Analysis of
Composite Steel and Concrete
Flexural Members
that exhibit
Partial Shear Connection

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Synopsis

This thesis presents an analysis of composite members of steel and concrete which exhibit partial shear connection. Such situations are found in many structural systems which include but are not limited to composite beams, composite slabs, profiled beams, reinforced concrete beams strengthened by external plates and composite walls. Each of these composite structural systems uses a variety of methods to ensure adequate connection between the concrete and steel elements. The breakdown in bond between the concrete and the steel causes a reduction in the strength and stiffness of the composite member. It is the parameters controlling the behaviour of the interface bond that are the focus of this research.

Stud shear connectors, which are the most common form of shear connection in composite beams, have limited ductility and are prone to failure by fracture in beams with low degrees of shear connection. A new mathematical model has been developed which determines the maximum end slip at the ultimate moment, based on the geometric and material properties of the beam. This theoretical end slip can then be compared to the slip capacity of the shear connectors, and the design of the member changed if necessary. The results of the mathematical model compare favourably with published experimental results.

In composite members incorporating light gauge steel sheeting, such as in composite slabs and profiled beams, the shear connection is most commonly provided by mechanical interlock between the concrete and the rib geometry of the sheeting. Embossments are commonly provided on the ribs to enhance the shear connection performance. The performance of the shear connection is usually assessed by a number of full scale slab tests, using a range of parameters which encompass those expected in practice. A small scale test procedure is proposed as an alternative to full scale testing. This allows the shear connection performance of different rib and embossment geometries to be tested with relative ease.

The small scale test procedure accurately represents the forces acting on the sheeting and the concrete away from the supports. This is achieved by removing any external lateral clamping forces acting on the specimen. It was found for most rib geometries incorporating
embossments, including re-entrant dove-tail ribs, that as longitudinal slip progressed there was a tendency for the sheeting to move laterally away from the concrete. This result indicates that any externally applied lateral force during testing of the specimen, will effect the resulting behaviour.

Three series of tests were carried out on small scale specimens in order to investigate general qualitative effects of varying parameters such as the rib geometry, surface condition and thickness of the sheeting. It was found that shear resistance increased for ribs with an increasing re-entrant geometry, and increased with an increase in sheeting thickness. The relationship between shear resistance and sheeting thickness was approximately cubic, indicating that the shear resistance increased with the cube of the sheeting thickness. This increase was due to the greater passive normal forces that develop due to the increase in 'spring action', which in turn result in greater longitudinal shear resistance. There was a marked increase in the shear resistance with the addition of embossments.

A model describing the ultimate moment capacity of profiled beams has been developed. It is based on rigid plastic analysis, and requires an understanding of the load-slip characteristics of the sheeting used. Equations are derived which give the ultimate moment capacity of the profiled beam based on the degree of shear connection at the critical cross-section. The equations are derived for two different forms of construction; welded construction and clipped construction. It is shown that greater development lengths are required to develop full shear connection when clipped construction is used.

The behaviour of profiled beams was investigated through a series of 6 full scale profiled beam tests. The load-deflection response was determined, as well as the variation in slip at different locations along the beam. It was found that close to complete interaction was achieved for the 4 beams which incorporated L-Ribs in the profiled sheeting, whereas the 2 beams which had Dove-Tail ribs exhibited partial interaction. The loss in moment capacity due to the loss in shear connection was only slight. The results from the experimental tests were in close agreement with the values predicted using the theory developed.
A series of tests were carried out to investigate the effect of the side profiled sheeting on the transverse shear strength of profiled beams. A small scale test specimen was designed and used to obtain results on the shear performance of different rib geometries, as well as to determine the influence of various parameters such as sheeting thickness, surface condition and development length. The results of the tests were compared to predicted values using theory developed by other researchers. It was found that with modifications, the theory provided a reasonable estimate for the increase in transverse shear resistance due to the side profiled sheets.
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