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Journal of Constructional Steel Research 61 (2005) 651–673
JOURNAL OF CONSTRUCTIONAL STEEL RESEARCH
www.elsevier.com/locate/jcsr

Static and fatigue tensile strength of friction-welded bar–plate connections embedded in concrete

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Received 12 March 2004; accepted 26 October 2004

Abstract

Friction-welded bar–plate connections are a basic structural component of Bi-Steel steel–concrete–steel sandwich construction. In Bi-Steel members, the bar–plate connections, embedded in concrete, are subject to tension, shear and bending. This paper describes experimental and numerical studies on the static and fatigue strength of the friction-welded connections with the bar loaded in tension. Finite element analysis is carried out to examine the effects of plate thickness, the collar ("flash") formed after friction welding, and possible initial defects or fatigue induced cracks. It is found that except for 6 mm plate specimens, the static tensile capacity of the embedded connections is governed by the tensile strength of the bar connectors. In the fatigue tests, single fracture and double fracture mechanisms were observed. Experimental stress vs. life (S–N) curves are derived from the fatigue test results, and they lie between the F-type and the S-type curves specified in BS5400 Part 10. Further papers will describe static and fatigue tests incorporating other force components, and on Bi-Steel beams.

Keywords: Bi-Steel; Composite construction; Static tests; Fatigue tests; Finite elements; Strength

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0143-974X/$ - see front matter
doi:10.1016/j.jcsr.2004.10.008

Nomenclature

d	bar diameter ($d = 25$ mm)
E	elastic modulus of steel ($E = 2.05 \times 10^5$ N/mm^2)
E_c	elastic modulus of concrete ($E_c = 3 \times 10^4$ N/mm^2)
f_{cu}	cube strength of concrete
f_y	yield stress
f_{yB}, f_{yP}	yield stress of bar and plate, respectively
f_u	ultimate strength
f_{uB}, f_{uP}	ultimate strength of bar and plate, respectively
F	tensile load applied to bar connector
F_u	ultimate tensile load applied to bar connector
m	the inverse slope of the log $\Delta\sigma$ vs. log N_f curve
N_f	number of cycles to failure
p	contact pressure
r	radial distance from bar centre
s	standard deviation of log N_f
t	plate thickness
α	the number of standard deviations below the mean line of log $\Delta\sigma$ vs. log N_f
Δ	deformation of plate disc (Fig. 2)
$\Delta\sigma_B$	bar tensile stress range, $\Delta\sigma_B = \sigma_{B,\max} - \sigma_{B,\min}$
$\sigma_{\max}$	maximum principal stress
ν	Poisson's ratio ($\nu = 0.3$ for steel, 0.15 for concrete)
σ_B	average tensile stress in bar connector, $\sigma_B = 4F/\pi d^2$
$\sigma_{B,\min}$, $\sigma_{B,\max}$	minimum and maximum bar stresses applied in cyclic tests
σ_{Bu}	average tensile stress in bar connector at failure, $\sigma_{Bu} = 4F_u/\pi d^2$
σ_P	maximum radial stress in plate disc

1. Introduction

Bi-Steel steel–concrete–steel sandwich construction [1,2], developed by Corus, uses a regular array of transverse bar connectors to interconnect two face plates. Both ends of the bar connectors are simultaneously friction-welded to the plates. In use, Bi-Steel units are joined together to form a structure which is then filled with concrete.

In conventional composite beams, connector tension exists but normally is not explicitly taken into account, whereas in Bi-Steel, connector tension is a variable which must be considered. Shear connectors in conventional composite beams terminate within the concrete slab and their prime functions are to resist longitudinal shear and beam/slab