A Computational Approach of Prestressed Concrete Bridge Deck Slab Analysis for various IRC Classes of loadings using Pigeaud Charts

Dr. M. Siva[#1]

[#1]*Assistant Professor, Department of Civil Engineering, RMK Engineering College, Kavaraipettai-601206, Tamil Nadu, India*

Abstract

This paper aims at solving the difficulty in arriving the bending moment coefficients of bridge deck slab from cumbersome Pigeaud charts. In this study, the bending moment coefficient values from pigeaud charts are tabulated for different IRC (Indian Road Congress) classes of loadings using interpolation technique. For this study, IRC classes of loadings viz., Class AA tracked and wheeled, 70R tracked and wheeled, Class A and Class B vehicle loadings are taken into considered. A program using MATLAB software is developed to interconnect these tabulated bending moment coefficient values in the analysis of pre-stressed concrete deck slab. It is observed there is a good agreement between computational analysis and theoretical analysis. This study facilitates the analysis of pre-stressed concrete deck slab to be easier and systematic.

Keywords — *prestressed, concrete, deck slab, IRC class loadings, pigeaud chart, bending moment, MATLAB*

I. INTRODUCTION

In the current scenario, the steady increase in the volume of the traffic throughout the world results in the demand for an efficient transportation system. One of the way for reducing the fast growing traffic problem is the construction of bridges. The widely used bridge which is meant for long span construction is pre-stressed concrete bridge [1]. Since bridges were subjected to different types of loadings, there are problems like general wear and tear in the structure. Hence it becomes necessary to analyze the slabs for various types of IRC loadings like Class AA¸70R, Class A and Class B loadings [2]. The maximum bending moment and shear force were got when the bridge deck is subjected to IRC Class AA and IRC Class 70R loading systems. It was observed that for a given span and end conditions, IRC Class AA tracked vehicle gives higher values of shear force, bending moment and deflection than IRC 70R loading [3]. The common rational methods which are used for the analysis of bridge deck for bending moments are Courbon's method, Guyon-Massonet method. Courbon’s method is observed to be used when the live loads act nearer to the kerb, in which the centre of gravity of live load acts eccentrically from the girder system [4]. Guyon-Massonet method is based on the application of orthotropic plate theory in which a set of distribution coefficients were used for different torsional cases on the slab for studying the load distribution behavior. Courbon's method is observed to give average result on bending moment values for the longitudinal girders than GuyonMassonet method, whereas the GuyonMassonet method gives lower bending moment values than courbon's method of analysis [5]. Grillage analogy method analysis is the most common analysis for bridge analysis and the effect of skew angle in the reinforced concrete bridges were studied by calculating maximum bending and torsional moments for different angles and spans [6]. Bending moment calculated for bridge deck using FEM is relatively higher than the bending moment obtained by grillage analysis [7]. In the case of pre-stressed bridge decks with Tee beams, the deck slab supported on all the four sides and are spanning in two directions, the bending moments in the two directions can be computed by using the design curves developed by M.Pigeaud [8]. It is observed there is complication in using the pigeaud charts in getting the bending moment coefficients for the analysis of the deck slab, as the curves are merging together in most of charts [9]. In this study, the complications in getting the coefficients value is reduced by converting all the IRC class loading pigeaud charts into tables which contains 1000’s of values using interpolation technique. A program is written in MATLAB software for deck slab analysis in which the tables generated were used for the bending moment calculations.

II. METHODOLOGY

A. General

The flow chart for the methodology of analysis adopted for the deck slab is presented in the Figure 1. The various classes of IRC loadings to be considered for the analysis of bridge deck slab are given in the Table 1. In this study, Class AA tracked and Class 70R tracked loadings are considered for the analysis of bending moment in the deck slab.

