International Journal of Scientific Research & Engineering Trends
Volume 7, Issue 2, March-April-2021, ISSN (Online): 2395-566X

Design and Deflection Analysis of Deck Slab

Kapil Mohaliya, Sourabh Dashore (HOD)
Department Civil Department
Sanghvi Institute of Management and Science,
Indore,MP,India

***Abstract*- Steel-Free Deck Composite Bridges system has been investigated during the past two decades. The concept is totally new and innovative. The new structural system enables the construction of a concrete deck that is totally devoid of all internal steel reinforcement. Traditionally, reinforced concrete bridge decks are designed to sustain loads in flexure. The new innovative bridges with steel-free decks develop internal compressive forces "internal arching" which leads to failure by punching shear at substantially higher loads than the flexural design load. Five composite bridges have been recently constructed in Canada adopting this new concept.**

***Keywords*- GUI, Simple Span Bridges, Solid Deck Slab Bridge, T-Beam Deck Slab Bridge, Finite element method.**

I. INTRODUCTION

A Deck Slab bridge is a structure having a total length above 6m between the inner face of the dirt walls to carry the traffic loads above the natural obstruction (streams, rivers etc.) or artificial obstructions. The superstructure of the bridge comprises of the deck slab and supports. On the simple span bridge, the deck slab lay specifically on bearings through which forces and moments are transferred to the sub-structure. The deck slab bridge comprises superstructure as deck slab and supports as abutments.

Fig. 1.1 shows the typical sections of the solid deck Slab Bridge which contains components such as deck slab wearing coat, abutment and footing. The solid deck slab casting is up-front with simple, and the concrete moulds are extremely easy to build. Solid volumes might be expanded. The T-beam decks Slab Bridge include deck slab sections supported by longitudinal girders are supported by abutments.

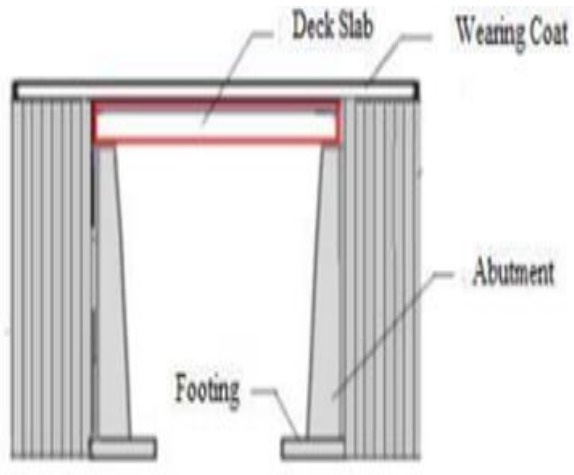

Fig 1. Longitudinal section of Solid Deck Slab.

The girders give the stiffness and strength essential for the length, and empower the section to be moderately thin and inexpensive to build. The details are required for the design of the abutment and substructure is span of bridge.

II. LITERATURE REVIEW

Cheung [2005]: studied analytically and experimentally the behavior of simply supported curved bridge decks with intermediate column supports. His analytical study was based on the finite-strip method, the results of which compared favorably with experimental values obtained from testing thirty 1:60 scale asbestos cement curved slab 13 decks.

He conducted a static analysis of orthotropic curved bridge decks with two radial edges simply supported and the other two curved edges free, using a combination of Fourier series and the finite-difference technique. The governing fourth-order partial differential equation of orthotropic plates was converted to an ordinary differential equation and solved by the finite-difference method.

Harik and Pashanasangi [2005]: presented a solution for the analysis of orthotropic curved decks subjected to uniform, partial uniform and patch loads, line and partial line loads in the radial and tangential directions, and point loads.

The analysis is based upon an approach similar to that of the finite strip, but does not require the polynomial representation and minimization procedure often associated with the finite strip. The deck was divided into radially supported curved strips, whose deflections and loads were expressed in a Levy Fourier series. Convergence was achieved by increasing the number of modes instead of the number of elements.

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Sato, Vecchio, and Andre [2005]: tested the scale model to study the behavior of reinforced concrete elements. Two important aspects of model construction and response analysis are the requirements of geometric similitude and material similitude, both must be satisfied in order for a proper model to exist. Geometric similitude requires that all linear dimensions of both the specimen and the load application system be scaled down from the corresponding dimensions of a prototype by a constant ratio, (1/S1), where S1 is the scale factor. Material similitude requires that, at any given load, the stress and strain in the model and prototype must be related by a constant stress factor Ss, and a constant strain factor Se.

