Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 60 (1990)

Artikel: Double skin construction

Autor: Wright, Howard / Oduyemi, Taiwo

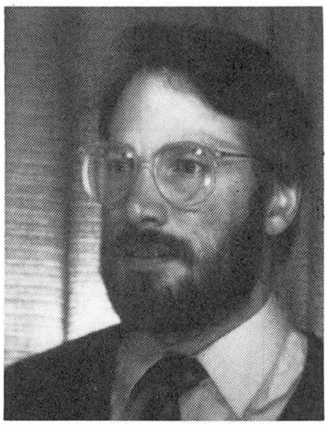
DOI: https://doi.org/10.5169/seals-46500

Double Skin Construction

Construction en sandwich

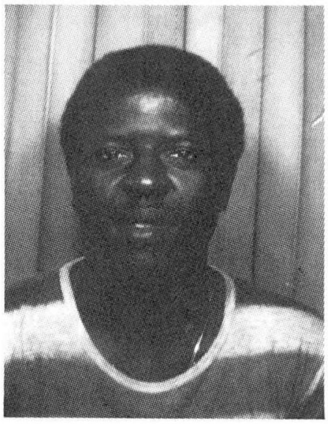
Doppelhaut-Konstruktionen

Howard WRIGHT
Lecturer
Univ. of Wales
Cardiff, Wales, UK



Howard Wright, born 1952 graduated from Sheffield University and has spent 9 years in practice before joining the staff at Cardiff. He has published extensively on composite construction including his Ph.D. on the subject in 1988.

Taiwo ODUYEMI
Res. Assist.
Univ. of Wales
Cardiff, Wales, UK



Taiwo Oduyemi graduated from the University of Birmingham in 1983 where he also obtained a Ph.D. in 1987. He has spent three years in Cardiff.

SUMMARY
Double skin composite elements are formed from two skins of steel plate and an infill of concrete. The sandwich acts compositely by means of welded stud shear connectors on the internal faces of the steel. This paper describes model tests on beam, column and beam column double skin elements. Comparisons are made with reinforced concrete design methods and guidance is given to allow engineers to dimension typical elements.

RÉSUMÉ
Les éléments mixtes en sandwich sont constitués d'un noyau de béton délimité par deux plaques métalliques. L'effet «sandwich» est réalisé au moyen de goujons soudés aux faces intérieures des plaques métalliques. Le présent article décrit des essais effectués sur des poutres, des poteaux et des éléments d'assemblage poutres-poteaux en sandwich. Une comparaison est faite avec les méthodes de dimensionnement du béton armé et un guide est fourni en vue de permettre aux ingénieurs de dimensionner des éléments typiques.

ZUSAMMENFASSUNG
Doppelhaut-Verbund-Elemente werden duch Verbindung zweier Stahlplatten mit einer Betonfüllung hergestellt. Die Schichtung wird durch geschweisste Beschlagnägel als Scherverbindungen auf den Innenseiten der Stahlplatten zusammengehalten. Hier werden Modellversuche an Trägern und Stützen aus Doppelhautelementen beschrieben. Vergleiche mit Entwürfen aus Stahlbeton und Ratschläge für die Bemessung werden gegeben.

1 INTRODUCTION

Double skin or dual skin construction is the term used to describe steel-concrete-steel sandwich elements where the steel skins are connected to the concrete core with welded stud shear connectors. Large structural elements may be fabricated in this way using the steel skins as both permanent formwork and reinforcement. Fig. 1 shows a typical section through a double skin element along with the possible failure modes that may occur. The system was developed primarily for use in submerged tube tunnel construction [1] but it has potential applications in nuclear containment and blast resistant structures.

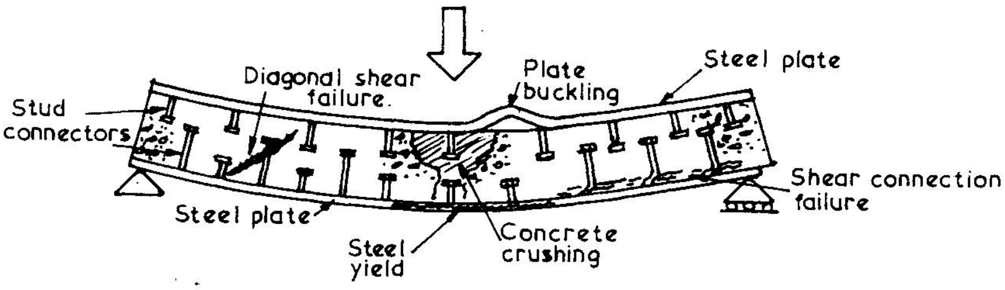


Fig. 1 Double skin composite construction

The failure modes are more various and more complex than those normally associated with reinforced concrete structures.

