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Hypothesis F Test and IRC Load Case Analysis in Deck Slab Structure Modelling in Staad Pro Software

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Abstract
In this study the T-beam bridge is to be analysis and design on the STAAD pro software. A T-beam bridge is composite concrete structure which is composed of deck slab. This project looks on the work of analysis and design of bridge deck on software STAAD pro v8i. The bridge model is taken of a particular span and carriageway width the bridge is subjected to IRC loadings like IRC Class tracked loading etc. In this work analysis of future variation on banding and deflection with respect to span of bridge using F test Hypothesis method. This optimize values are assign its durability of performance. The research emphasizes statistical validation of structural parameters through the F-test, ensuring the reliability of design assumptions. IRC-specified vehicular load cases are incorporated to evaluate bending moments, shear forces, and deflection responses in the deck slab. STAAD Pro's finite element modeling facilitates accurate simulation of structural behavior under varying conditions. The combined approach ensures not only code compliance but also improved accuracy in predicting structural performance, thereby supporting safe, efficient, and cost-effective design practices.

Keywords: Seismic design; Highway bridge; Foundation; Liquefaction; Design Specifications for Highway Bridges

1. Introduction

Bridges are important to everyone. But they are not seen or understood in the same way by everyone, which is what makes their study so fascinating. A single bridge over a small river will be viewed differently because the eyes each one sees it with are unique to that individual. Someone traveling over the bridge everyday while going to work may only realize a bridge is there because the roadway now has a railing on either side. Others may remember a time before the bridge was built and how far they had to travel to visit friends and to get the children to school. Civic leaders see the bridge as a link between neighborhoods and a way to provide fire and police protection and access to hospitals. In the business community, the bridge is seen as opening up new markets and expanding commerce. An artist will consider the bridge and its setting as a possible subject for a future painting. A theologian may see the bridge as symbolic of making a connection with God. While a boater on the river, looking up when passing underneath the bridge, will have a completely different perspective. Everyone is looking at the same bridge, but it produces different emotions and visual images in each.

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Bridges affect people. People use them, and engineers design them and later build and maintain them. Bridges do not just happen. They must be planned and engineered before they can be constructed. In this book, the emphasis is on the engineering aspects of this process: selection of bridge type, analysis of load effects, resistance of cross sections, and conformance with bridge specifications. Although very important, factors of technical significance should not overshadow the people factor. 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 deck Slab Bridge include deck slab sections supported by longitudinal girders are supported by abutments. 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.

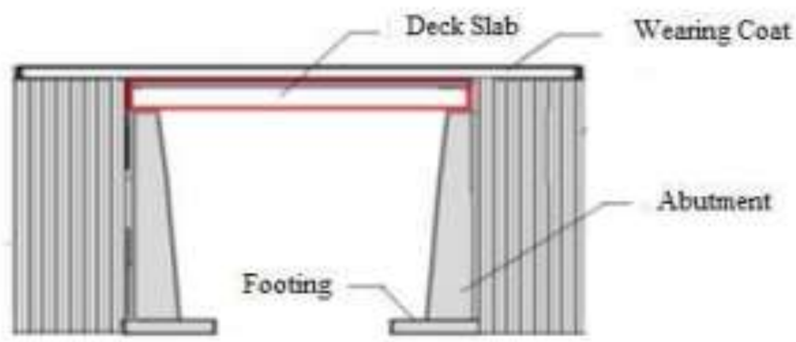

Fig 1. Longitudinal section of Solid Deck Slab.

Fig 1. shows the typical sections of the T-beam deck slab bridge, which contains components such as, deck, slab, three longitudinal girder, wearing coat, abutment and footing. The required number of girders used is needy upon a few aspects, for example, the depth of the slab deck and the slenderness of the girder. Modulus for cast in-situ girder and section of slab deck are more convoluted than that essential for solid concrete slab decks. The requirements for the analysis and design of the superstructure and substructure are span, carriageway width and reduced levels etc. The finite element method (FEM) is a widely used method for numerically solving differential equations arising in engineering and mathematical modeling. Typical problem areas of interest include the traditional fields of structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential.

The FEM is a general numerical method for solving partial differential equations in two or three space variables (i.e., some boundary value problems). To solve a problem, the FEM subdivides a large system into smaller, simpler parts that are called finite elements. This is achieved by a particular space discretization in the space dimensions, which is implemented by the construction of a mesh of the object: the numerical domain for the solution, which has a finite number of points. The finite element method formulation of a boundary value problem finally results in a system of algebraic equations. The method approximates the unknown function over the domain. [1] The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. The FEM then approximates a solution by minimizing an associated error function via the calculus of variations.