The experimental results which they made indicate that reinforced 14 concrete scale models, when fabricated and tested to the requirements of replica scaling, can be used to accurately predict many aspects of prototype behavior under loading conditions.

Iqra Zaffar and Piranha Singh "Analysis and Design of Deck Slab Bridge" [2001]: Bridges are the lifelines and supporters for the improvisation of the road network. Not only do the bridges help in traffic flow without any interference but also maintain the safety of roads.

Due to this reason the bridges design has gained much importance. This paper is basically concerned about the analysis and design of Deck Slab Bridge by STAAD Pro using IRC Loading. This contains a span of 100m X 16m and has a 4-girder system.

The objective is to check the result for particular input design, properties and parameters and the approach has been taken from AASHTO standard design. The nodal displacement, beam property, vehicle loading details, concrete design can be easily found out performing the analysis and design method.

Rittik Bhowmik, S. Mukherjee, Sulagno Banerjee "Review on bubble deck with spherical hollow balls" [2011]: The aim of this paper is to discuss about various significance of Bubble Deck Slab against Conventional Slab based on the various studies. Reinforced concrete slabs are one of the most common components in modern building construction consuming most of the concrete.

Due to the sheer amount of concrete required to produce these slabs, the dead weight of them tend to be very large. Heavier structures are less desirable than lighter structures in seismically active regions because a larger dead load for a building increases the magnitude of inertia forces which the structure must resist, as large dead load contributes to higher seismic weight.

Bubble Deck is a revolutionary method which was developed in the 1990s in Europe and is gaining popularity and acceptance worldwide.

This method virtually eliminates concrete from the middle of the conventional slab, thereby dramatically reducing structural dead weight. Bubble Deck slab uses hollow spherical or elliptical balls made by recycled plastic. Plastic voided slabs are capable of reducing the amount of concrete necessary to construct a building by 30 percent or more. Voids in the middle of a flat slab eliminate up to 35% of a slab's self-weight removing constraints of high dead loads and short spans. This provides a wide range of cost and construction benefits.

III. DECK SLAB DESIGN

In addition to designing the deck for dead and live loads at the strength limit state, the AASHTO-LRFD specifications require checking the deck for vehicular collision with the railing system at the extreme event limit state. The resistance factor at the extreme event limit state is taken as 1.0. This signifies that, at this level of loading, damage to the structural components is allowed and the goal is to prevent the collapse of any structural components.

The AASHTO-LRFD Specifications include two methods of deck design. The first method is called the approximate method of deck design and is typically referred to as the equivalent strip method. The second is called the Empirical Design Method.

The equivalent strip method is based on the following:

- A transverse strip of the deck is assumed to support the truck axle loads.
- The strip is assumed to be supported on rigid supports at the center of the girders. The width of the strip for different load effects is determined using the equations in S4.6.2.1.The truck axle loads are moved laterally to produce the moment envelopes. Multiple presence factors and the dynamic load allowance are included. The total moment is divided by the strip distribution width to determine the live load per unit width.
- The loads transmitted to the bridge deck during vehicular collision with the railing system are determined.
- Design factored moments is then determined using the appropriate load factors for different limit states.
- The reinforcement is designed to resist the applied loads using conventional principles of reinforced concrete design.
- Shear and fatigue of the reinforcement need not be investigated.

The Empirical Design Method is based on laboratory testing of deck slabs. This testing indicates that the loads on the deck are transmitted to the supporting components mainly through arching action in the deck, not through shears and moments as assumed by traditional design. Certain limitations on the geometry of the deck are listed

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in S9.7.2. Once these limitations are satisfied, the specifications give reinforcement ratios for both the longitudinal and transverse reinforcement for both layers of deck reinforcement. No other design calculations are required for the interior portions of the deck.

The overhang region is then designed for vehicular collision with the railing system and fordead and live loads acting on the deck. The Empirical Design Method requires less reinforcement in the interior portions of the deck than the Approximate Method. For this example, the Approximate Method (Strip Width Method) is used.

1. Deck Thickness:
The specifications require that the minimum thickness of a concrete deck, excluding any provisions for grinding, grooving and sacrificial surface, should not be less than 7 in. (S9.7.1.1). Thinner decks are acceptable if approved by the bridge owner. For slabs with depths less than 1/20 of the design span, consideration should be given to prestressing in the direction of that span in order to control cracking.

