Slimdek: development of an integrated floor system

Slimdek - Development of an integrated Floor System

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Summary

The paper outlines the Slimdek floor system introduced in 1997, which allows the integration of the strucural and service elements in multi storey building construction. The system eliminates downstand steel beams and introduces new beam and deck components designed to maximise structural efficiency.

1. Overview

In the United Kingdom, Ireland and Sweden, steel frames have achieved a high market share through the introduction of efficient design methods of floor construction. Structural systems based on both pre-cast units and composite steel decks, supported on steel beams either below or within the floor plate have been well researched and reported. These have until now been based on standard components.
In May 1997 British Steel plc launched a totally new floor system which addressed the need to integrate the Architectural, Structural and Servicing demands of construction in a single engineered package - **Slimdek** See fig 1.

The initiative is an innovative approach to the design and construction of multi storey buildings, being engineered to optimise efficiency in both room temperature and fire design states, whilst allowing extensive options for both passive and active servicing of structures. The project has built on the experiences of the Slimflor sections developed for the UK construction market.

In 1991 British Steel invested heavily in its Lackenby Beam mill at Teesside which gave the capability to roll the first new Universal Beam section for over forty years, the Asymmetric Slimflor Beam (ASB). Coupled with this new beam is the design and production of a new deep composite profiled steel deck, SD225. These products, together with a new Rectangular Hollow Slimflor Beam (RHSFB) and the existing Slimflor Beam SFB) form the major components of **Slimdek.**

The **Slimdek** system development has been managed by the Structural Systems Development Team of British Steel SP&CS. The project has been a joint initiative based on team work between several British Steel Divisions, The Steel Construction Institute and the UK Department of Trade and Industry through the LINK Enhanced Engineering Materials Programme.

2.1 The Asymmetric Slimflor Beam (ASB)

The Asymmetric Slimflor Beam (ASB) is designed for with maximum standardisation and optimum structural efficiency in both the normal design state and at elevated temperatures.
The section is rolled with an embossed top flange to enhances the shear bond between the beam and the over-lying in-situ concrete thus eliminating the need for welded shear connectors. Tests have shown that a design shear bond strength of $0.6N/mm^2$ can be developed between the steel and concrete.

As with the existing Slimflor Fabricated Beam (SFB) the ASB achieves a fire rating of 60 minutes due to the inherent fire resistance of the section. It has a web of greater thickness than that of the flange to achieve the fire resistance properties. The thicker web also enhances the section's torsional properties. Three ASB sections are currently available, two of which are nominally 280mm deep and one 300mm deep. These dimensions have been chosen to achieve specific target load and span characteristics. The load / span range is targeted for the medium span building :

Beam Section	Beam Span	Deck Span	Imposed Load kN/m^2
280ASB 100	6m	6m	5 + 1
280ASB 136	7.5	6	3.5 + 1
	6	7.5 propped	5 + 1
300 ASB 153	7.5	7.5 propped	3.5 + 1
	7.5	6	5 + 1

The ASB is designed specifically for use with the SD225 composite deck and has been designed to enhance the deck's capabilities by allowing service voids to be formed through the web at 600mm centres, aligned with the deck profile.

2.2. The SD225 Deck

This advanced composite deck profile is 225mm deep with spanning capabilities of up to 6.5m unpropped and up to 9m propped. Composite action is improved by the transverse embossments in the deep deck profile, and by reinforcing bars located in the ribs of the deck. These bars also enhance the fire resistance of the slab. The deck has been detailed to facilitate complete service integration either within the depth of the deck profile and through holes in the ASB section, or hung from a dovetail housing in the rib trough.
'Cut outs' are provided at the ends of the deck sheet to facilitate ease of handling on site and also to ensure adequate placement of concrete around the steel section. The SD225 decking is supplied by Precision Metal Forming Ltd., a subsidiary of British Steel.

2.3. RHSFB Section

In order to achieve a completely flat slab finish, the RHSFB has been developed to complement the **Slimdek** system. It consists of a Rectangular Hollow Section with a plate welded to its underside. The hollow section has superior torsion properties to normal open sections and is ideal for use as an edge beam where the outer face of the RHS is often exposed giving the ability to fix cladding attachments directly on to the steel section.

