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A Study on Composite Structures – A Solution for High rise Structures in India

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***Abstract*: The development of composite structures resulted in a significant reduction in dead-load and was viewed as a viable replacement for traditional R.C.C structures in Western and European countries. Composite construction was quickly adopted for a wide range of construction projects that were generally based on structural steel frame due to its efficiency and benefits. This research study begins with an overview of the history, contemporary advances, theory, and design of steel and concrete composite structures, with a focus on building an Indian standard code of practice for precast composite structures for widespread application in India's construction industry. Technical research papers and live tests are recommended for the establishment of an Indian standard book of Codal practice for precast composite construction. The use of composite construction in high-rise residential apartments can assist meet the ever-increasing demand for housing in urban areas by speeding up construction and finishing projects within the needed time period, among other advantages.**

***Keywords*: Adaption, composite construction, cater, high-rise, precast.**

1. Introduction

When two or more materials are joined together, they behave as one thing, establishing a strong structural bond. Concrete is good in compression, while steel is good in tension, which is why composite construction is typically so good. After execution, the goal is to achieve a higher degree of performance with both of these aspects than if they had functioned alone. This study examines a new concept of Steel Concrete Composite Structures, including its benefits, types, and composite construction scenario in India, as well as the necessity for the development of an Indian standard code of practice to address its implications in the Indian construction industry. The recent experience in the field of prefabrication has made it feasible to build solutions that are both effective and cost-effective. By removing or minimizing formwork and making construction sites cleaner and safer for workers to complete a project, the composite slab system helps to speed up the construction process. Metal decking in a composite slab system serves as both a long-lasting framework for the concrete and a pliable reinforcement for the slab, eliminating the need for props. The key concepts of composite construction in high-rise residential towers are cost-effectiveness, functionality, architectural flexibility, and ease of assembly.

2. Literature Review

It is the most common type of construction in the multi-story building industry. One of the first research on full-scale composite slabs used experimental experiments to study the behaviour of metal decks, resulting in well-documented data on overall performance and slabs' maximum load-carrying capability (Baskar R.) [3]. As shown in Table 1 below, projects with Composite slab systems and varieties of Steel Concrete Composite slabs were used in the construction of respective projects in Western and European countries.

When compared to traditional R.C.C. buildings, using composite slabs with composite beams has numerous advantages. As a result, Western and European countries have modified the use of Composite slab systems to respond to the expanding population by adopting Composite construction to build residential high-rise apartments. This type of composite structure consists of Slabs, beams, shear studs, and columns.

Table 1
Projects with adaption of composite construction

Floor beam type	Slab type	Project	Location	Use	Completed
Integrated floor beam	Hollow core	ArcelorMittal Office Building	Luxembourg, German	offices	1993
Slim floor beam	Hollow core	Santa Maria della Misericordia Hospital	Udine, Italy	Hospital	2013
Slim floor beam	Cofradal slab200	Petrusse Building	Luxembourg, German	offices	2016
Slim floor beam	Cofraplus 220	Galerie Kons building	Luxembourg, German	offices, retail shops, residential flats, underground parking’s	2016
CoSFB	Cofradal slab 260	University residence	Nimes, France	Residential	2016
USFB	Hollow core precast slab	Phoenix Medical Centre	Newbury, UK	Hotels and retails	2010

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3. History and Development of Composite Structures

By the end of the 1930s, the composite slab system had evol ved in the American construction sector, and by the late 1950, it had been adopted by European countries.

Metal decks are available in a wide range of items from the American and European industries. Pentti and Sun [8] (1999] investigated the shear-connection behaviour of composite slabs with profiled steel sheets. In two test series, twenty-seven push-out test specimens of various shapes, sizes, embossment sites, and steel sheets thicknesses are used. Increases in embossment depth, length, and thickness result in considerable increases in shear stress, according to the findings. The depth of embossment is the most important of these three characteristics. Following that, a novel calculating approach was offered as an alternative to full scale testing for composite slabs with metal decks used in structures. K. N. Lakshmikandhan [7] proposed a study on composite deck systems in 2013. Three types of mechanical connectors were used in the method. These three mechanical shear connector schemes produce full shear interaction with no evident delamination or slippage. The shear connection improves the composite deck system's flexural capacity, stiffness, ductility, and energy absorption. In terms of shrinkage and temperature impacts, the flexural capacity of a steel concrete composite slab with wire mesh is determined to be competitive. In Industrialized countries, this sort of structure is rather frequent. Its success can be attributed to the strength and stiffness that can be obtained with the smallest amount of materials. R.P. Johnson (2008). In terms of building speed, composite slab technologies are also advantageous. The design of flooring systems is regarded as having the greatest influence on the total weight of steel buildings, particularly taller structures, and it is becoming increasingly important as the requirement for longer spans between columns grows. To accommodate for lightweight systems, composite deck floor slabs have been developed in the recent decade. The reductions in floor depth that composite construction may achieve can also provide significant savings in terms of services costs and building envelope, which can have a significant influence on the real estate market. U. Shah [12] (2014) used ANSYS-15 to model different thicknesses and embossments. The thickness of the profile sheet has a significant impact on the composite slab's deflection and stress. When comparing the without embossments and with embossments composite slabs, it is found that the with embossment composite slab has less deformation (almost 34%) and less stress (nearly 26%) when the thickness increases from 0.9 mm to 1.2 mm. As a result, the thickness of the decking sheet is critical in mitigating the live load.

