CS - 82 ANALYTICAL METHOD TO PREDICT THE FATIGUE STRENGTH OF STEEL-CONCRETE SANDWICH BEAMS

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1. INTRODUCTION

Steel-concrete sandwich beams consist of core concrete which is sandwiched by upper and lower steel plates. Shear connectors are provided at the interface between the concrete and the steel plates. The flexural capacity and also the shear capacity of this type of beams have been thoroughly investigated under static loading conditions. However, the strength of this type of beams under fatigue loading has not. Hence, this study presents a simple analytical approach to predict the fatigue strength of steel-concrete sandwich beams by using the finite element method.

2. FINITE ELEMENT ANALYSIS

A nonlinear finite element method computer program (WCOMR)[1] was used to analyze the steel-concrete sandwich beam shown in Fig.1, which has a span length of 265 cm and a cross section of 25×40 cm. The shear span to effective depth ratio (a/d) is equal to 3.0. The thickness of the upper and lower steel plates is 16 mm. The compressive strength and the tensile strength of concrete are 250 kgf/cm^2 and 25 kgf/cm^2, respectively. The yield strength of the steel plates is equal to 2450 kgf/cm^2. The sandwich beam is not provided with shear reinforcement. Bond elements are provided to simulate the interface between the concrete and the lower steel plate. Enforced displacements are given at the loading point as shown in Fig.1.

At first, the sandwich beam was analyzed under static monotonic loading. The monotonic load - deflection curve is shown in Fig.2. It is observed that the load increases with high stiffness until about 23.0 tons. At this load, main diagonal cracking occurs (point C in Fig.2). This could be illustrated by the crack pattern in Fig.3. Then, the load-deflection curve increases further with small stiffness until the ultimate failure load which is about 34.0 tons. In this study, the fatigue life for the main diagonal cracking is investigated.

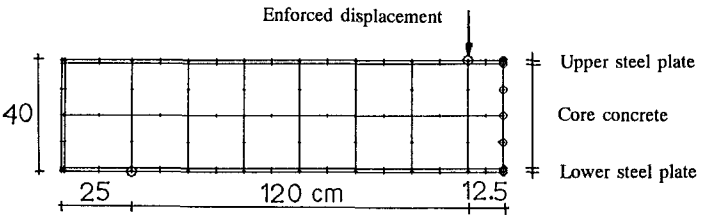


Fig.1 The finite element mesh

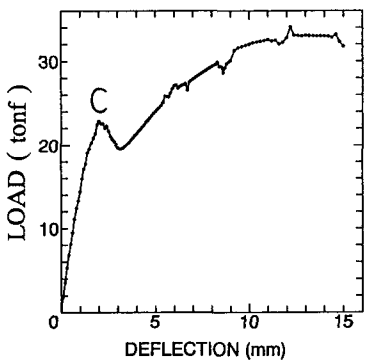


Fig.2 Load-deflection curve (static monotonic loading)

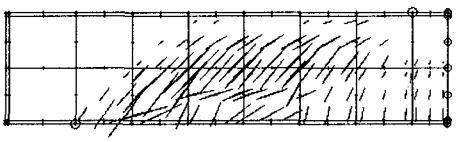


Fig.3 Crack pattern at point (C) (load = 23.0 tonf)

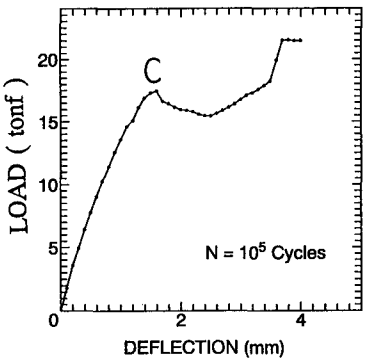
The fatigue life for the main diagonal cracking was predicted by using the finite element method. As a primary simple approach, the analysis procedure was based upon reducing the tensile strength of concrete

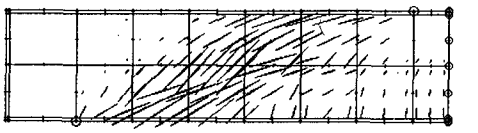
with increasing the number of loading cycles (N). The tensile strength of concrete is reduced according to the following equation,

$$F_t(N) = F_t\ (\ 1.0 - (\log N / 10.954)) \quad \text{.....(1)}$$

where: $F_t(N)$: the reduced tensile strength after (N) cycles
F_t : the tensile strength at the first cycle
N : the number of loading cycles
This equation was proposed by Balaguru and Shah[2] to predict the deflection of RC beams under fatigue loading.

The sandwich beam was analyzed for different input numbers of loading cycles (N). For 10, 100, 10^3, 10^4, 10^5, 10^6, and 10^7 cycles, the predicted diagonal cracking load was 95%, 89.9%, 85.5%, 80.0%, 76.4%, 71.1%, and 64.5%, respectively of the main diagonal cracking load under static monotonic loading ($P_{stat.}$=23.0 tonf)(see point C in Fig.2). The output load-deflection curve for one case as well as the corresponding crack pattern are shown in Fig.4. Experimental work was carried out for the above described sandwich beam. The results of this experimental study are presented in detail in reference [3]. Fig.5 illustrates the analytical and the experimental S-N relationships for the main diagonal cracking of the sandwich beam.





(crack pattern at point C)

Fig.4 Load-deflection curve and crack pattern (P_{max} = 76.4 % of $P_{stat.}$)

3.CONCLUSION

The sandwich beam investigated in this study indicates a shear failure mode under static loading, which is characterized by main diagonal cracks. The fatigue life for the main diagonal cracking was predicted by using the finite element method in which an experimental S-N relationship was applied to reduce the tensile strength of concrete. This strength reduction depends on the number of loading cycles (N) only. However, further analytical study is needed to account for another factors such as the stress range or the loading duration.

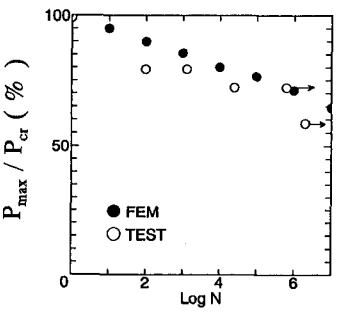


Fig.5 S-N relationships for the main diagonal cracking

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3. Zahran, M. and et al.,"Shear-Fatigue Behavior of Steel-Concrete Sandwich Beams Without Web Reinforcement," Proceedings of the JCI Conference, Vol.16, June 1994.