3. Advantages of Slimdek

The System is fully engineered for minimum construction depth with all the benefits Slimflor plus:

- **Composite Action without the need for shear stud connectors**
  The ASB section is rolled with a patterned top flange to enhance the composite action with the in-situ concrete, so eliminating the use of shear connectors. This major advantage has been validated through extensive testing.
  The dynamic and static load tests carried out at City University on 7.5m span ASB sections have demonstrated that a design shear bond strength of 0.6N/mm^2 may be developed around the upper flange and web. This composite action is enhanced by the raised pattern on the top flange. However, it is not normally necessary to utilise full composite action at the ultimate limit state, since serviceability and fire limit states tend to control the design.

- **Inherent fire resistance**
  The ASB gives optimum design performance in both the normal design state and at elevated temperatures. The section has a web of greater thickness than that of the flange which not only provides good fire resistance properties but, enhances the section's torsional properties. The three current ASB sections have been developed to achieve 60 minutes fire resistance in **Slimdek** construction without requiring protection of the exposed bottom flange.

- **Savings in fabrication costs**
  By eliminating the need to fabricate up the Slimflor section, a lighter and more economic section is produced. Economic assessments of the **Slimdek** system have shown that there is a potential weight saving in the order of 15% to 25% over the conventional Slimflor concept. Lower costs for the attachment of connection plates and the avoidance of secondary beam connections are also achieved.

- **Readily available section with defined properties**
  Because the ASB is a rolled section, its properties are easily calculated and tabulated. All the sections are Class 1 to EC3, thus allowing their moment resistance to be calculated for plastic analysis principles.

- **Reduced Construction Costs**
  The spanning capability of the SD225 deck allows most short to medium span floor grids to be achieved by the system without the need for secondary beams. This allows the weight of the ASB to be offset against the costs of construction with primary and secondary beams of traditional composite decks. The savings in shear studs, fire protection and fabrication make **Slimdek** a highly competitive system.

- **Enhanced servicing of deck**
  The **Slimdek** system has been designed to allow the maximum ease of serving either below the deck or integrated into the floor system. Simple fixing systems for service supports have also been developed to compliment the system.

4. Slimdek details

4.1. ASB

Currently three ASB sections are available for use in the system. Each are designated by their nominal weight, 280 ASB 100, 280 ASB 136 and 300 ASB 153, and all are rolled in S355 grade steel. Common to all three sections is a nominal 190mm wide top flange and a nominal 300mm wide bottom flange onto which the SD225 deck spans. The required end bearing for metal decks of 75mm is thus satisfied. The optimum span range for the 280 ASB section is between 6.0m and 7.5m. The 300 ASB 153 section has greater load carrying / spanning properties and is designed so that the slab surface can be cast 30mm over the top of the section, thereby achieving composite action, or alternatively flush with the top of the section (non-compositely). For the latter condition additional bars are required to pass through the section to develop the necessary tying action in the floor slab.

The slab depth is controlled by the concrete over the top of the ASB to permit the placement of crack control mesh. 30mm is the minimum figure allowing a total depth of 290mm to 315mm, depending on the section size. These slab depths satisfy the insulation requirements for 60 minutes fire resistance with both normal and lightweight concrete. When designing beams with a concrete cover to the steel section greater than 60mm concrete above this thickness is ignored in strength and stiffness calculations.

4.2. SD225 Decking

The new deck developed for the **Slimdek** system is designated SD225. This deck has been designed to achieve greater unpropped spans than any other deck todate, and also to facilitate erection and subsequent servicing operations. The wide re-entrant profile to the crest increases the effective use of the steel, and allows the services fixing developed for the system to be easily clipped into position by hand. Additional re-entrants in the rib give additional fixing points for the ceiling grid. As with all composite decks embossments rolled into the steel along the length of the sheet generate the bond to resist slip with the concrete topping. Both normal and lightweight concretes may be specified. The minimum depth of the SD225 slab formed is 290 which permits the 30mm cover to the 280ASB.

5. Longitudinal Shear Connection

The encasement of the ASB by the concrete topping to the SD225 deck produces a block of concrete which is effectively locked between the flanges of the section. Mesh reinforcement across the top flange acts to transfer longitudinal forces from this block into the slab, and controls cracking across the beam. The degree of interaction is relative to the shape of the section, the slab depth and width, and the natural bond between steel and concrete. The ASB uses an embossed pattern to the top flange to enhance the natural bond and to permit this bond to be effectively taken into account in the design.