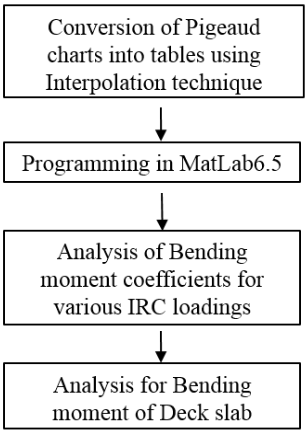

Fig 1: Flow chart for the methodology

Table 1: IRC loading standards

Type of load	Class AA		Class A wheeled	Class B wheeled	Class 70R	
	Tracked	wheeled			Tracked	wheeled
Load intensity (kN)	350	200	57	34	350	100
Contact length along longer span (mm)	3600	150	250	380	4570	263
Contact length along shorter span (mm)	850	300	500	200	840	810

B. Bending Moment Analysis For Slab Panel

The bending moment in short and long span is calculated using the formula as given below:

$$u = \sqrt{((x + 2D)^2 + H^2)}$$
$$v = \sqrt{((y + 2D)^2 + H^2)}$$
$$M_B = (m_1 + 0.15m_2)\ P$$
$$M_L = (m_2 + 0.15m_1)\ P$$

Where,

u = Dimension of the spread load, parallel to shorter span, after allowing for dispersion through deck slab in ‘mm’

v = Dimension of the spread load, parallel to longer span, after allowing for dispersion through deck slab in ‘mm’

M_B = Bending Moment along shorter direction in ‘N.mm’

M_L = Bending Moment along longer direction in ‘N.mm’

x = Wheel Contact dimension along shorter span in ‘mm’

y = Wheel Contact dimension along longer span in ‘mm’

m_1 = moment coefficient along shorter span

m_2 = moment coefficient along longer span

K = Span Ratio

L = Longer span of slab panel in ‘m’

B = Shorter span of slab panel in ‘m’

C. Conversion Of Pigeaud Chart Into Pigeaud Tables

Pigeaud chart are used for the analysis of slab panel for obtaining Bending Moments coefficients (i.e. m_1 and m_2) along longer and shorter spans. Depending on the span ratio (K) there are totally 16 charts are available. Span ratio ranges between 0.4 to 0.10. Pigeaud chart are used for estimation of moment coefficients m_1 and m_2. One of such Pigeaud chart is presented in Fig.2. Since it is difficult in getting values from the chart, it is because the curves in the chart are closer to each other. So that the Pigeaud Chart is converted into tables using interpolation technique. Twenty tables were formed and each table consists of 400 values and making a total of 8000 values on a whole.

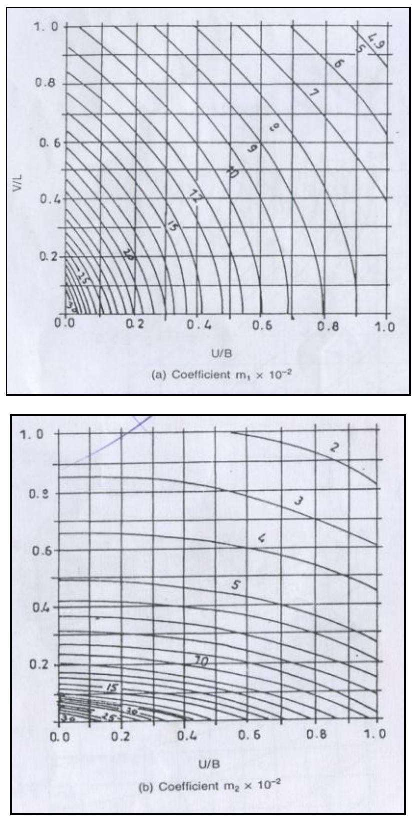

Fig 2: Pigeaud Chart for Class AA tracked (K=0.5)

D. Role Of Matlab:

MATLAB Software used for programming, because of its high-performance, numerical computation and visualization. Most of these functions use state-of- the art algorithms. The users not only limited to the built-in functions they can write his own functions in the MATLAB language. Once written, these functions behave just like the built-in functions. The basic building block of MATLAB is the matrix. The fundamental data-type is the array. Vectors, scalars, real matrices and complex matrices are all automatically handled as special cases of the basic data-type. As the bending moment coefficients from pigeaud charts are converted into the table format, it can be considered as array and can be used in MATLAB for the analysis of deck slabs. Hence in this study, a program is written in MATLAB for the analysis of deck slab. The tables that are created are converted into matrix. Various loop functions are used in the program to make it simple. The values are retrieved by using fopen command. The formulae involved in the Bending moment calculations are written in the program. A program is made in such a way that the calculations for the Bending moment are made and the result of such calculation gets printed as a output report file.