Most jurisdictions require a minimum deck thickness of 8 in., including the ½ inch integral wearing surface. In addition to the minimum deck thickness requirements of S9.7.1.1, some jurisdictions check the slab thickness using the provisions of S2.5.2.6.3. The provisions in this article are meant for slab-type bridges and their purpose is to limit deflections under live loads.

Applying these provisions to the design of deck slabs rarely controls deck slab design. Design Step 4 – Design of Deck Prestressed Concrete Bridge Design Example Task Order DTFH61-02-T-63032 4-3.

For this example, a slab thickness of 8 in., including the ½ inch integral wearing surface, is assumed. The integral wearing surface is considered in the weight calculations.

However, for resistance calculations, the integral wearing surface is assumed to not contribute to the section resistance, i.e., the section thickness for resistance calculations is assumed to be 7.5 in.

2. Overhang Thickness:
For decks supporting concrete parapets, the minimum overhang thickness is 8 in. (S13.7.3.1.2), unless a lesser thickness is proven satisfactory through crash testing of the railing system. Using a deck overhang thickness of approximately ¾" to 1" thicker than the deck thickness has proven to be beneficial in past designs.

For this example, an overhang thickness of 9 in., including the ½ in. sacrificial layer is assumed in the design.
The project gives an idea about the analysis and design of Deck Slab Bridge using IRC Loading 70R by STAAD. Pro V8i. Here the model is being designed as per IRC 70R loading which is applicable on all roads on which the permanent bridges and culverts can be constructed.

Analysis and Design process by STAAD Pro determines the performance of Structures. The designing by the software saves the design time and by this way we can check the safety of the structure very easily.

3. Design Process of STAAD Pro Vi8:
Design RCC deck slab for the span of 100m.The width is taken 16m. The Supports are fixed. Use dead load (DL) and IRC Class 70R (displacement Y+ve and Y-ve) Loading as live load LL by STAAD. Pro using following input values:

4. Design of Typical Tee-Beam Girder RCC T- Beam Type Super Structures Design:

- This type of Super Structure involves rigorous analysis of load distribution between longitudinal girders, cross girders and panel slabs.
- We have readymade charts developed by SERC Roorkee for shear force and bending moments at critical points in girders to design steel.
- The SERC Roorkee have also developed design charts bending moments at salient points in slab panels to design steel.
- We can also develop model in STAAD- pro with beam and slab elements and analyze with moving loads input. Output gives BM and SF in girders and BM in panel slabs so that the required steel can be calculated.

5. Calculations for Sectional Properties:
Sectional Properties for the Longitudinal Girders at the Mid Span:

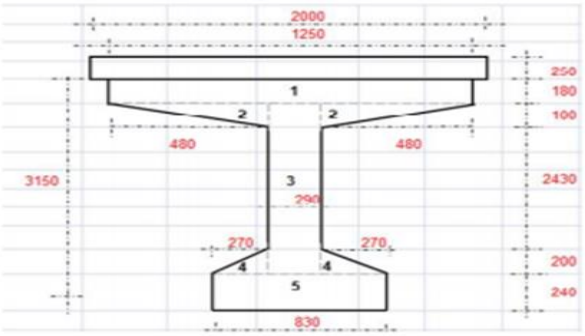

Fig 2. Longitudinal Girders at the Mid Span.

IV. RESULT AND SIMULATION

1. Design Of Longitudinal Beams:
C/C of Bearing = 50.75m
Grade of concrete= M40
Grade of steel = Fe500
Dead Load of Slab (250mm Thick)
Unit weight of concrete = 2.5T/m3

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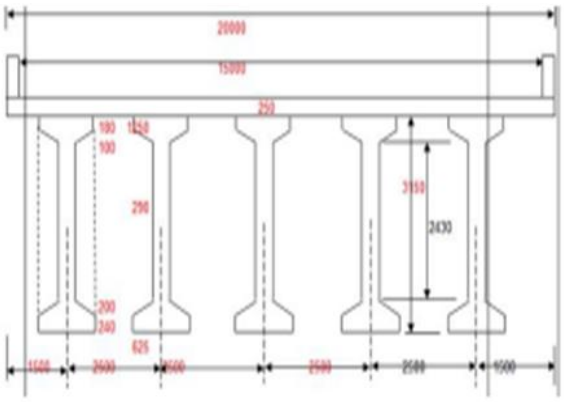
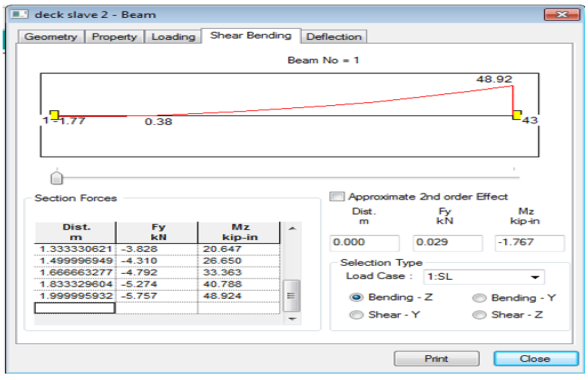
Unit weight of Wearing coat = 2.4T/m3
Thickness of slab = 250mm