4. Composite Construction in India

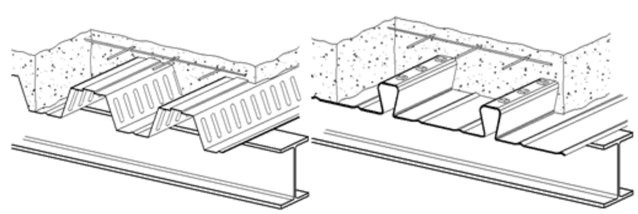
Due to overcrowding in India, particularly in metropolitan centres, there has been an increase in demand for services, which has resulted in an increase in population, which has resulted in an increase in demand for housing, which has resulted in the development of high-rise towers. When aiming for a high rise, it is imperative to lessen the structure's dead weight. The introduction of cold-formed steel decking as a construction material for high-rise structures in India was one of the most significant revolutions.

Fig. 1. Triangle of balance

The advantages of composite building have contributed to the expanding popularity of steel framed construction. Steel framed buildings with composite floors would result in a significant decrease in overall project cost while increasing construction speed and preserving project quality. Any innovative system must meet specific requirements, such as time, cost, and quality, in order to be developed. Steel deck manufacturers exist in the Indian construction market, but demand is low owing to a lack of competition and the expensive cost. However, based on current conditions and previously planned investments, India's steel production industry has a bright future for cold-formed steel deck sections. Steel costs would undoubtedly fall in the near future, making composite slab building in India more competitive.

5. Composite Construction and its Components

In the civil engineering business, the phrase "composite construction" refers to the employment of steel and concrete built together into a component in such a way that the final configuration acts as a single module, comparable to reinforced concrete construction. Composite action is what happens when this happens. As illustrated in Fig. the composite slab system consists of in situ reinforced concrete cast on top of the metal deck in two types: trapezoidal and re-entrant.


(a) (b)
Fig. 2. Composite Slabs Types (a) Re-entrant, (b) Trapezoidal

Deep decking is defined as trapezoidal decking that is more than 200 mm deep. Additional reinforcing bars may be placed in the decking troughs, particularly for deep decking or to meet fire design requirements; such bars are more effective than the decking in a fire because they are insulated within the concrete, which prevents cracking and protects against decking

Table 2
Various depths of Cofradal slab with varying spans

Floor Type	Maximum Span (m)	Unit Depth (mm)	Overall Floor Depth (mm)	Total Floor Weight (kN/m^2)	Live Load (kN/m^2)	Unit Width (mm)
Cofradal 200	7.0	200	200	2.4	4.3	1200
Cofradal 230	7.5	230	230	3.1	3.5	1200
Cofradal 260	7.8	260	260	2.8	2.5	1200

degradation, preventing slip and delamination. There are a variety of profiled metal sheets available, ranging from shallow to deep profiles, all of which are excellent for use in thin floor building systems. Composite slabs' supporting parts, namely the beams, are located at the same level as the metal decks, allowing for substantial material savings by reducing the required depth of building construction.

6. Prefabricated Composite Slabs

Prefabricated composite flooring is widely used in developed nations due to its qualities such as lightweight, ease of installation, faster construction speed, and cost effectiveness. Prefabricated composite floor slabs include hollow core (HC) precast floors and Cofradal flooring.

