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Time Dependent Material Analysis of Box Girder using Different Codes of Practice

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Abstract— The time dependent material analysis delivers helpful understanding into the resilience of box girder helping in their design, construction and maintenance. This paper presents a comprehensive analysis of the time dependent behavior of box girder bridges, with a particular emphasis on compressive strength of concrete. This paper utilizes different concrete design codes including IRC (Indian Road Congress) 112:2011, ACI (American Concrete Institute) and CEB-FIP (International Federation for structural Concrete) 2010 for design of M50 grade of concrete. The comparative analysis of compressive strengths based on all methods carried out shows that compressive strength calculated are in close agreement with each other. The outcomes focus on the time dependent analysis of compressive strength for the structural integrity and safety of box girder bridge.

Index Terms— Box girder bridge, Compressive strength, Grade of concrete, Time dependent material properties

I. INTRODUCTION

A bridge is a building designed to cross a physical barrier (such a water bodies, valley, road, or rail) without obstructing the path below. It is designed to allow passage over the obstruction, which is typically something that would be difficult or impossible to cross otherwise [1]. Bridges come in a wide variety of designs, each with a specific function and range of applications [2]. The role of a bridge, the characteristics of the terrain where it is built and anchored, the material used to produce the bridge, and the amount of funding available all affect how it is designed [3]–[5]. Cable Stayed Bridge is a simple type of bridge used worldwide nowadays. In this bridge the superstructure is retained by the cables which are connected to one or more towers. The cable stayed bridges are particularly used in the span reach of 100 to 1000 m and thus offer a conversion among the continuous box girder bridges and the braced suspension bridges.

The present work of structure constantly changes or evolves as the construction progresses with varying material properties such as compressive strength. The changes in concrete compressive strength gains relative to the maturities of concrete members in analyses [6]. The compressive strength gain functions can be defined as per standard specifications such as IRC 112: 2011, ACI and CEB-FIP 2010 by using MIDAS Civil.

II. METHODOLOGY

The properties should be considered, and material properties should be added after selection of appropriate concrete grade of concrete to be considered which is required for box girder bridge that is crucial for structural performance. Time dependent effect was studied using MIDAS civil software by the means of different codes used to find the compressive strength analysis. The graphs are drawn for variation of compressive strength of concrete with respect to time.

III. TIME DEPENDENT MATERIAL ANALYSIS

The time dependent material variation is to be found out with the help of codes mention above [7], [8]. The time dependent material properties are of different types such as Creep in concrete members having different maturities, Shrinkage in concrete members having different maturities and Compressive strength gains of concrete members as a function of time [9], [10]. The parameter considered is on compressive strength of concrete used in box girder bridge the concrete's material characteristics, such as its compressive strength, elastic modulus, and creep coefficients, are crucial to the understanding of time-dependent behavior.

Compressive Strength of concrete defines as the change of modulus of elasticity to reflect the variation of modulus of elasticity with time [11]. The grade of concrete used in this study is M50 and compressive strength after 28 days with respective code.

IV. DESIGN CODES

Design codes used for Analysis-

1. IRC (Indian Road Congress) 112:2011-

It is standard published by the Indian Road Congress that specifies parameters for the design and construction of various types of roads in India. It covers many aspects of road engineering, geometric design, pavement design, material, drainage and traffic control.

Formula-

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$$f_{ck}=0.35\sqrt{(28\ days\ cube\ strength)}$$

Where –

f_{ck} = Compressive strength of concrete in megapascals (MPa).

28-day cube strength = Compressive strength of concrete cubes tested after 28 days of curing.

To use this formula in Midas Civil, you would normally identify the parameters of the concrete material and specify the suitable compressive strength value based on the outcomes of the 28-day cube strength test.

2. CEB-FIP 2010-

This code is published by the Comité Euro-International du Béton (CEB) and the Fédération Internationale de la Précontrainte (FIP). It give the procedure for the design, analysis, and construction of reinforced and prestressed concrete structures. The code covers a wide range of topics associated to concrete structure, consist of material properties, structural analysis, design principle, durability and construction practices.