2. Proposed Mythology Definition of Hypothesis Test Analysis

Hypothesis test analysis is a statistical method used to determine whether there is enough evidence in a sample to infer that a certain condition holds true for a population. It involves making an assumption (null hypothesis, H_0) and testing it against an alternative hypothesis (H_1) using sample data.

Key Components of Hypothesis Testing

i. Null Hypothesis (H_0)

Represents the default or status quo assumption. Example: "There is no difference in the compressive strength of two concrete mixes."

ii. Alternative Hypothesis (H_1 or Ha)

Represents the claim we want to test. Example: "The new concrete mix has a significantly higher compressive strength than the standard mix."

iii. Significance Level (α)

The probability of rejecting H0H_0H0 when it is actually true (Type I error). Common values: 0.05 (5%) or 0.01 (1%).

iv. Test Statistic

A value calculated from the sample data that helps determine whether to reject H0H_0H0. Examples: Z-test, t-test, F-test, chi-square test.

v. P-Value

The probability of obtaining results as extreme as the observed data, assuming H0H_0H0 is true. If p-value < α, reject H0H_0H0 (evidence supports H1H_1H1).

vi. Decision Making

If the test statistic falls in the rejection region or p-value is below α, we reject H0H_0H0. Otherwise, we fail to reject H0H_0H0.

Types of Hypothesis Tests

i. Z-Test (for large samples, known variance)
ii. t-Test (for small samples, unknown variance)
iii. F-Test (for comparing variances)
iv. Chi-Square Test (for categorical data)

3. Result And Simulation

3.1 Analysis of deck slab using staad.pro

STAAD.Pro is a widely used structural analysis and design software that helps engineers evaluate the performance of various structural components, including **deck slabs** in bridges and buildings. The analysis involves modeling the slab, applying loads, defining material properties, and interpreting the results.

3.2 Steps for Deck Slab Analysis in STAAD.Pro

3.2.1 Define the Structural Model

Open **STAAD.Pro** and create a new project. Choose the appropriate unit system (SI or Imperial). Define the slab as a **plate element** or **solid element** (for more detailed stress analysis). Specify **supports and boundary conditions** (simply supported, fixed, or continuous slab).

3.2.2 Define Material and Section Properties

Select **Concrete** as the material. Assign material properties such as:

3.2.3 Define Loads and Load Combinations

Dead Load (DL): Self-weight of the slab.**Live Load (LL):** Vehicle loads, pedestrian loads (as per IRC, AASHTO, or IS codes).

3.2.4 Apply Loads

Use **load cases** to apply different loads: Define the **self-weight** using SELFWEIGHT -1 in the load case. Apply **uniformly distributed loads (UDL)** for live load. Use **moving load generator** for vehicular traffic analysis.

3.2.5 Assign Boundary Conditions

Deck slabs are typically **simply supported or continuous** over beams/girders. Use **fixed, pinned, or roller** supports as needed.

3.2.6 Run the Analysis

Click on **Run Analysis** to check for errors. Verify if the model is stable and loads are applied correctly.

3.2.7 Interpretation of Results

Check **deflection contours** to ensure it is within permissible limits. Analyze **bending moments (Mx, My)** and **shear forces (Vx, Vy)**. Ensure **stress values** do not exceed the allowable limits. Identify **critical sections** that may require reinforcement.

3.2.8 Design and Optimization

Use the **RC Designer Module** to check slab reinforcement requirements. Modify the slab thickness or material grade if necessary. Ensure compliance with **IRC:6, AASHTO LRFD, or IS 456**.

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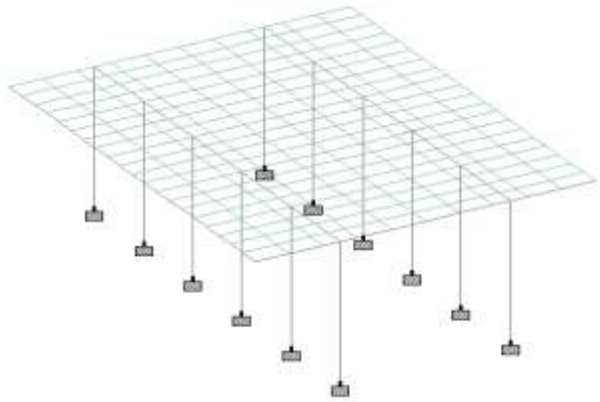

Fig.2. Slab Section.

