EXPERIMENTAL STUDY ON METAL DECK SLAB

Lokesh S[1], Madhan Y[2], Sanju A[3], Dineshkumar S[4], Rajeshkannan A[5]

[1]Assistant Professor, [2345]UG Student,

Civil Engineering Department, AVS Engineering college, Salem-636003.

Lokeshselvam09@gmail.com[1], madhanv111@gmail.com[2], sanjuazhaku@gmail.com[3], dineshcvl3006@gmail.com[4], rrajesh64794@gmail.com[5]

Abstract:

Metal deck slabs are a popular construction solution, combining a metal

deck sheet with concrete to create a composite structure. This system offers numerous benefits, including reduced structural load, faster installation, and increased durability. slabs consist of a metal deck profiled sheeting which is topped with a concrete slab. The metal deck serves as a formwork for the concrete, providing a structural platform for the slab. is widely used in commercial, industrial and high-rise buildings, metal deck slabs provide excellent strength, versatility and efficiency, making them an ideal choice for modern construction projects. This study investigates the structural behavior of metal deck slabs subjected to loading. This study also highlights the importance of considering dynamic loading effects, such as vibration and impact, in the design of metal deck slabs.

Key words: Metal deck, Reinforcement, Concrete, Deck installation, Shear connector

1. Introduction

Metal deck slabs have become an increasingly popular choice for building construction due to their numerous benefits including low cost and ease of installation. Metal deck slabs are widely used in various building applications including commercial, industrial and residential construction. They offer several advantages over traditional building materials such as reduced construction time, lower costs and improved durability. This research aims to investigate the structural performance, durability and corrosion resistance with a focus on their behavior under various loading conditions. The findings of this research will contribute to the development of more efficient, sustainable, and resilient building systems.

1.1 Benifits of composite construction:

SPEED OF CONSTRUCTION

Bundles of decking can be positioned on the structure by crane and the individual sheets then installed by hand. Using this process, crane time is minimal, and in excess of 400 m^2 of decking can be installed by one team in a day, depending on the shape and size of the building footprint. The use of the decking as a working platform speeds up the construction process for following trades. Minimal reinforcement is required, and large areas of floor can be poured quickly. Floors can be concreted in rapid succession. The use of fibre reinforced concrete can further reduce the programme, as the reinforcement installation period is significantly reduced.

SAFE METHOD OF CONSTRUCTION

The decking can provide a safe working platform and act as a safety 'canopy' to protect workers below from falling objects.

SAVING IN WEIGHT

Composite construction is considerably stiffer and stronger than many other floor systems, so the weight and size of the primary structure can be reduced. Consequently, foundation sizes can also be reduced.

SAVING IN TRANSPORT

Decking is light and is delivered in pre-cut lengths that are tightly packed into bundles. Typically, one lorry can transport in excess of 1000 m2 of decking. Therefore, a smaller number of deliveries are required when compared to other forms of construction.

STRUCTURAL STABILITY

The decking can act as an effective lateral restraint for the beams, during construction, provided that the ribs run transversally and the decking fixings have been designed to carry the necessary loads and specified accordingly. The decking may also be designed to act as a large floor diaphragm to redistribute wind loads in the construction stage, and the composite slab can act as a diaphragm in the completed structure. The floor construction is robust due to the continuity that can be achieved between the decking, reinforcement, concrete and primary structure.

SHALLOW CONSTRUCTION

The stiffness and bending resistance of composite beams means that shallower floors can be achieved than in non-composite construction. This may lead to smaller storey heights, more room to accommodate services in a limited ceiling to floor zone, or more storeys for the same overall building height. This is especially true for shallow floor forms of composite construction, whereby the beams are integrated within the slab depth.