Formula:

$$f(t) = (f_{ck} + \Delta f) \times exp\left(s\left(1 - (28/_{teq})^{0.5}\right]\right)$$

Where -

$f_{(t)}$ = Characteristics compressive strength of concrete at time t.

Δf= Strength increase factor. (Representing the long-term strength gain of concrete due to hydration and other factors).

f_{ck}= Characteristic compressive strength of concrete.

s= Coefficient representing the decay rate of strength over time.

teq= Equivalent age of concrete (expressed in days).

Concrete is classified in three categories of oven-dry density:

- lightweight aggregate concrete (800-2000 kg/m3)
- normal weight concrete (>2000-2600 kg/m3)
- heavyweight concrete (>2600 kg/m3)[12].

Table 1. Type of Aggregates

Type of Aggregate	α_E	$E_{CO}.\alpha_E$
Basalt, dense limestone aggregate	1.2	25800
Quartzite aggregate	1.0	21500
Limestone aggregate	0.9	19400
Sandstone aggregate	0.7	15100

Table 2. Type of Cement

f_{ck}	Strength class of cement	s
≤ 60	32.5 N 32.5R,42.5N 42.5R,52.5N,52.5R	0.38 0.25 0.25
> 60	All classes	0.20

3 ACI (American Concrete Institute) 209R-92-

This code is published by ACI that provides recommendations for the design of concrete mixture. It Focuses on the selection and proportioning of material, such as aggregates, cement and water to achieve desired concrete properties. The code offers guidance on factors like workability, strength, durability and economy in concrete mix design.

Formula:

$$f_c'(t) = \frac{t}{a + \beta t}(f'c)_{28}$$

Table 3. Type of cement and curing method.

Type of curing	Cement Type	a	β
Moist	I	4.0	0.85
Moist	III	2.3	0.92
Steam	I	1.0	0.95
Steam	III	0.7	0.98

Where-

a and β= function of cement type, curing method and the parameters that affect the shape of the strength development curve over time.

t = Time (measured in days).

$(f'c)_{28}$= 28-day compressive strength of concrete.

V. MIDAS CIVIL ANALYSIS

Graphs in MIDAS civil software

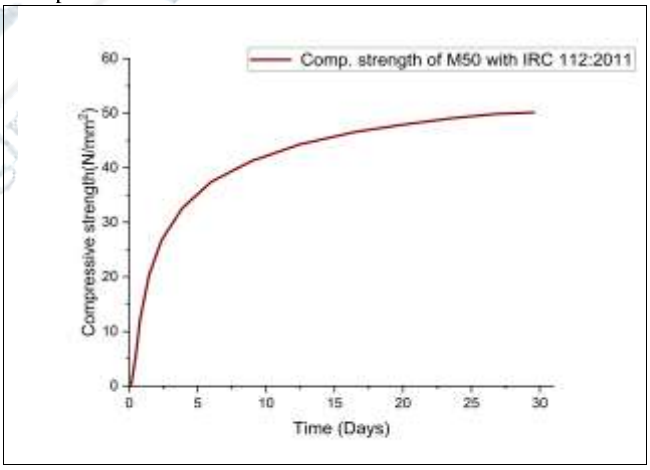

Figure 1. IRC: 112:2011 presents compressive strength of M50 grade of concrete.

