes. Scant experimental results suggest a lower strength for concrete subjected to nonproportional loading[2]. In regions of high shear stress and low normal stress, this shear stress reversal may cause alternating tension and compression stresses on certain planes. This is particularly critical at the tip of a shear crack as can be seen from the mode of failure of the test beams and the strain measurements. The repeated alternation from tension and compression induces more damage on the concrete resulting in lower fatigue life[3,4].

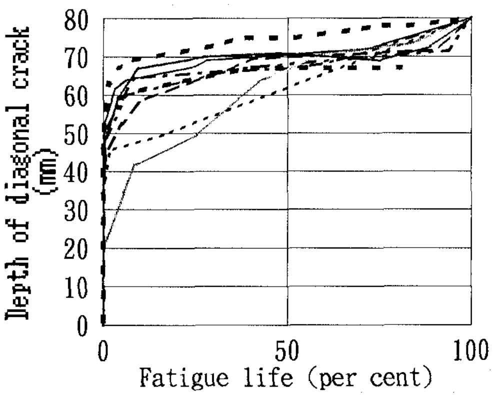

Fig. 2 Growth of critical diagonal crack

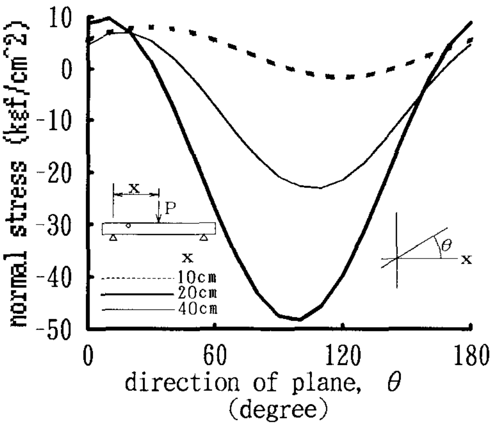

Fig. 3 Variation of normal stress

5. Conclusion

Repeated moving load results in the rotation of the principal stress. In regions of high shear stress and low normal stress, particularly at the tip of a shear crack, alternating tension and compression stresses on certain planes may result. This loading condition induces a more severe damage to beams resulting in lower fatigue life.

Acknowledgement

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Reference

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