PARAMETRIC STUDY OF BRIDGE PIERS

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Abstract - *Midas civil is widely used software in bridge design. In the present work, finite element analysis of RCC pier models have been carried out. The height of Integral Pier is kept constant i.e 10m for all piers. The width and thickness is changed. In order to study the effects of changing the width and thickness of Integral Pier on the structure, also to study the effect of increase in stiffness of member on structure. The study is based on the fact that stress and displacement variation depends on pier width & thickness. Present study is aimed to know the variation of displacement, stresses, Quantity of steel and Quantity of concrete. Linear static analysis is carried out using Midas Civil Software. Load on bridge is calculated from 20 m span bridge deck. Analysis of bridge pier is carried out for different pier width & thickness. Parameter considered is to study the effect of pier width on stress and displacement. The study shows that total displacement and stresses increases with respect to decrement of pier width. Also quantity of concrete and steel.*

Key words:Integral piers, displacements, Stresses, Indian road congress.

1.INTRODUCTION

A pier is a raised structure of bridge typically supported by widely spread piles or pillars. Piers are an integral part of the load path between the superstructure and the foundation. Piers are designed to resists the vertical loads from the superstructure as well as the horizontal loads not resisted by the abutments. A multi-span bridge requires piers to support the ends of spans between these abutments.

The substructure of a bridge comprises the piers and the abutments which are located below the ground level of the bearings and rest above the foundations. The piers are generally constructed of brick or stone masonry or concrete are supported on foundation like spread footings, piles, wells or caissons. The superstructures comprising the slab or beams transmit the reactions to the piers and abutments through the bridge bearings and bed locks.

The magnitude of the superstructure loads applied to each pier shall consider the configuration of the fixed and expansion bearings, the bearing types and the relative stiffness of all of the piers. The analysis to determine the horizontal loads applied at each pier must consider the entire system of piers and abutments and not just the individual pier. The piers shall also resist loads applied directly to them, such as wind loads, ice loads, water pressures and vehicle impact. The connection between the pier and superstructure is usually a fixed or expansion bearing which allows rotation in the longitudinal direction of the superstructure.

This has the effect of eliminating longitudinal moment transfer between the superstructure and the pier. In rare cases when the pier is integral with the superstructure, this longitudinal rotation is restrained and moment transfer between the superstructure and the pier occurs. Pier types illustrated in the Standard Details shall be considered to be a pinned connection to the superstructure. The length of piers shall be sufficient to provide proper seating for the girders.

2.LITERATURE SURVEY

Literature studied in relevance to the objectives of the present study.There is various studies done by the researchers on bridge piers. The study on effectiveness of IRC live load on bridge pier is done by M.G. Kalyanshetti & C. V.Alkunte. A parametric study is carried out for effectiveness of IRC live load for various height of pier & span of bridge for different shape of pier is studied. Another study is carried out by Premsai T. on bridge pier. They have done structural analysis & optimization of bridge pier using ANSYS. The study of bridge pier is to know the variation of displacements, stresses, quantity of steel & quantity of concrete. A parametric study of concrete abutment bridge is done by Jimin Huan & Carol K. In this a parametric study was conducted to extend the results of an experimental program on a concrete integral abutment (IA) bridge in Rochester, MN to other integral abutment bridges with different design variables including pile type, size, orientation, depth of fixity, and type of surrounding soil, fixity of the connection between the abutment pile cap and abutment diaphragm, bridge span and length, and size.

2.1 Aim of study

The aim of this project is to explore the analysis of Integral pier by changing its parameter to have optimum results that could help the engineers to finalize the shape or size of pier.

2.2 Objectives of study

Following objectives were finalized for the present study:

1. Structural analysis & optimization of integral bridge pier using Midas civil.

2. To study the effect of increase in stiffness of member on integral structure

3. To study the effect of pier width on stress and displacement.

4. To study the effect of change in width & thickness of pier on quantity of steel & concrete.

3. FINITE ELEMENT ANALYSIS USING MIDAS CIVIL

Midas Civil is the ultimate Integrated Civil Engineering Solution for designing bridges and general civil structures. It retains construction stage analysis capabilities for Prestressed /Post –tensioned concrete, Suspension, Cable Stayed, Specialty and Conventional bridges and Heat of hydration. The MIDAS in-house researchers have developed an efficient CAD modeling technique, which is a totally new concept. Powerful automatic modeling functions such as Auto-Mesh Generation and Bridge Wizards are introduced. Once the basic section and bridge information and tendon placement data for the case of a PSC bridge are provided, the Wizard creates the completed bridge model as well as the construction stage models. Also, a new Multi-frontal Sparse Gaussian solver has been added lately, which has accelerated the analysis speed dramatically.

