I -116

A STUDY ON THE FATIGUE FRACTURE OF STEEL PLATES IN STEEL-CONCRETE SANDWICH BEAMS

Mohab Zahran[1], Tamon Ueda[2], and Yoshio Kakuta[2]

1) Department of Civil Engineering, Hokkaido University, Graduate student
2) Department of Civil Engineering, Hokkaido University, Dr, JSCE member

1. Introduction

The steel–concrete sandwich member is composed of core concrete, steel skin plates, and shear connectors (i.e., steel angles) as shown in Fig.1. The sandwich member has many weldings between the steel plates and the steel angles. Under fatigue loading, fatigue cracks originate at these welding points. Then, these cracks propagate gradually through the steel plate until complete fracture occurs. Hence, this paper presents an experimental and analytical study on the fatigue fracture of steel plates in steel–concrete sandwich beams.

2. Experimental and analytical study

Experimental works were carried out for the steel–concrete sandwich beam shown in Fig.1, which had a span length of 2.65 m and a cross section of 250 ×400 mm. The shear span to effective depth ratio (a/d) was equal to 3.0. The compressive strength of the concrete was 25 MPa. The yield strength of the steel plates was 400 MPa. Under static monotonic loading, the sandwich beam failed at 318 kN, and the failure mode was a shear compression failure. Then, fatigue tests were carried out for the sandwich beam. For large maximum fatigue loads (65%, 70%, and 82% of the static strength), the failure mode of the beam was crushing of concrete between diagonal cracks, while for smaller loads (50% and 60% of the static strength), the failure mode was fracture of the tensile steel plate at the supporting point. These fatigue failure modes are illustrated in Fig.2. The S–N relationship for the sandwich beam is shown in Fig.3. More details about the experimental results can be found in reference [1].

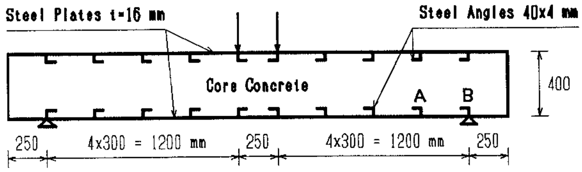

Fig.1 Geometry of the sandwich beam

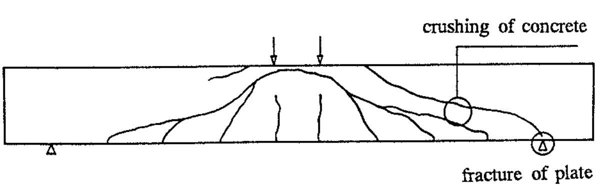

Fig.2 Crack pattern and failure modes under fatigue loading

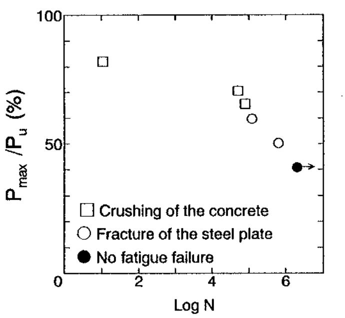

Fig.3 The S–N relationship for the sandwich beam

Then, tensile fatigue tests were carried out for a number of steel plate specimens in air. The tested steel specimen is shown in Fig.4, which had a width of 30 mm and a thickness of 16 mm. A steel angle of 40×4 mm size was welded to the center of the steel specimens as shown in Fig.4. The specimens were tested for different tensile stress ranges. The S_r–N relationship for the steel specimens is shown in Fig.5, and also compared with the S_r–N relationship for the tensile steel plate in the sandwich beam. The S_r–N relationship for the steel plate in the beam was plotted using the stress range in the part (AB) of the steel plate (see Fig.1). The fatigue strength of the steel plate in the beam was found to be weaker than the fatigue strength in air. This may be caused by the shear transfer between the concrete and the lower steel plate through the shear connector and also the local bending deformations of the plate itself specially after diagonal cracking.