1.2 Applications:

Composite slabs have traditionally found their greatest application in steel-framed office buildings, but they are also appropriate for the following types of building:

- Commercial buildings
- Industrial buildings and warehouses
- Leisure buildings
- Stadia
- Hospitals
- Schools
- Cinemas
- Housing; both individual and residential buildings
- Refurbishment projects
- Car parks

2. Literature review

i."Investigation on the Structural Performance of Metal Deck Slabs with Different Materials" by Y. Zhang

This study investigates the structural performance of metal deck slabs with stainless steel and Fiber Reinforced Polymer (FRP). The specimens were subjected to monotonic and cyclic loading conditions to evaluate their structural performance.

The conclusion is the metal deck slabs with FRP material exhibit higher ultimate strength and stiffness compared with stainless steel materials.

ii."Experimental Study on Shear Bond Behavior of Composite Deck Slab Equipped With Shear Connectors" by Hanan Eltobgy

Hanan Eltobdy is from Egypt and this study was published on June 2021. It investigates the bond strength between lightweight concrete and steel elements in composite deck slabs. The study focuses on enhancing bond performance through the use of shear connectors.

The results showed that shear connectors improved bond strength by 20% compared to specimens without connectors and it also improves ductility.

iii."Guidelines for the Design and Construction of Metal Deck Slabs" by the American Institute of Steel Construction (AISC)

AISC publishes "Guidelines for the Design and Construction of Metal Deck Slabs" to provide recommendations for the design, fabrication and construction of metal deck slabs. These guidelines cover various aspects including materials, design, fabrication, erection and quality control.

iv."Handbook of Structural Steel Connection Design and Details" by Akbar R. Tamboli

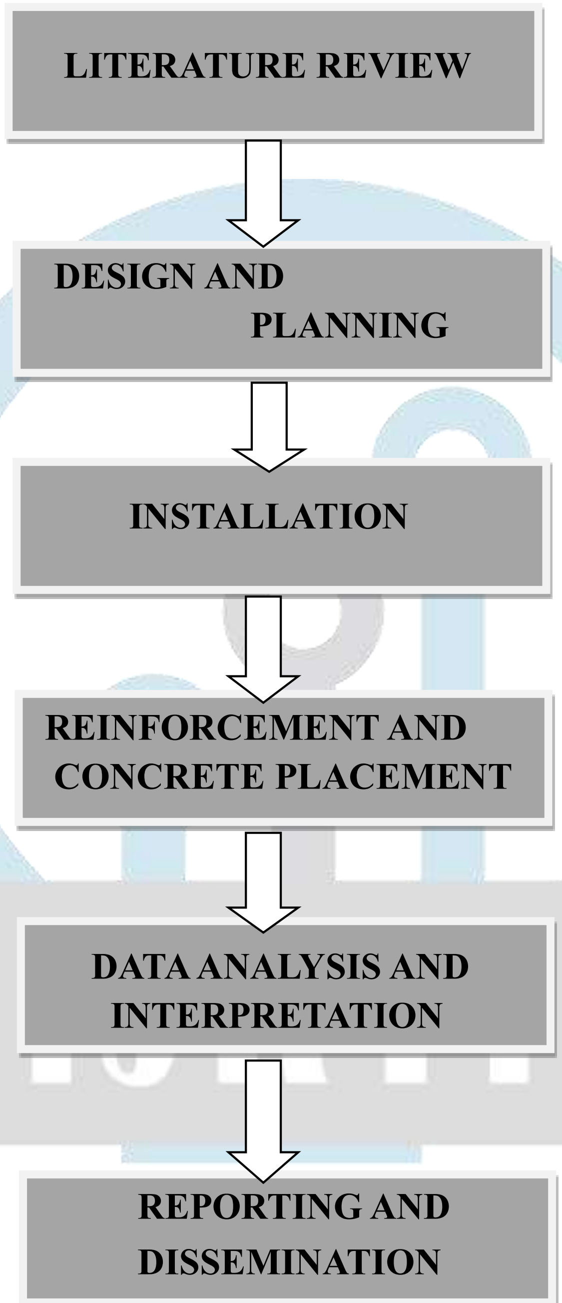
This book covers various types of connections including bolted, welded and riveted connections. It also provides fundamental principles of connection design, spacing and end distance requirements.

v."Behavior of Metal Deck Slabs under Static and Dynamic Loads" by S. K. Singh

It was published on March 23, 2021. This paper presents an experimental investigation on the behavior of metal deck slabs using galvanized steel with Re-entrant profile under static and dynamic loads. 10 mm aggregate size is used and mix proportion is 1:1:2(M25).