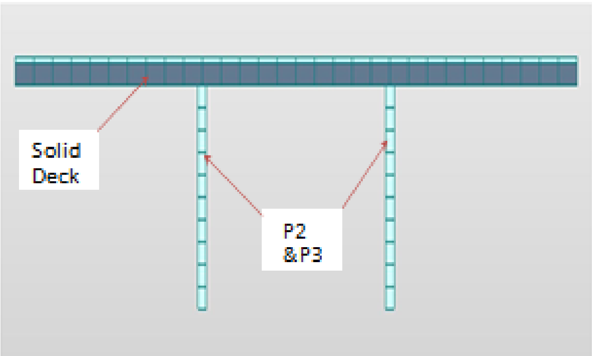

Fig-1 Model of Integral Bridge with Pier (Midas-Software)

As shown in Fig.1 the superstructure consists of two lanes of traffic running in both directions. The width of solid deck slab is 9.8m which includes crash barrier of 0.5m on both sides. The carriageway of the bridge superstructure is 9.7m excluding crash barrier. The depth of solid deck slab is 1.2m (assumed).The total thickness of wearing coat is 125mm including future overlay of 50mm (assumed future overlay of 50mm).The longitudinal length of one span is 20.0m.The intermediate span is integrated with Integral Pier whereas the other two spans are supported on bearings. The details of anti-crash barrier are taken from the IRC 5:2015. The main aim of our research is parametric study of Integral Pier by changing's its parameters rather than changing the superstructure or the piers at the ends. This study will be for future purpose. The following Table 1 shows the cases of Integral Pier.

Table 1 Different cases of Piers

Case no.	Parameters		
	Width in M	Thickness in M	Height in M
1	3.6	0.9	10
2	3.6	1.2	10
3	3.6	1.5	10
4	4	0.9	10
5	4	1.2	10
6	4	1.5	10
7	4.4	0.9	10
8	4.4	1.2	10
9	4.4	1.5	10
10	4.8	0.9	10
11	4.8	1.2	10
12	4.8	1.5	10

The height of Integral Pier is kept constant i.e 10 m for overall project work. The width and thickness is changed. In order to study the effects of changing the width and thickness of Integral Pier on the structure. The above cases are considered for the study. The stiffness plays a major role in Integral Pier.

3.1 Material properties:

Grade of concrete M50 & grade of steel is Fe500.

3.2 Defining section

In this step, we are going to define the section by help of Midas Section Property Calculators. There are so many sections defined in the Midas Section Library but as in our case is Solid Deck Slab, we are going to take help of Section Property Calculator. Section Property Calculator is very useful tool in calculating the section properties of irregular shaped bodies. Simply, we have to make 2D or 3D models in AutoCAD software and export the same file in Midas Software.

3.3 Defining pier properties

In this step, pier properties for all cases are defined & the pier is modeled in the Midas. Rectangular section is chosen from section properties file.

Properties are assigned & loads are defined as per IRC after that loads are assigned to respective pier models. Then analysis is performed for different pier cases & results are extracted for pier cases.

4. ANALYTICAL RESULTS

After analysis of all pier models the results are extracted. The summary of forces are obtained from analysis in MIDAS CIVIL for all twelve cases & the graphs regarding variation of forces moments against height of pier are drawn below. The forces are summarized in Axial force (P), Moment in longitudinal direction (MZZ), Moment in transverse direction (MYY) for P2 Pier and P3 Pier at top and bottom location for different section.