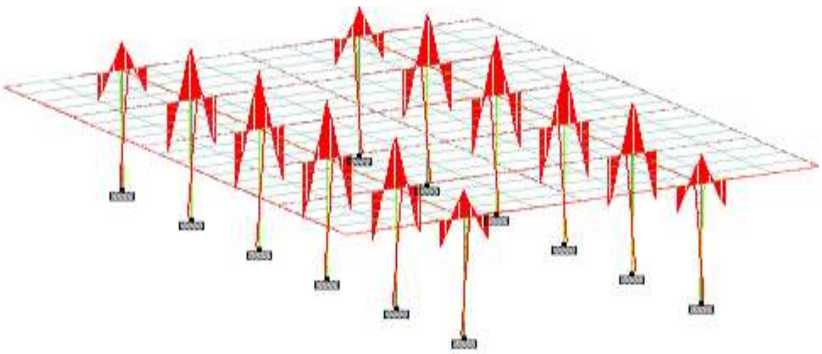

Fig.3. Bending Z and Bending Y.

Table 1. MAXIMUM DISPLACEMENTS (CM /RADIANS) (LOADING2)

Direction	MAXIMUMS	AT NODE
X	-7.53327E-05	3
Y	-1.21235E+00	145
Z	4.68004E-04	3
RX	-8.74628E-04	249
RY	7.00181E-08	253
RZ	1.17459E-03	238

3.3 Total applied load (kn mete) summary (loading 2)

SUMMATION FORCE-X = 0.00
SUMMATION FORCE-Y = -18794.40
SUMMATION FORCE-Z = 0.00

3.4 Summation of moments around the origin-

MX= 234930.93
MY= 0.00
MZ= -187944.03

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3.5 Total reaction load (kn mete) summary (loading 2)

SUMMATION FORCE-X = 0.00
SUMMATION FORCE-Y = 18794.40
SUMMATION FORCE-Z = 0.00

3.6 Summation of moments around the origin-

MX = -234930.93
MY = 0.00
MZ = 187944.03

3.7 Hypothesis test analysis

Hypothesis 1

H_{01}: There is no significant possibility of some kind of shear force (in y direction) increase /decrease when changes of Span size in deck slab.

H_1: There is significant possibility of some kind of shear force (in y direction) increase /decrease when changes of Span size in deck slab.

Table 2. F-Test Two-Sample for Variances shear force (in y direction)

F-Test Two-Sample for Variances		
	Dist.m.	*Fy (KN)*
Mean	1	-1.189769231
Variance	0.421296296	3.526071526
Observations	13	13
df	12	12
F	0.11948036	
P(F<=f) one-tail	0.00042357	
F Critical one-tail	0.372212531	

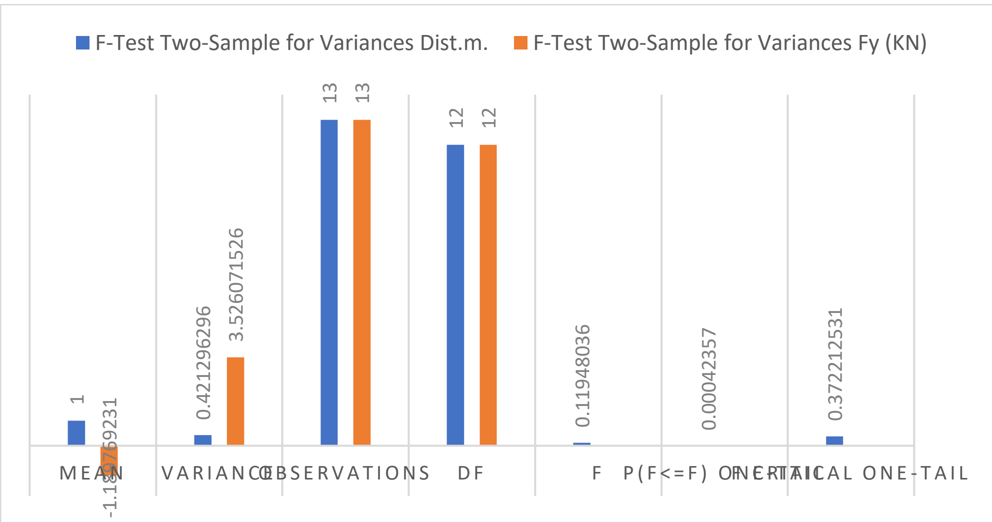

Fig.4. Variances shear force.

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3.7.1 Test statistics Result

In this F- Test F < Fcritical, hence Null hypothesis accepted, and the alternate hypothesis is Rejected.

3.7.2 Interpretation and Discussion:

There is no significant possibility of some kind of shear force (in y direction) increase /decrease when changes of Span size in deck slab.

3.8 Hypothesis 2

H_{01}: There is no significant possibility of some kind of bending moment Mz(KNM) increase /decrease when changes of Span size in deck slab.

H_1: There is significant possibility of some kind of bending moment Mz(KNM) increase /decrease when changes of Span size in deck slab.