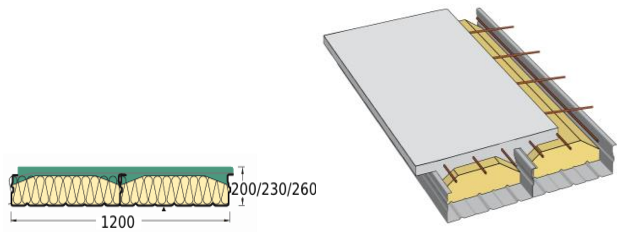


Fig. 3. Cofradal slab

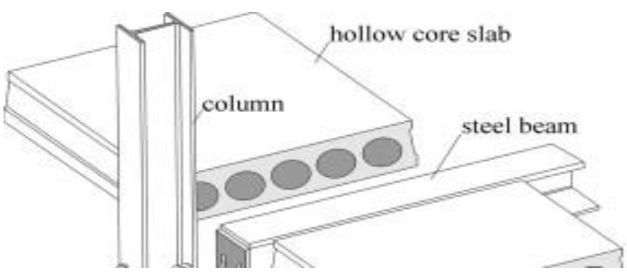


Fig. 4. Hollow core precast slab

However, these flooring systems with a depth of 250mm have spans and widths of up to 8.0m for Cofradal and 9.5m for hollow core precast units with a width of 1.2m (1,2). To meet architectural and functional requirements, as well as to reduce the number of columns and foundations, the industry has become clear that increased spans with the lowest possible structural depth and weight of the flooring system are desired, resulting in a lighter and more sustainable construction with reduced time and costs. As a result, many types of flooring systems using innovative lightweight materials have lately been created. When compared to typical composite slabs, the usage of prefabricated composite slabs is greatly enhanced since it results in additional reductions in overall floor weight, primary energy and resource consumption, as well as overall building cost. One of the prefabricated composite slabs utilized with the CoSFB beam is the Cofradal slab. It's a fully prefabricated composite slab made up of a cold-rolled metal deck and a layer of thermal insulation. The unit's depth is set at 260 mm, with a weight of 2.8 kN/m^2 and a total thickness of 260 mm. With a span of 7.8 m, two widths of 600 and 1200 mm are available.

7. Case Study

Full scale testing were conducted in collaboration with the ITB strength tests laboratory on two types of constructions, each consisting of a composite beam and prefabricated floor slabs. For this investigation, one composite beam with a theoretical span of 5.80 m, a depth of 200 mm, and a width of 300 mm in its RC section, as well as a second beam with a theoretical span of 7.80 m, a depth of 270 mm, and a wide of 350 mm in its RC part, were built. Figure 3 depicts a view of such a sort of beam. A simple supported beam loaded symmetrically by pre-tensioned Hollow core type floor slabs with a span of 6 m was used as a static method (see Fig. 3). The slabs were coated with a levelling layer of sand before the test began. A force gauge load cell was installed between either end of the beam and the support prior to the test. This allowed for the calculation of support responses and, as a result, the total load operating on the beam.

Fig. 5. Experiment photograph

The starting value of the load (derived from the weight of the beam, floor slabs, and sand levelling layer) was then read, and the force gauge load cell was cleared. The imposed load in the first phase was in the form of road RC (reinforced concrete) slabs set using a crane on a levelling layer of sand. Figure 3 depicts the layout and stacking order of the plates. The tanks were filled with water and set on the pre-arranged road RC slabs in the study's second phase. Figure 3 depicts the tank arrangement for a composite beam with a theoretical span of 7.80 m. The LDVT sensor was used to register the deflection of the beam in the centre of the span during the research. The influence of beam sinking on supports with elastomeric bearings was removed by this method of measurement. The strain gauges recorded the deflections, support responses, and stresses in chosen sections of the longitudinal reinforcement and beam surface, in addition to the deflections. During the tests, there were no evidence of splitting between the beam and the hollow core slabs that were subjected to design stresses. According to test findings, the deflection of the composite beam with a theoretical span of 7.80 m at the centre of the span in proportion to total external loading is shown in Fig. 4. (the curve 1).

8. Case Study Analysis

The test findings were compared to the rigid-plastic solutions for load-bearing capabilities of the composite beams under consideration and the slab-beam floor system solution. It should be noted that the loading operation was terminated before the slab-beam floor system's limit load was reached. Here, the deflection and ULS of a beam with a theoretical span of 7.80 m are taken into account. Due to test results, the midpoint of a beam with a theoretical span of 7.80 m deflects in response to total external loading (curve1).