III. RESULTS AND DISCUSSION

In the analysis of slab panel, the analysis of bending moment for all the IRC loadings such as IRC Class AA tracked and wheeled, 70R tracked and wheeled, Class A and Class B is shown in the Table 2. It is observed that the bending moment of Class AA tracked vehicle caused maximum value as the load intensity is maximum compared to all IRC loadings. The bending moment of 70R wheeled load which has same intensity as that of Class AA tracked load has relatively less which is due to increased contact area compared to Class AA tracked vehicle. Hence for design of national highway and express way, Class AA tracked vehicle is chosen as the base.

Table 2: Results of bending moments for various IRC loadings

Type of load	Class AA		Class A wheeled	Class B wheeled	Class 70R	Class 70R
	Tracked	wheeled			Tracked	wheeled
Load intensity (kN)	350	200	57	350	350	100
Bending moment in longer span (Mx) (N mm)	12206	3633	994.08	603.84	8960	1974.5
Bending moment in shorter span (My) (N mm)	35530	4670	1241.17	835.04	30082.5	1889.5

A. *Analysis using Programming in MATLAB*

In order to avoid the difficulty in manual analysis of deck slab, a program is written in the MATLAB software in the command window (Fig. 3) and executed (Annexure II). For calculation purpose, the maximum IRC loads Class AA tracked and 70R tracked are considered for the analysis. The output file shows the values of the bending moment which were generated as a result of analysis (Fig. 4). A report was generated at the end of the analysis which gives a clear picture of the input and output of the analysis (Fig. 5). The output of the analysis is verified with the theoretical calculation for similar span ratio of the bridge deck slab as shown in the Table 3. The percentage differences are observed to be minimal which proves the computational method can be used for the effective analysis of bending moments using pigeaud charts.

Table 3: Comparison of theoretical and computational method for bending moment analysis

Method of calculation	Bending moment (N mm)			
	Class AA tracked	Class AA wheeled	Class 70R tracked	Class 70R wheeled
Theoretical calculation	12206.25	3633	8960	1974.5
Computational method using MATLAB	12217	3642	8974	1984
Percentage difference	0.09%	0.24%	0.15%	0.47%