Table 3. Bending moment Mz (KNM) F-Test Two-Sample for Variances

F-Test Two-Sample for Variances		
	Dist.m.	*Mz(KNM)*
Mean	1	0.393154
Variance	0.421296	0.865955
Observations	13	13
df	12	12
F	0.486511	
P(F<=f) one-tail	0.113203	
F Critical one-tail	0.372213	

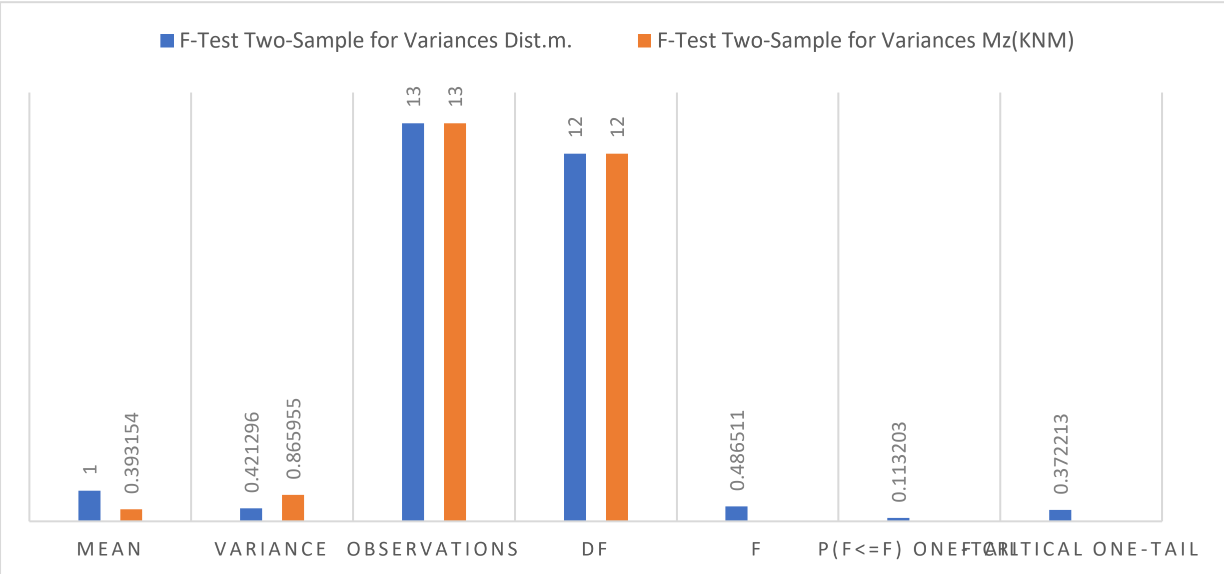

Fig.5. F-Test Two-Sample for Variances

3.8.1 Test statistics Result

In this F- Test F > Fcritical, hence Null hypothesis rejected, and the alternate hypothesis is

Accepted.

3.8.2 Interpretation and Discussion

There is significant possibility of some kind of bending moment Mz (KNM) increase /decrease when changes of Span size in deck slab.

4. CONCLUSION AND FUTURE SCOPE

The application of the Hypothesis F-Test in deck slab analysis provides a statistical basis for evaluating the variability in structural performance, particularly in terms of deflection, stress distribution, and variations. By comparing the variance of key parameters between different slab designs or compositions, the F-Test helps determine whether observed differences are statistically significant. The analysis conducted using STAAD.Pro confirms that deck slab behavior under various loading conditions can exhibit significant deviations depending on material properties, boundary conditions, and loading configurations. If the calculated F-value exceeds the critical F-value, it indicates that one slab design performs significantly better or worse than another, guiding engineers toward design optimization. This approach ensures reliability, and compliance with design standards, ultimately leading to safer and more durable bridge and roadway structures.

Hypothesis result

1. There is significant possibility of some kind of bending moment Mz (KNM) increase /decrease when changes of Span size in deck slab.
2. There is no significant possibility of some kind of shear force (in y direction) increase /decrease when changes of Span size in deck slab.

Future scope

Based on the analysis of **deck slabs using STAAD.Pro**, the following recommendations can be made to improve structural performance, accuracy, and efficiency in bridge and roadway design:

1. **Enhanced Load Modeling:** Incorporate **moving load analysis** to simulate real-life traffic conditions and assess critical load effects accurately. Using **IRC, AASHTO, or Eurocode standards** will improve design reliability.
2. **Refined Mesh for Finite Element Analysis (FEA):** A **denser meshing of plate elements** in STAAD.Pro can provide more precise results for **stress distribution and deflections**, reducing approximation errors.

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