The results showed that metal deck slabs exhibit significant strength and stiffness but Shrinkage occurred.

3.Methodology



3.1 Literature review:

1. Conduct a comprehensive literature review of existing research on metal deck slabs including their design, analysis and performance.

2. Identify gaps in current knowledge and understanding.

3.2 Design and planning:

1. LOAD CALCULATION: Determine the loads including dead loads, live loads and any special loads.

2. SLAB THICKNESS DETERMINATION: Choose the slab thickness based on load calculations and span requirements.

3. DECK PROFILE SELECTION: Select a suitable metal deck profile considering factors like strength, stiffness and corrosion resistance.

4. MATERIAL SELECTION: Choose the metal deck material such as galvanized steel or aluminum, based on project requirements.

3.3 Installation:

1. DECK INSTALLATION: Install metal deck sheets, ensuring proper alignment and securement to the supporting structure.

2. FASTENING: Use appropriate fasteners to secure the metal deck to the supporting structure.

3.4 Reinforcement & concrete placement:

1. DETERMINE REINFORCEMENT REQUIREMENTS: Calculate the required reinforcement based on load calculations, slab thickness and span requirements.

2. **SELECT REINFORCEMENT TYPE:** Choose the type of reinforcement, based on project requirements.

3. DESIGN REINFORCEMENT LAYOUT: Design the reinforcement layout, considering factors like spacing, size and placement

4. CONCRETE SPECIFICATION: Specify the concrete mix design, strength and finish requirements.

5. CONCRETE PLACEMENT: Place concrete over the metal deck, ensuring adequate cover and finish.

6. **CURING:** Cure the concrete according to specified requirements.

3.5 Data analysis and interpretation:

1. Draw conclusions regarding the structural performance and durability of metal deck slabs.

3.6 Reporting and dissemination:

1. Prepare and submit research papers to peer-reviewed journals.

4. Materials

4.1 METAL DECKING:

0.75mm thickness Galvanized steel deck sheet is used. It has Re-Entrant profiled shape to provide structural support. The height of the rib is 51mm and the spacingof the rib is 152mm

Fig 4.1 DECK SHEET

4.2 CONCRETE:

M25 grade concrete is used. The mix proportion for M25 is 1:1:2.

4.2.1 CEMENT:

Ordinary Portland Cement (OPC) is used (53 grade). It acts as the primary binding agent.

4.2.2 SAND:

M-Sand is used which is sieved in 4.75 mm sieve. The passed sand through the sieve is used. It improves workability, durability and overall strength.

4.2.3 COARSE AGGREGATE:

20mm size aggregate is used in the concrete. The role of coarse aggregate in concrete is improving the durability through resisting the abrasion, strength and stability.

4.3 SHEAR CONNECTORS:

Headed stud shear connector is used which has 19 mm diameter and 80mm length. The stud is extended 30mm into the concrete above the decking profile. Shear connectors are spaced at 300 intervals in both longitudinal and transverse directions.

Fig 4.3 SHEAR CONNECTOR

4.4 REINFORCEMENT:

Fe415 HYSD bars are used to provide additional strength and stability. The provided reinforcement type is Mesh reinforcement.

4.5 COATINGS:

G90 Zinc coating is provided in deck sheet for corrosion resistance. In G90, G is stand for Galvanized and 90 stands for total weight of the zinc coating on both sides of the metal sheet.

5. Design of metal deck slab:

5.1 STEEL DECKING:

The steel decking has two main structural functions:

▪ During concreting, the decking supports the weight of the wet concrete and reinforcement, together with the temporary loads associated with the construction process. It is normally intended to be used without temporary propping.