2. End Girders:
Length of the Slab (1.5+1.25 = 2.75m
b = b/ + = 7.395m
(Ref. clause 305.15.2 of IRC: 21-2000) Consider least value from above two
UDL = 1.71875T/m

3. Middle Girders:
Length of the slab (1.25+1.25) = 2.5m
UDL = (2.5×0.25×2.5) = 1.5625T/m



(a)



(b)

Fig 3. Share bending EPS.

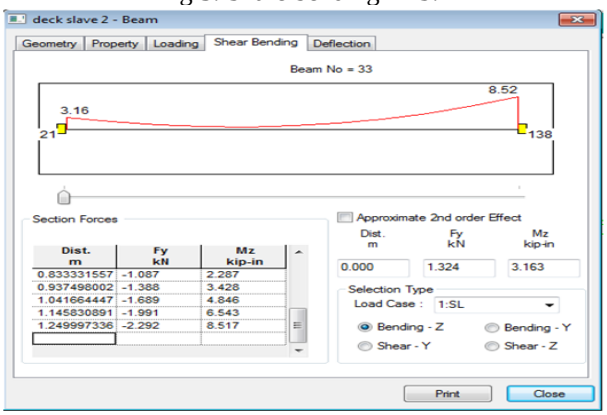


Fig 4. Share bending of steel material.

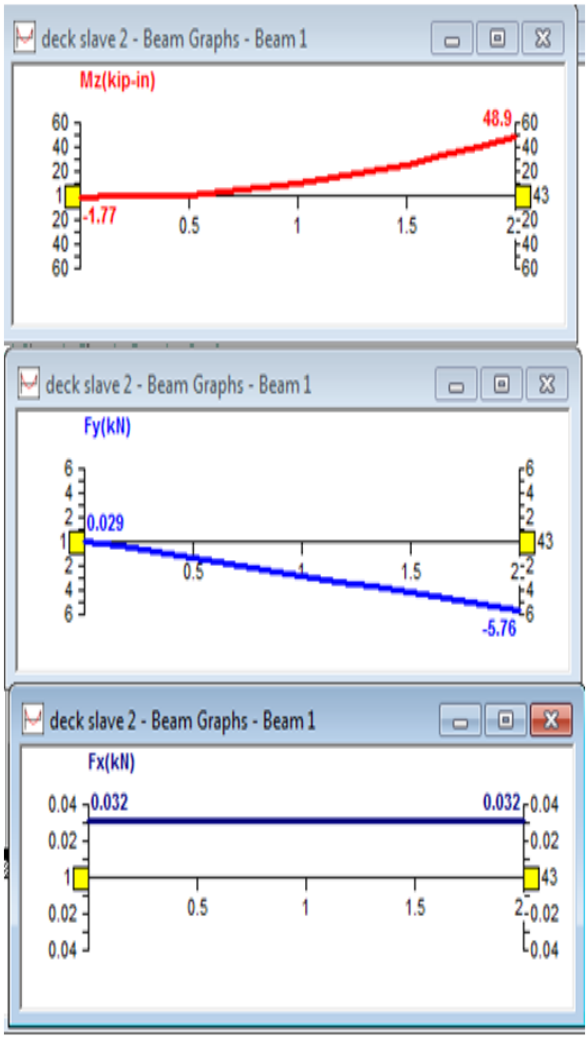


Fig 5. Movement force Fx,Fy EPS.

