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# Ultimate behaviour and design of post-tensioned composite slabs

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ABSTRACT

Post-tensioned composite slab systems consist of concrete slabs poured on thin-walled profiled steel sheeting and prestressed soon after casting. This paper presents six experimental tests that investigate the influence of different parameters on the ultimate behaviour of post-tensioned composite slabs. For this purpose, the samples were tested to failure in a simply-supported configuration. The parameters considered in this study included the slab thickness, the number of prestressing strands, the span length and the continuity of the profiled sheeting. A design model is also presented for the evaluation of the ultimate moment capacity by extending the applicability of procedures currently available for composite and prestressed floor slabs. The proposed theoretical approach was validated against the measurements presented in the paper and available in the literature. The comparisons carried out between the experimental measurement and the calculated capacities showed close agreement.



## 1. Introduction

Post-tensioned composite floors consist of concrete slabs poured on thin-walled profiled sheeting and prestressed soon after the casting. This structural solution is commonly used in concrete construction where the post-tensioned composite slab spans between reinforced or prestressed band beams, as illustrated in Fig. 1. The potential advantages of this structural system based on strength considerations were first pointed out, to the knowledge of the authors, by Schravendeel et al. [1]. A decade later, further research on post-tensioned composite slab systems was carried out in Scandinavia placing particular focus on the characterisation of the bond behaviour between the concrete and the steel deck during post-tensioning and on the ultimate behaviour of continuous slab arrangements. [2,3] In the last decade, an innovative use of profiled sheeting combined with prestressing was proposed in the UK where the tensioning of the tendons was induced by the concrete self-weight. [4,5] For the post-tensioned system investigated in this paper, the strands are not connected to the sheeting and the prestressing takes place only after the hardening of the concrete. Patrick and Lloyde [6] performed three tests to compare the performance of a composite slab and of a post-tensioned solid slab to the one of a sample combining the use of the prestressing and the profiled sheeting. In this study, the profiled sheeting was Fielders KF57 [7]. In recent years, six long-term and ultimate tests were reported in [8,9] and related to samples cast on Stramit steel profiles [10].

In this context, the main contributions of the paper can be subdivided in: (i) the reporting of new experimental measurements to be used as reference for the benchmarking of theoretical and design models; and (ii) the development of a new theoretical model suitable for routine design (currently included in the final draft of the Australian composite code [11]) by extending the applicability of procedures currently available for the composite steel-concrete slab design, e.g. [12,13], and for the design of prestressed solid slabs, e.g. [14–17]. In particular, the proposed experimental programme, with samples cast on profiled sheeting, evaluated the influence of different parameters, such as the slab thickness, the number of prestressing strands, the span length and the sheeting continuity over the supports, on the ultimate post-tensioned composite response, as summarised in Table 1. Comparisons carried out between the predictions obtained with the proposed theoretical model and those measured during the experiments presented in this paper and available in the literature [9] showed good agreement.

## 2. Experimental programme

### 2.1. Test specimens

Six post-tensioned composite samples were prepared and tested to failure in this experimental programme. The static configuration specified in the experiments was a simply-supported one. The adopted steel sheeting was 1 mm thick and consisted of Stramit Condeck HP® profile which possesses a cross-sectional area of 1620 $mm^2/m$ [10]. These specimens are referred to as S1-S6 in the following. Their dimensions and number of strands are specified in

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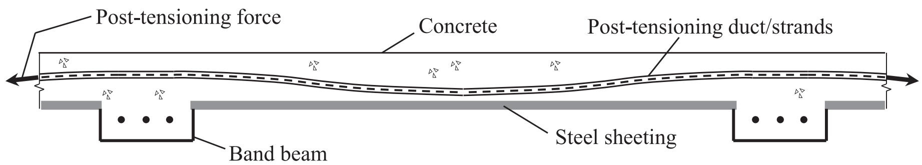
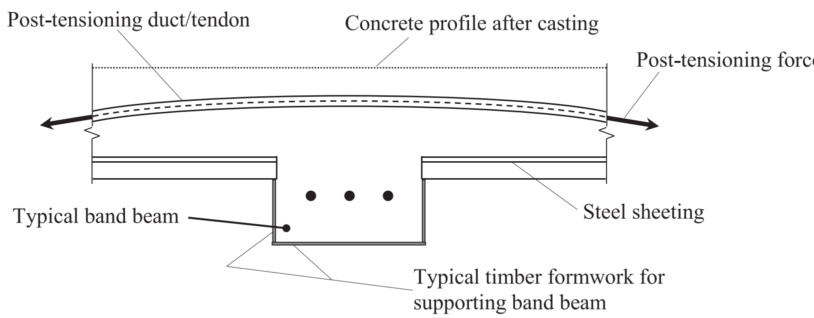