▪ In service, the decking acts 'compositely' with the concrete to support the loads on the floor. Composite action is obtained by shear bond and mechanical interlock between the concrete and the decking. This is achieved by the embossments rolled into the decking – similar to the deformations formed in rebar used in a reinforced concrete slab - and by any re-entrant parts in the deck profile (which prevent separation of the deck and the concrete).

5.2 DECKING PROFILE:

The used Re-Entrant profiled deck sheet spacing between the rib is 152mm and height of the rib is 51 mm.

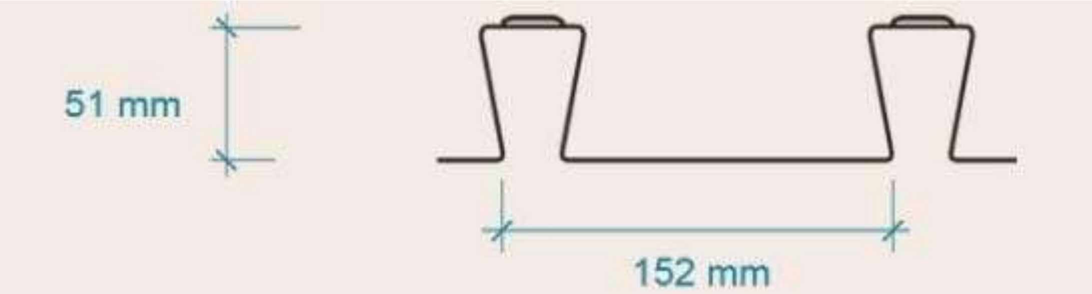


Fig.5.2 DECK PROFILE

Benefits of Re-Entrant Deck profile:

1.Enhanced Stiffness and Load Capacity:

The inward-facing corners in re-entrant profiles offer greater resistance to buckling and bending, leading to a stiffer structure capable of supporting heavier loads.

2.Potential for Suspension:

The re-entrant profile's design can incorporate stiffeners that serve as support points for hanging items from the underside of the slab.

3.Negative Poisson's Ratio:

Re-entrant structures can exhibit auxetic behaviour, meaning they expand under tension and contract under compression, which can be beneficial in certain applications.

5.3 COMPOSITE SLAB:

Composite slabs are normally used to span between 3 m and 4.5 m onto supporting (downstand) beams or walls. The ability of the decking to support the construction loads, without the need for temporary propping, generally dictates the maximum span that can be achieved (longer spans are possible when props are used to avoid the construction stage being critical). Slab thicknesses are normally in the range of 100 mm to 250 mm for shallow decking. When deep decking is used to span between shallow floor beams, the slab span is typically 6 m and depth, in the range of 280 mm to 320 mm.When the concrete has gained sufficient strength, it acts in combination with the tensile strength of the decking to form a 'composite' slab. It can be considered as a reinforced concrete slab, using the decking as external reinforcement.The load carrying capacity of composite slabs is normally dictated by the (mechanical) shear bond between the decking and the concrete, rather than by yielding of the decking. From tests, it is known that this shear bond generally breaks down when a 'slip' (relative displacement between the decking and the concrete) of 2 to 3 mm has occurred at the ends of the span. In practice, this will not occur below ultimate load levels. An initial slip, which is associated with the breakdown of the chemical bond, may occur at a lower level of load. The interlock resistance that is relied upon in design is therefore solely due to the performance of the embossments in the deck (which cause the concrete to 'ride-over' the decking), and the presence of re-entrant parts in the deck profile (which prevent the separation of the deck and the concrete).Information on improving the bending resistance of composite slabs by providing additional reinforcement, or end anchorage such as shear connectors to further control slip, can be found in BS EN 1994-1-1:2004 and BS 5950-4.If the slab is unpropped during construction, the decking alone resists the self-weight of the wet concrete and construction loads. Subsequent loads are applied to the composite section. If the slab is propped, all of the loads have to be resisted by the composite section. Surprisingly, this can lead to a reduction in the imposed load that the slab can support, because the applied horizontal shear at the decking-concrete interface increases. However, for both unpropped and propped conditions, resistances well in excess of loading requirements for most buildings can be achieved.Composite slabs are usually designed as simply supported members in the normal condition (i.e. at ambient temperature), with no account taken of the continuity offered by any reinforced concrete that is continuous over the supports. Two methods of design are generally recognised, both of which use empirically derived information on the 'shear bond' resistance of the slab from uniformly distributed loading arrangements. The more traditional method, and one which is given in both BS EN 1994-1-1:2004 and BS 5950-4, is the so-called 'm and k' method. However, this method has limitations and is not particularly suitable for the design of slabs subject to concentrated line and point loads. An alternative method of design is included in the Eurocode, which is based on the principles of partial shear connection. This method provides a more logical approach to determine the slab's resistance. It is likely that the 'm and k' method will not be retained in the Generation 2 BS EN 1994-1-1, as by now all manufacturers know the shear bond properties needed to apply the partial connection method for their decks. It is not normally necessary for designers to understand the design methodology in detail, as manufacturers normally present the design data in the form of load-span tables or software. Tables are normally only applicable for uniformly loaded conditions.