A test programme, designed by the Steel Construction Institute, was conducted, to establish the appropriate shear bond, and to develop a design methodology for the ASB. Dynamic tests on a load up to 85% of the bending resistance of the steel section, through 1000 cycles, and static loads to establish the unloading stiffness of the section after plasticifation started.The permanent deflection measured load test was less than 1mm, proving negligible slip between steel and concrete.
The failure criteria for the static load tests was set at span/50. This failure criteria was achieved at very close to the plastic resistance of the composite section. Back analysis of the results proved that the shear connection between steel and concrete was between 90 and 100%, and the corresponding increase in bending resistance of the plain section between 42 and 46%

From the tests a design methodology for ASB sections has been established which utilises the shear bond generated between the steel and concrete topping to three decking profile. Minimum and maximum concrete cover to the steel sections have been set to ensure the bond generated is achieved. Typical calculations are normally found to be serviceability dependent for room temperature calculations.

6. Fire Resistance

The ASB Section generates optimum design efficiency at the fire limit state. The web is more effective than the exposed bottom flange, which acts at a reduced strength in a fire situation to achieve 60 minutes fire resistance. The minimum depth of concrete over the top of the decking is dictated by fire insulation requirements at the fire limit state. Recommended depths over the top of the SD225 deck to achieve 60 minutes are 60mm for lightweight concrete and 70mm for normal weight concrete.
The fire resistance of the slab formed with SD225 deck is achieved by reinforcing bars within the deck ribs seated in circular spacers which locate the bars and ensure adequate cover.
Fire testing on the ASB with decking was carried out at the Warrington Fire Research Station, UK. The results of the tests showed that the shear bond between the ASB section and the concrete is not decreased at elevated temperatures, and the bond can be used for in design at the fire limit state. This allows the ASB sections to perform at maximum efficiency in both cold and fire design.

7. Service Integration

In buildings where, for individual comfort and control, there is a need to accommodate a variety of natural and mechanical ventilation systems, pre-planning can have a beneficial effect on the choice of structure. The **Slimdek** system gives free space directly below the floor slab, for unhindered services.

The SD225 deck allows vertical ductwork to be taken through openings formed by either wiring polystyrene blocks in place, or by using shuttering, prior to concreting. After the slab is cast and adequately cured the deck can be cut away to allow access for vertical service runs. It is also possible to integrate the services within the depth of the deck.
The SD 225 deck is detailed to allow extensive underfloor servicing. The wide indent dovetail to the top of the crest is intended for service suspension, reducing the structural floor depth by permitting services to pass through the ASB section in pre-defined duct openings.

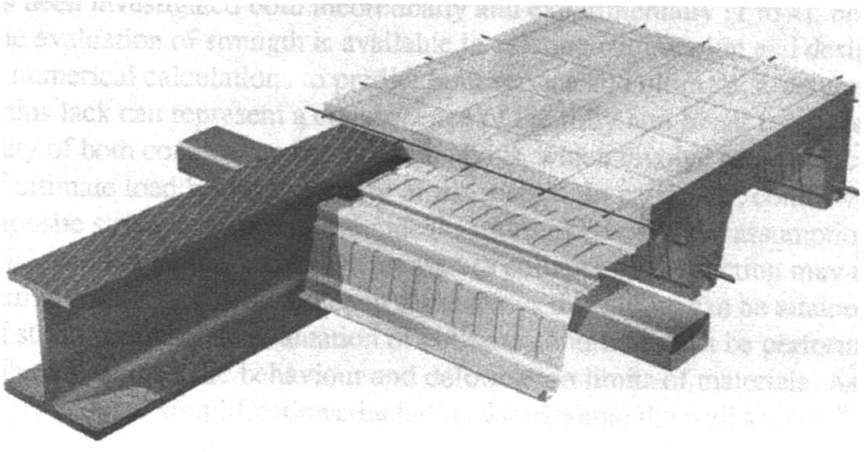
Circular or oval shaped openings may be formed in the webs of the ASBs. For detailing purposes, the openings are located at 20mm above the top of the bottom flange of the steel section. This allows clearance for the horizontal services support hangers to be located above the duct. The openings may be up to 160mm deep and the oval shaped openings may be up to 320mm wide.
When web openings are used to integrate the services, the ASB sections will always require fire protection to be applied to the underside of the bottom flange.

8. Thermal Capacity

Thermal performance and inherent durability necessitate the use of building materials and components that can respond to external environmental conditions and provide stable interior environmental control. There is a growing demand for the construction industry to tackle the 'green issues' of energy consumption both during production / construction, and throughout the operational life of the building.

The system provides simple options for natural ventilation, night time cooling and air circulation within the profile ribs reducing reliance both on mechanical services and energy requirements.

Steel frames allow the sought after flexibility of use and adaptability for the future which are essential elements for sustainable development.



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