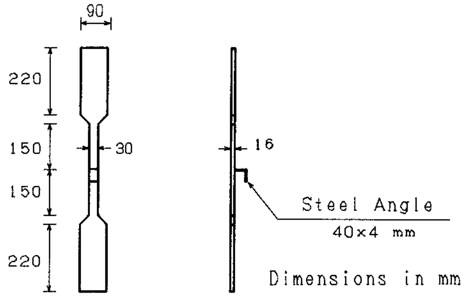

Fig.4 Steel specimen for the tensile fatigue test

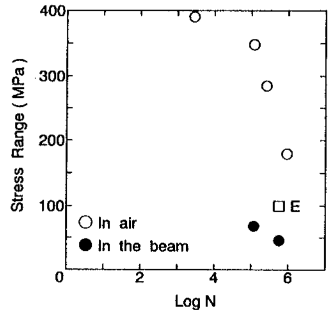

Fig.5 S_r–N relationship for the steel plate

Hence, it is necessary to estimate the tensile stresses induced in the lower steel plate of the beam due to the local bending deformations. Fig.6 shows the maximum tensile stress distribution at the bottom fiber of the lower steel plate in one of the fatigue tests (i.e., stress distribution at the maximum fatigue load). In this figure, the dotted line indicates the stress distribution before diagonal cracking, while the solid line indicates the stress distribution after diagonal cracking. The difference between the solid line and the dotted line indicates the additional tensile stresses induced in the plate due to the local bending deformations. However, the maximum tensile stress at the fractured point (i.e., the supporting point) was unknown since no strain gauges were attached to this point. Therefore, analytical study was carried out by using the finite element method in order to calculate the maximum tensile stress at the supporting point. The finite element mesh used in the analysis is shown in Fig.7. Downward enforced displacements were given at points a, b, c, and d. Hence, for the enforced displacements shown in Fig.7, the tensile stresses induced in the steel plate were close to the experimental values given in Fig.6. Therefore, the maximum tensile stress at the supporting point was equal to 126 MPa. Similarly, the minimum tensile stress at the supporting point was calculated (i.e., at the minimum fatigue load). Finally, the tensile stress range at the supporting point was equal to 100 MPa. If this stress range is plotted on the S–N relationship in Fig. , point (E) is obtained. It is observed that the stress range at point (E) is still smaller than the stress range for the fatigue test in air. this gap may be caused by the shear transfer between the concrete and the lower steel plate through the shear connector.

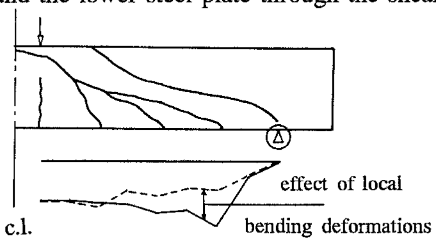

Fig.6 Tensile stress distribution at the bottom fiber of the lower steel plate (10 mm = 63 MPa)

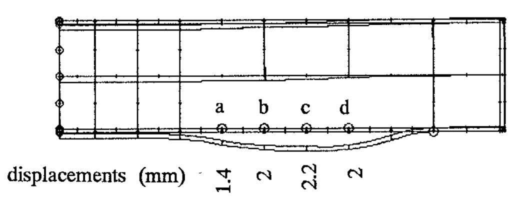

Fig.7 The finite element mesh and the deformed shape for the lower steel plate

3. Conclusion

In order to avoid fatigue fracture of the lower steel plate, it is recommended to remove the shear connector at the supporting point. Another alternative is to provide the sandwich beam with a vertical steel plate at the support in the longitudinal direction of the beam. This vertical plate will decrease the local bending deformations of the lower steel plate.

References

1. Zahran, M. and et al.,"Shear–Fatigue Behavior of Steel–Concrete Sandwich Beams Without Web Reinforcement," Proceedings of the JCI Conference, Vol.16–2, 1994, pp.1217–1222.