5.4 CONCRETE:

M25 concrete grade is used. The mix proportion for M25 is 1:1:2.

5.4.1 SURFACE FINISHES:

There are two basic performance conditions; concrete to be used as a wearing surface, and concrete that is to be covered by raised floors, screeds, carpets, tiles, sheet vinyl, etc. When the concrete is to be used as a wearing surface, the concrete is first power floated.The specification should then require the slab to be allowed to stiffen for a short time prior to power trowelling, which compresses and polishes the surface material, resulting in a harder and more durable surface. Recommendations for power floating and power trowelling are given in BS 8204[22] and Concrete Society Technical Report 34[23].When the concrete is not to be used as a wearing surface, it is recommended that a wood floated, skip floated or power floated finish is specified.

6.4.2 DRYING:

Because the concrete is only exposed on the upper surface of a composite floor, it can take a longer period than a traditional reinforced concrete slab to dry out. If moisture sensitive floorings and/or adhesives are to be applied, many months may be needed before the slab is sufficiently dry to accept them. Measures such as the specification of special concrete, dewatering or surface vapour-proof membranes, may need to be considered if inadequate time for drying is allowed in the contract programme.If surface vapour-proof membranes are used, moisture will be trapped in the slab. This trapped moisture will not be detrimental to the concrete or the decking, as the steel in contact with the concrete is prevented from corrosion by its high pH. Although sometimes considered, the provision of small holes, perforations, in the decking to aid drying is ineffective; the area represented by the holes is insufficient to have any significant effect on drying times.

AD 163[24] provides additional guidance on provisions for water vapour release.

5.5 REINFORCEMENT:

Mesh reinforcement is provided in the metal deck slab. It is a grid of steel wires used to strengthen concrete and mortar by providing tensile strength and reducing cracking. It increases structural integrity and distributes loads more evenly.

Benefits:

1.Increased Tensile Strength:

Concrete is strong in compression but weak in tension. Mesh reinforcement adds tensile strength, allowing the concrete to withstand tensile forces and prevent cracking.

2.Reduced Cracking:

By reinforcing the concrete, mesh helps to control and limit the size and number of cracks that may occur, enhancing the durability and appearance of the structure.

3.Enhanced Structural Integrity:

Mesh reinforcement improves the overall structural integrity of the concrete element, making it more resilient to external forces and loads.

4.Improved Load Distribution:

Mesh distributes loads more evenly throughout the concrete, reducing the risk of stress concentrations in specific areas.

5.Cost-Effective:

While the initial cost of mesh can be higher than individual rebar, it can save time and labour during installation, leading to cost-effectiveness in certain applications.

6. Slab design

It is a one way slab with a clear span of 3.5 m.