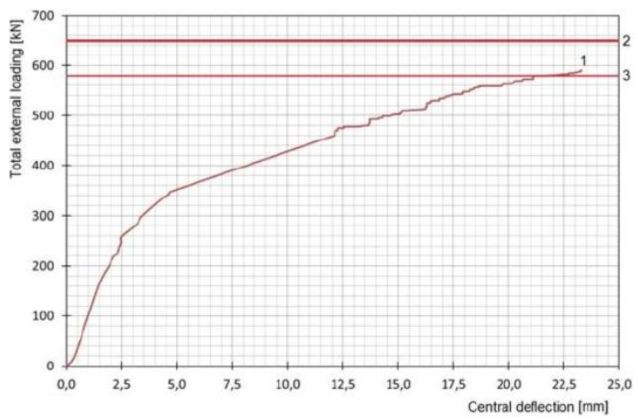


Fig. 4. Curve 1, Indicating total loading

2 – limit load of slab-beam floor system, 3 – limit load of separated composite beam Rigid-plastic solutions for load-bearing capabilities The self-weight of the slab-beam floor structure caused a bending moment of 206.7 kNm. The difference between the ultimate bending moment for slab-beam floor systems as well as isolated composite beams and the bending moment owing to the structure's own weight was used to compute ultimate bending moments due to external loads. The ultimate moment in the first example is 566.8 kNm, whereas in the second case it is 633.3 kNm. The limit load of the slab-beam floor system was calculated to be 649.5 kN (line 2), whereas the limit load of the isolated composite beam was calculated to be 581.4 kN. (Line 3, Fig. 4). The selection of the suitable assessment of load-bearing capacity of composite beams in the service condition was based on ULS of separated composite beam, according to previous experimental results. The gap between analytical (midspan deflection of 35.7 mm) and test (deflection of 22.5 mm) values for the service load of the composite beam is due to an underestimating of extra stiffness provided by the floor slabs operating with the beam. Precast H.C. and R.C. slabs demonstrated less deflection empirically than theoretical values, according to the results of the aforementioned experiment. As a result, precast composite slabs are preferred over traditional R.C.C.

9. Pros. of Composite Construction

The following are some of the benefits: The expense of lowering the height, as well as the cost of lowering the height, are also factors to consider. Rooms are freed up by longer spans with the same height column. Additional storeys that are the same height as the building's overall height Time to erection is shorter. Materials are used efficiently. Better earthquake resistance, with the ability to withstand many loading cycles without cracking. absorbing a lot of energy Quality Control Improvements, Budget-friendly Steel is more long-lasting and recyclable than other materials. Foundation expenses are reduced, formwork costs are reduced, and deflection is reduced. As a result of the benefits it provides, it is clear that this form of steel concrete composite slabs, as described, should be used by the Indian building industry., Because this new technology is not inexpensive in India due to low demand and limited competition, but it has various advantages in addition to cost, this style of building will make a significant impact in meeting the needs of the rising Indian population.

10. Need for the Development of Indian Standard Code of Practice for Precast Composite Construction

The absence of study and development of Indian standard code for its relevance in the Indian building industry is the key impediment for Composite structures not being performed on a wide scale in India. For the building of steel concrete composite structures, each nation has its own book of codal practice. As a result, it's critical to conduct extensive study in order to build a code of practice for Indian norms. In the building sector, substantial technical research data and live experimental tests are required to determine the implications in real life. "Experimental and Numerical Studies on Composite Deck Slabs," International Journal of Engineering and Technology, July 2012. Baskar, R. The following are the codal provisions of Western and European countries: (EC4-Design of composite steel and concrete structures, Part 1.1. General building rules) (BS5950: Part 4-Structural use of steel in construction.) Design of composite slabs with profiled steel sheets (Code of Practice). Standard for composite steel floor deck slabs (ANSI/SDI-C-2011). IS 11384-1998: Code of practice for composite construction in structural steel and concrete is a book of codal practice in India. Only one Indian code is currently accessible. Only the Steel Concrete Composite Beam is covered by this Indian regulation. The virtues of profile decking sheet in composite beam design are not taken into account by the Indian standard requirement. Though there is a growing trend in the composite building industry for column and floor design, there is presently no such code in India that allows it to be implemented. As a result, design advice for composite slabs is required in the Indian context. Since its inception, composite action has grown in popularity as a cost-effective way to improve structural performance while lowering costs.

11. Conclusion

In India, the use of precast composite slabs and beams is advocated in the construction of high-rise towers, for which an

Indian standard codal practice for precast composite structures, as well as technological research and tests, is required. Given the circumstances stated in this study article, there are several advantages of composite construction over traditional R.C.C., and adopting this technological breakthrough into the Indian building sector would show to be a wise move. Prior to that, technical study papers with tests based on Indian standards for precast composite building must be prepared. Some of the benefits it provides include the elimination of 50% of dead load as compared to R.C.C., quicker building speed, and the elimination of the water necessary for curing. As a result, Precast Composite Building is a must-have in the Indian construction sector to meet the ever-increasing need for housing.

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