1) The steel skins may yield in tension and in compression although it is more likely that buckling will dictate the latter.

2) The concrete may crush in the compression zone and diagonal tension cracks may cause failure in areas of high shear.

3) The connection between the concrete and steel may fail and the flexibility of the studs is likely to precipitate alternative modes of failure.

These failure modes have been investigated by the authors in a programme of experimental and theoretical studies. The experimental programme invoved 53 scale model tests on beam, column and beam-column specimens. The theoretical studies have included classical modelling along with design oriented approaches. The results of this work have been correlated into a series of guidance notes for designers.

2 BEAM BEHAVIOUR

Eighteen model scale double skin beams have been tested by the authors. A typical test specimen in shown in fig. 2 along with the loading pattern applied in all cases. The parameters investigated in the tests were steel sheet thicknesses, concrete strengths, connector spacing and connector lengths. The interaction of these parameters is complex and has been presented elsewhere [2]. The major criteria for design appear to be the size, number, position and length of the shear connectors.

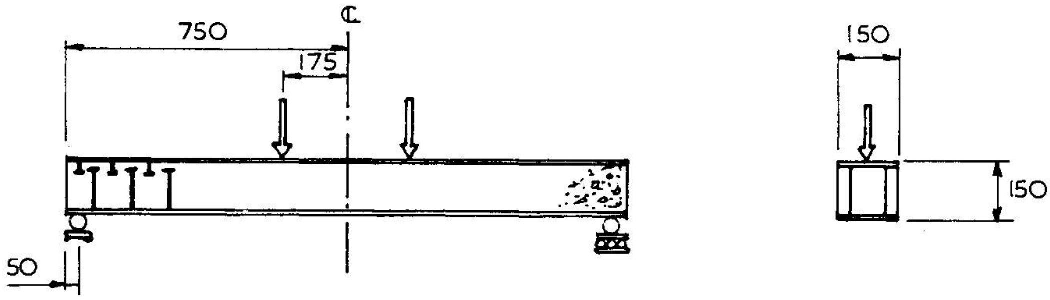


Fig. 2 Test set up

The connectors fulfil several roles. Firstly they transmit shear stresses between steel and concrete. Secondly they act to prevent diagonal tension in the areas of high shear in much the same way as links in reinforced concrete beams. Finally they act as stiffeners to the compression skin of steel and prevent buckling.

Unfortunately they also have a slight detrimental effect on the concrete in the tension zone as they act as crack inducers. The connector strength and stiffness is adversely affected when it is placed in cracked concrete.

The ultimate strength of the section in bending can be reliably predicted using a stress block approach similar to that used in reinforced concrete design [3]. It is also possible to predict the ultimate strength of sections that have fewer connectors than are required to transmit the potential force that can be generated in the steel. This partial connection design is similar to that used in composite beam design [4].

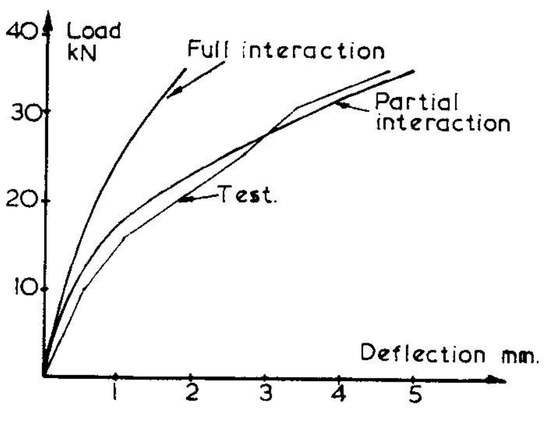


Fig. 3 Load deflection

The successful analytical modelling of the stiffness of the system is dependent upon the correct prediction of the concrete and connection behaviour. Fig. 3 shows two attempts to model the behaviour of one of the beam tests.

Initially a simple fully composite beam analysis was carried out by assuming that the full connection existed between each layer in the system. This approach can be seen to considerably overestimate the stiffness of a beam that had only partial connection and a method was therefore developed to include connector flexibility. Governing differential equations were derived using the partial interaction theory of Newmark [4]. This approach included a piecewise linearisation technique to model the non-linear connection between the various layers. The results show close agreement with the experimental work but the method is restricted to simple boundary condition problems. It should be noted, however, that the stiffness and strength of a double skin element that has been provided with sufficient well placed and adequately long connectors will be very close to that of the fully composite section.