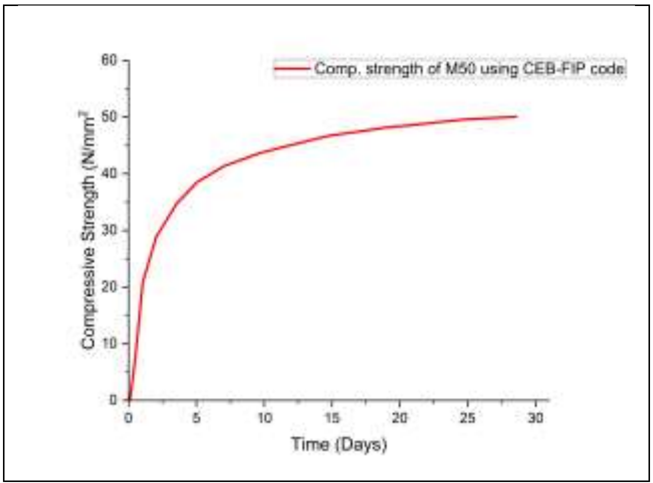

Figure 2. - CEB-FIP 2010 presents compressive strength of M50 grade of concrete.

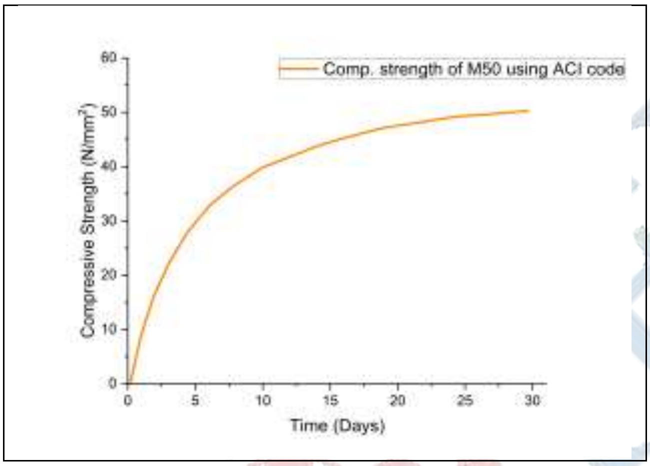

Figure. 3. ACI code presents compressive strength of M50 grade of concrete.

VI. RESULT

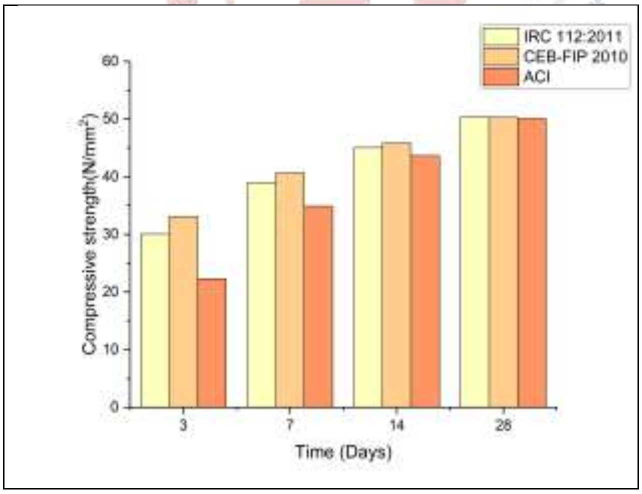

Figure. 4. Difference between codes for M50 grade of concrete.

Table. 4. Compressive strength percentage of M50 concrete grade with different codes.

Days	IRC 112:2011	CEB-FIP 2010	ACI
3	60.11 %	66.20 %	44.57 %
7	77.89 %	81.25 %	69.77 %
14	90.07 %	91.60 %	87.29 %
28	100.73 %	100.55 %	100.15 %

VII. CONCLUSION

The study of time dependent material behavior precisely focusing on compressive strength is important for forecast of the performance of box girder bridges. This analysis offered full research using IRC: 112:2011, ACI, CEB-FIP 2010 procedures and the MIDAS software. It was observed that compressive strength of M50 grade of concrete gives greater results for CEB-FIP 2010 for 3, 7, 14 days as compared to other codes and IRC 112:2011 give maximum value of compressive strength for 28 days and the results highlight the significance of considering time dependent material properties in bridge design and emphasize the conceivable effects on structural behavior. Further research is endorsed to improve the consideration of time dependent effects on box girder bridge.

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