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4.5.3 DESIGN AND CONSTRUCTION OF STEEL-CONCRETE COMPOSITE BUILDING STRUCTURES: AUSTRALIAN PRACTICE

By Emil Zyhajlo
For The Warren Centre

The selection of a building structural frame may be based on a cost-comparative preliminary design study, or it may be the result of judgement based on previous experiences. The building size, shape, location and occupancy type may favour or require a particular structure. Building elements cost relativity at the time of design, and the supply capacities of sub-trades and fabricated components (whether factual or perceived), underlie decisions on the structure selected. Designer bias and designer level of familiarity in alternative materials design methods and in the codes, particularly from smaller design offices, is a factor of design outcome. Office design procedures depend on having relevant design guides, codes and software to output cost-effective and constructible structures. Steel fabricators may need to adapt to producing hybrid steel-concrete prefabricated structural members.

Introduction

The current suitability and competitiveness of structural steel in buildings is represented by the different structures that are common to building occupancy types of residential, office, retail, and car parking. Architecture and occupancy determines the services and fire protection requirements and floor to ceiling heights, and usually the columns grids. The structure is then selected to satisfy the building function and the relevant serviceability performance parameters expected for that building. In high-rise buildings the steel structure versus concrete structure has different competitiveness and preferences outcomes to that same comparison for low-rise, multi-span construction.

The issues reflecting the total construction cost of a structure include engineered input, contractual agreements, reliability, construction method skills, logistics, construction environment and safety protection requirements. Only engineered input as applied to composite construction is considered in this discussion.

In Australia, building structure design typically assigns lateral load and stability strength to stairwells and service cores. This is particularly so in the case of multi-storey buildings; low rise may have diagonally braced frames. Moment (sway) resisting frames are not used therefore in steel-frame structures – the steel beams and steel columns basically support gravity loads.

Beams need to support floor slabs. Floor slab types that are currently used may be in situ concrete cast on strippable formwork, or cast on profiled metal decking which becomes composite acting with the concrete, or as a concrete topping cast on precast planks to form a composite concrete floor slab. Each of the available slab methods has differing suitability and is keenly cost competitive. Making the steel beams act compositely with the slab introduces direct economies in the floor costs. Design of the beams needs to further address services reticulation in the ceiling plenum space, fabrication costs, and beam connections to facilitate erection. Fire protection cost of beams and on-site installation is a fundamental issue.

In column-beam structures steel columns are rarely used without steel beam floor frames and similarly steel beams are rarely used without steel columns. They are complementary. A downside or unsuitability of one can render the total steel frame unsuitable or uncompetitive.

The cost of bare steel section structural columns is high, up to three to four times that of reinforced concrete columns in multi-storey buildings. To design a competitive steel frame using bare steel columns would require a steel-favourable structure grid or loading conditions or erection times considered to be faster than in concrete.

Codes for composite construction

A summary of coverage of composite design by Australian Codes as compared with European and American practice is as follows:

- There is no Australian Standard Code for the design of composite concrete slabs with profiled steel decking.
- There is an Australian Standard Code AS2327.1 (www.standards.org.au) for the design of simply supported beams composite with solid concrete insitu slabs (without a haunch) cast on formwork or on steel decking of re-entrant ribs profile. For the design of composite beams with negative moment actions AS2327 defers to British Standard BS5950.3 (www.bsi-global.com).
- The Australian Bridge Design Code (Austroads in collaboration with Standards Australia) Section 6 deals with composite beams and box girders for simply supported or continuous actions. The slabs must be solid concrete (haunch included), not cast on profiled steel decking.
- There is no Australian Standard Code (buildings) for the design of composite steel-concrete columns. The Australian Bridge Code Section 6 does cover the design of composite compression members using concrete-filled circular and rectangular hollow steel sections only. Section 6 is a condensed version of the Eurocode and BS Standards (that also include compression members of fully concrete encased steel sections and partially concrete encased steel sections).
- The American Institute of Steel Construction's *Manual for Load and Resistance Factor Design Specification for Steel Buildings* (www.aisc.org) includes the design of composite compression members using concrete-filled circular and rectangular hollow steel sections and fully concrete-encased steel sections and the design of simply supported or continuous beams composite with a slab or concrete encased.

Design of floor slabs

The design of composite slabs is being done using manufacturers' design guides that also include computer design software. The design method intent in each of these guides is to conform to AS3600 Concrete Structures Code. The emphasis is on capacity tables for the design of decking to support concrete in a plastic state and in the composite state on formats that relate loads, slab and decking thicknesses, and number of spans. The *Design of Composite Slabs for Strength* booklet (BHP, 1998) provides the most comprehensive Australian publication on strength design using decking that conforms to AS2327 Composite Beams Code. Longitudinal shear connection between deck and concrete has been rationalised for different decks and as vertical shear design at simply supported ends. The booklet introduces partial shear connection for different concrete strengths into flexural strength design. Design for other limit states and design conditions such as deflection, cracking control, fire, continuity design over internal supports, and lateral distribution to concentrated loads are not covered. These other conditions are treated separately and at times differently by each decking manufacturer. It is up to the designer to assess each situation individually.

For straightforward uniformly distributed load conditions onto composite slabs in steel structures, design information is adequate. There is some inconsistency of design output between designers, however that is usually within the varying bounds of designer approach.

Composite slabs on steel decking are frequently used to span between concrete, masonry or steel supports. Other forms of floor slabs using pre-cast concrete are

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