LOAD CALCULATION: (As per IS 456 (2000))

Self weight of slab = Depth of slab * Density

= 0.1 m * 25 KN/m^3

= 2.5 KN/m^2

Floor finish = 1.5 KN/m^2 (ranges from 0.75 to 1.5 KN/m^2)

DEAD LOAD = 2.5 + 1.5 = 4 KN/m^2

Total load = Dead load +Live load

TOTAL LOAD = 4 + 4 = 8 KN/m^2

Factored load = 1.5 * Total load

FACTORED LOAD = 12 KN/m^2

BENDING MOMENT:

Bending moment = (Factored load * Effective span^2) / 8

Effective span = Clear span + depth of slab

Depth of slab = span / depth ratio

= 3500 / 25

Depth of slab = 140 mm

Effective span = 3500 + 140 = 3640 mm

Bending moment = (12 * 3.64^2) / 8

BENDING MOMENT = 19.87 KN/m

SHEAR FORCE:

Shear force = (Factored load * Effective span) / 2

= (12 * 3.64) / 2

SHEAR FORCE = 21.84 KN

LIMITING MOMENT OF RESISTANCE:

Limiting moment of resistance = 0.138 fck bd^2

= 0.138*25*1000*140^2

LIMITING MOMENT OF RESISTANCE = 67.62*10^6 N/mm^2

Bending moment (19.87) < Limiting moment of resistance (67.62)

So the section is under reinforced section.

MAIN REINFORCEMENT:

Bending moment = 0.87 Fy*Ast*depth*(1- ((Fy*Ast) / fck*b*depth))

19.87*10^6 = 0.87*415*Ast*140*(1- ((415*Ast) / 25*1000*140))

Area of steel = 419.3 mm^2

Use 10mm diameter bar,

Spacing = (ast / Ast) * 1000

= (((3.14*10^2)/4) / 419.13) * 1000

Spacing = 190 mm

So provide 10 mm diameter bar at 190 mm centre to centre spacing of main reinforcement.

Spacing = (((3.14*8^2) / 4) / 198) * 100

SPACING = 255 mm

So provide 8mm diameter at 255 mm centre to centre as distribution reinforcement.

DISTRIBUTION REINFORCEMENT:

Area of steel = 0.12% of gross sectional area

= (0.12/100) * 1000 * 140

AREA OF STEEL = 198 mm^2

Using 8mm diameter bars,

7. Zinc coating Requirement

Area of deck sheet = 12.25 m^2 = 131.86 ft^2

G90 zinc coating = 0.9 oz/ft^2

TOTAL ZINC COATING IN OUNCES

131.86 ft^2 * 0.9 oz/ft^2 = 118.67 oz

TOTAL ZINC COATING IN GRAMS (Note: 1 oz = 28.35 g)

118.67 oz * 28.35 g/oz = 3365 grams

8. Conclusion

Through the experimental investigation "Metal deck slabs offer a reliable, efficient and durable solution for modern construction projects. Their composite structure provides excellent strength for various applications. It provides also various benefits like faster installation, cost-effectiveness and high strength. This study provides valuable insights into the structural behaviour of metal deck slabs under various loading conditions. The results of this study can be used to improve the design and construction of metal deck slabs, ensuring safer and more efficient structures.

9. Recommendations

1. Design and Installation: Follow manufacturer guidelines and industry standards (e.g., ASTM, AISC) for design, installation, and safety.

2. Material Selection: Choose suitable metal decking materials (e.g., galvanized steel, aluminum) based on load requirements, corrosion resistance, and budget.

3. Structural Integrity: Ensure proper support and fastening systems to maintain structural integrity and prevent damage.

4. Fire Resistance: Consider fire-resistant coatings or treatments if required by local building codes.

5. Maintenance: Regularly inspect and maintain the metal deck slab to prevent corrosion and damage.

6. Consult Experts: Collaborate with structural engineers, architects, or construction professionals for specific project requirements.

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