Consequently for design purposes the engineer may analyse the section as a fully composite element and assume that the stiffness will be that derived from a cracked section analysis. This procedure will be valid as long as the following conditions are met.

a) The spacing of connectors on the steel skin in compression must be close enough to ensure buckling does not take place. This may be achieved if the centres of the studs to plate thickness ratio does not exceed 33.

b) The capacity of the shear connectors joining the steel skin in compression to the concrete should be taken as 80% of their characteristic value. This is in accord with British codes dealing with conventional composite beams [4].

c) The capacity of the shear connectors joining the steel skin in tension to the concrete should be taken as 50% of their characteristic value. This is due to the loss of strength found in connectors sited in cracked tension concrete.

d) Sufficient long studs should be provided to act as links to prevent shear failure. These may be designed using the same rules quoted in concrete codes of practice [3] although the head of the stud should normally be situated in the compression area of concrete.

3. COLUMN BEHAVIOUR

Twenty three columns of similar proportions to the beam specimens were tested to investigate the behaviour of double skin elements under axial load. Ten of the specimens were tested under a concentric load and the remaining thirteen under eccentric loads. Again the major parameters under investigation were; steel area, concrete strength and connector spacing and length. The results of this work have been presented in a report [6] and are not reproduced here. The steel skins are generally in compression in axially loaded columns and this dominates the behaviour.

The steel skins are more prone to lateral instability than the reinforcement in a conventional reinforced concrete column. The connector spacing to steel thickness ratio is therefore important. The concrete core of the double skin element needs to be confined by the steel skins in a similar way to concrete filled rolled hollow section columns. Consequently the stud pull out resistance is also critical.

However with an adequately designed section the full squash load can be achieved. It is, therefore, recommended that double skin columns can be designed using conventional reinforced concrete methods of section analysis. Once again certain restrictions are necessary.

a) The stud spacing to steel plate thickness ratio should not exceed 33 if buckling of the plate is to be avoided.

b) The length of the studs must be greater than ten times their diameter in order to avoid pull out failure.

c) For concentrically loaded columns the strength of the shear connectors should be taken as 80% of their characteristic value. This reduction is the same as that used for the connectors in the compression area of the beam elements.

d) For eccentrically loaded columns the strength of the shear connectors should be taken as 60% of their characteristic value. This reduction takes account of the possibility that some tensile strain is possible on one face of the column.

4. BEAM COLUMNS

Concentric and eccentrically loaded columns are subject to mainly compression. In order to obtain the full spectrum of behaviour between pure compression and pure bending it is necessary to test beam columns. 12 specimens of similar size and proportions to the beam and column specimens were tested with a combination of axial and lateral loads. Again steel plate thickness, concrete grade and stud spacing was varied. The detailed results of these tests are presented in a report [7].

From these tests it has been established that a ductile flexural failure may be achieved if the conditions stated above for beams and columns are met. However for beam columns where bending failure is likely then the shear connectors should be assumed to have only half of their characteristic strength in the tensile area of the section.

5. CONCLUSIONS

This paper has described an experimental programme that has invstigated the behaviour of double skin composite elements. It has been found possible to predict their strength using conventional reinforced concrete design methods as long as the shear connectors have been designed to resist shear and pull-out and are spaced closely enough to prevent steel plate buckling.

The stiffness of double skin beam elements can be analysed using partial interaction methods, although if full or nearly full connection is provided then the stiffness will be close to that determined using a conventional cracked section analysis.

6 ACKNOWLEDGEMENTS

This work has been carried out under a contract with the Science and Engineering Research Council in Britain. The authors would like to thank the sponsors for their support.

7 REFERENCES

1. NARAYANAN R., WRIGHT HD., EVANS HR., & FRANCIS RW., Double skin Composite Construction for Submerged Tube Tunnels. Steel Construction Today 1(1987)185-189.

2. ODUYEMI T O W., & WRIGHT H D., The Behaviour of Double Skin Composite Beams. Report DS1, University of Wales College of Cardiff, 1988.

3. B.S.8110: Structural use of Concrete, Part 1: Code of Practice for Design and Construction, British Standards Institution, London 1985.

4. NEWMARK, N M., SIESS, C P., & VIEST, I M., Tests and Analysis of Composite beams with incomplete Interaction, Proc. Society for Experimental Stress Analysis, 9(1), 1951, pp75-95.

5. B.S.5950: Structural use of Steelwork in Building, Part 3.1: Code of Practice for the Design of Composite Beams, British Standards Institution, London 1988 (draft for public comment)

6. ODUYEMI T O W., & WRIGHT H D., The Behaviour of Double Skin Composite Columns, Report DS2, University of Wales College of Cardiff 1989.

7. ODUYEMI T O W., & WRIGHT H D., The Behaviour of Double Skin Composite Beam-columns, Report DS3, University of Wales College of Cardiff 1990.