(a) Typical elevation of a post-tensioned composite slab supported by band beams




(b) Typical construction detail of profiled steel sheeting being supported from formwork of band beam before concrete pour

**Fig. 1.** Typical post-tensioned composite slab.

**Table 1**
Summary of test specimens.

| Sample ID | Thickness, $D_c$ (mm) | Internal Span, $L$ (mm) | Distance between line loads, $L_2$ (mm) | No. of strands |
|---|---|---|---|---|
| S1 | 180 | 6000 | 600 | 3 |
| S2 | 180 | 6000 | 3000 | 3 |
| S3 | 180 | 6000 | 600 | 3 |
| S4 | 180 | 6000 | 600 | 3 |
| S5 | 225 | 7450 | 600 | 4 |
| S6 | 225 | 7450 | 600 | 5 |

Table 1 considering the layout shown in Figs. 2a and b. The parameters varied in the preparation of the specimens included their geometry, the sheeting continuity over the support, the number of strands and the curing process. In particular, the overall length of specimens S1-S4 was 7.2 m. The samples were 180 mm thick. Their internal span between roller supports was equal to 6 m. Samples S5 and S6 had a larger thickness equal to 225 mm. Their overall length and internal span were 8.65 m and 7.45 m, respectively. An overhang with a length of 600 mm was included at each end of the slabs to minimise the prestressing anchorage influence over the internal span length. Slab widths were measured before the tests and were equal to 880 mm (for sample S1), 880 mm (for S2), 890 mm (for S3), 895 mm (for S4), 900 mm (for S5) and 900 mm (for S6). Transverse N10 reinforcement (where N10 is the Australian designation for a 10 mm diameter reinforcing bar with normal ductility) was specified at the top of the samples at a spacing of 300 mm (this reinforcement is not shown in Fig. 2 for clarity). In the preparation of the samples the profiled sheeting was terminated before the supports by a distance of 100 mm (except S3) as shown in Fig. 2c. This was carried out to better reflect the real site conditions, in which case the sheeting is not able to develop a reliable grip within the supporting band beams as depicted schematically in Fig. 1b. In current construction practice, band beams are cast on timber formwork. A continuous profiled sheeting was adopted in the preparation of sample S3 to develop a frictional resistance over the support and to determine whether there could be ductility issues arising from this arrangement, particularly significant in view of the brittle failure of the post-tensioned composite slab reported in [6].

12.7 mm diameter strands were used for all prestressing operations. They were installed using flat metal duct. The strands were tensioned to 85% of their capacity (i.e. equivalent to 156 kN/strand). The number of strands specified varied between samples, i.e. 3 strands for samples S1-S4, 4 strands for specimen S5 and 5 strands for S6 (Table 1). Over the overhang segments the prestressing duct was located horizontally at mid-height of the slab, while its profile varied parabolically between the roller supports (i.e. over the internal span). The distances between the top of the slab and the centreline of the strands were measured (at the mid-span) after completion of the tests and after cutting the specimens in half. In particular, these distances were equal to 123 mm, 137 mm, 130 mm, 146 mm, 175 mm and 168 mm for samples S1–S6, respectively, while, for sample S2, the distance measured at the location of the line load was about 120 mm.

### 2.2. Material properties

Average compressive cylinder strengths for the concrete were measured at the time of the different slab tests and these varied among the samples because the ultimate tests were carried out