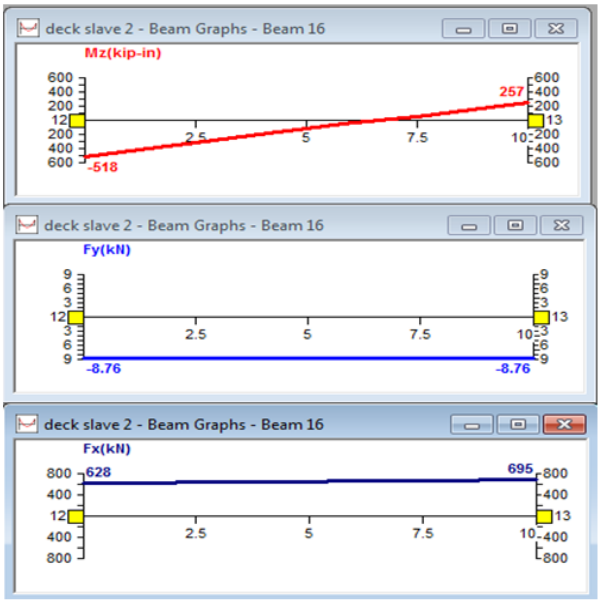


Fig 6. Movement force Fx, Fy steel deck slab.

4. Comparison Parameters:

The main purpose of this investigation is to study the properties (compressive and tensile strengths) of lightweight concrete containing expanded polystyrene beads. Its properties are compared those of the normal weight concrete (control mix). The results showed that the amount of polystyrene beads incorporated in concrete influence the properties of hardened concrete; that is lightweight aggregate could reduce the strength of concrete. However, the compressive strengths of lightweight concrete with 15 % polystyrene beads (Mix II) at 28 days for example, could maintain up to 86 % compared to those of normal weight concrete, while the tensile strength was 87%.

With the increase in demand for construction materials, there is a strong need to utilize alternative materials for sustainable development. The main objective of this investigation is to study the properties, such as compressive strength and tensile strengths of light weight concrete containing Expanded Polystyrene (EPS) beads. Its properties are compared with those of the normal concrete without EPS beads. EPS beads are used as partial replacement to coarse aggregates. The results showed that the amount of polystyrene beads incorporated in concrete influences the properties of hardened concrete. EPS beads are used as partial replacement to coarse aggregates. The results showed that the amount of polystyrene beads incorporated in concrete influences the properties of hardened concrete. At 28 days, it was found that compressive strength of 5%, 10%, 15%, 20%, 25% and 30% EPS incorporated concrete strengths were 91%, 77 %, 71%, 63%, 57%, and 45%,respectively.

- The relationship between the compressive strength and the volume fraction of the EPS concrete nearly follows an exponential decay, which is related to the particle size of the EPS and its composition.
- The EPS particle size affects the flexural strength, primarily affecting the reduction of the effective cross-section flexural height.
- The failure modes of EPS concrete is related to the EPS volume fraction: the higher the content, the better the plastic deformation. The replacement by using EPS has shown a positive application as alternate material inbuilding nonstructural members, and it also serves as a solution for EPS disposal.

V. CONCLUSION

Analysis and design of the Deck Slab Bridge as per IRC codes (here IRC 70R loading) can be easily done by STAAD. Pro. In connection with STAAD.vi8. Mechanism is well understood.

The maximum resultant nodal displacement is for node 1529; 0.015mm in x, -51.203mm in y and -.287mm in x.

The maximum and minimum values for beam maximum forces by section property are computed for axial, shear and bending.

The effect of vertical loading for 6 traffic lanes showing width, front clearance, rear clearance, no. of axles, positon in x, and position in y with orientation can be determined. The orientation varies from 0 to 1.5708.

The concrete design for element 61 gives the top and bottom longitudinal reinforcement is 0.540 and 0.545. The top and bottom transverse reinforcement are 0.540 and 0.780 for element 61. Similarly, for other element, it can be found out.

It is must for today's engineers, designers, research scholars to make an effective contribution to what is the purpose of each high quality design and for the improvement of quality of environment in which we all are residing. Thus evolution of software must be properly used so that it meets the beneficiary needs.

A linear elastic analysis of the skewed deck slab was carried out using a finite element modeling of the slab and all applicable loadings and was carried out using a scaled model too. Based on the findings of this study, the following conclusions are drawn.

The skewed slab geometry has contributed to the development of high torsional moment throughout the deck slab. This, in combination with the bending moments in two orthogonal directions, has resulted in high principal moments.

The computed load deflections of the slab correspond reasonably well with the deflection of the scaled model measured in the lab. The maximum load deflection is at the same location through FEM results and experiment work which is at 2.0 m from the point of maximum reaction of the long span 5.2 m.

A reasonably good correlation between the experimental results and the theoretical results of the model was noted. The agreement was much closer with respect to deflection. The measured reaction at the N-W corner also matched reasonably well with the theoretical values. With respect to stresses, the correlation was not as good as expected.

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