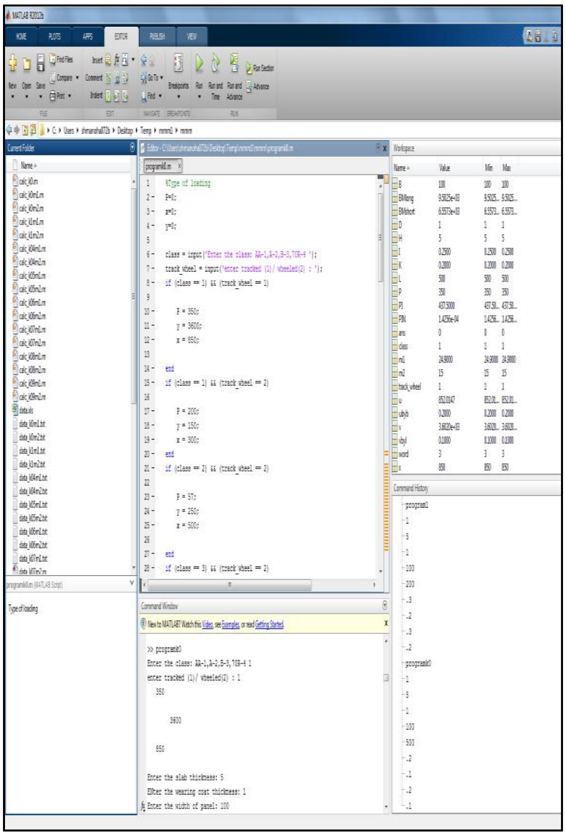

Fig 3: Sample Command window in MATLAB

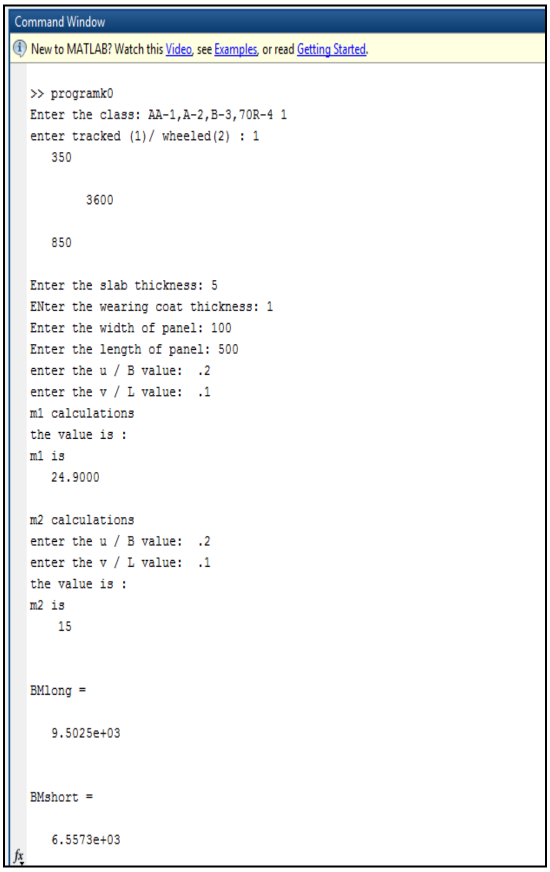

Fig 4: Sample Input and output in MATLAB

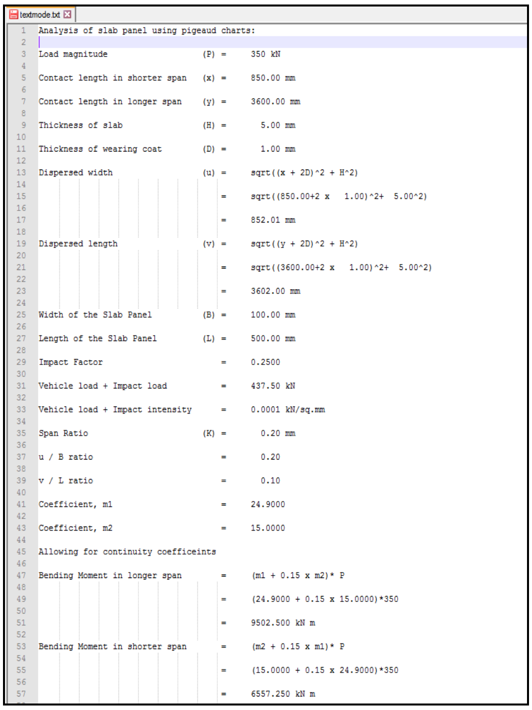

Fig 5: Sample Report generation of the Output file

IV. SUMMARY AND CONCLUSION

The difficulty in the selection of bending moment coefficients from the cumbersome pigeaud charts were eliminated through the conversion of charts into tables. A software program which is written in MATLAB software has been utilized for the effective analysis of the bridge deck slab for all the IRC loadings (as IRC Class AA tracked and wheeled, 70R tracked and wheeled, Class A and Class B). Class AA tracked vehicle caused the maximum bending moment because of its maximum load intensity and minimal contact area than 70R tracked vehicle. This study facilitates all the design engineers in the field of bridge engineering for the effective analysis of bridge deck slab using Pigeaud charts.

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