Table 2 Axial force, moments of pier at top for pier P2, Section (3.6X0.9)m

PIER-P2, SECTION - 3.6mx0.9m TOP			
Load	P	MZZ	MYY
	Kn	Knm	KNm
DL	5189.560	-955.600	0.000
SIDL	526.450	-97.190	0.000
SURFACING	535.300	-98.820	0.000
WIND	196.650	-300.660	0.070
TEMP RISE	-16.470	479.980	0.000
TEMP FALL	16.470	-479.980	0.000
TRANS.SEISMIC	-32.610	509.895	48.260
LONG. SEISMIC	-108.700	1699.650	14.478
CREEP	18.360	-180.330	0.000
SHRINKAGE	1.400	-55.150	0.000
LL MAX R	-2627.11	-81.290	494.920
LL MAX ML	-699.280	-1718.37	718.940
LL MAX MT	-1042.13	-432.65	1265.180

In such a way results are extracted for integral pier 2 & pier 3 at top & bottom of the pier & graphs are plotted.

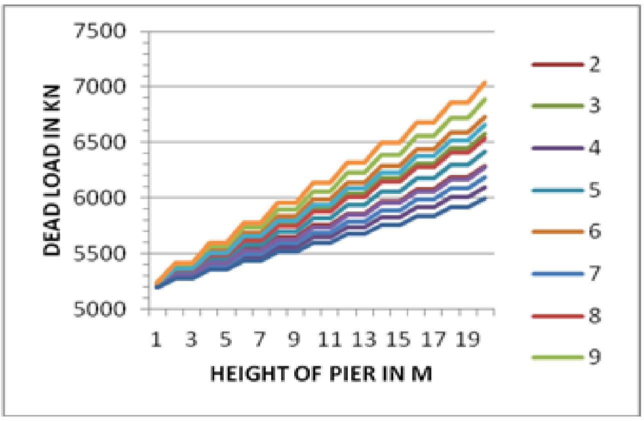

Fig-2. Dead load in KN Vs Height of pier

The graph shows that variation of dead load through the height of pier which varies from 5270KN for pier case 1 to 7038 KN for pier case 12.

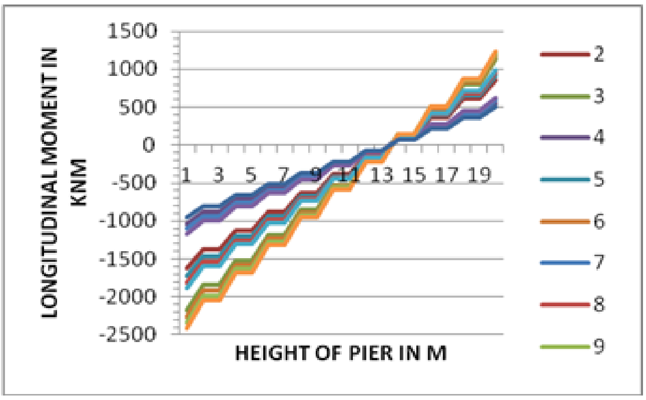

Fig-3. Moment due to Dead load Vs Height of pier.

The graph shows moment variation due to dead load through the height of pier. As c/s area increases stiffness of member increases. In such a way the graphs are plotted for integral pier 3 also.

As we see the results, the most economical section is (3.6X0.9) m. Because it has less stiffness as compared to all other cases & amount of steel required as compared to other cases is also less. Hence it is economical one & by referring the plots of load vs height of pier, we come to the conclusion that as stiffness of member increases the force in integral structure is also get increases.

The table for displacements & stresses for different pier models given below.

Table 3 Displacements & stresses for different pier cases

Case No.	Dimension of pier in m	Thickness in m	C/S area in sqm	Stress in KN/sqm	Displacement in m
1	3.6	0.9	3.24	43370	0.00632
2	4	0.9	3.6	42800	0.00606
3	4.4	0.9	3.96	42300	0.00585
4	4.8	0.9	4.32	41525	0.00487
5	3.6	1.2	4.32	41525	0.00452
6	4	1.2	4.8	40255	0.00438
7	4.4	1.2	5.28	39800	0.00423
8	4.8	1.2	5.76	39500	0.00413
9	3.6	1.5	5.4	39225	0.0037
10	4	1.5	6	38880	0.00364
11	4.4	1.5	6.6	38200	0.00358
12	4.8	1.5	7.2	37535	0.00342

Analysis is performed for all the pier cases given in table below by using Midas civil. The results obtained for displacement, stresses & quantity of concrete & steel are given in the Table 3

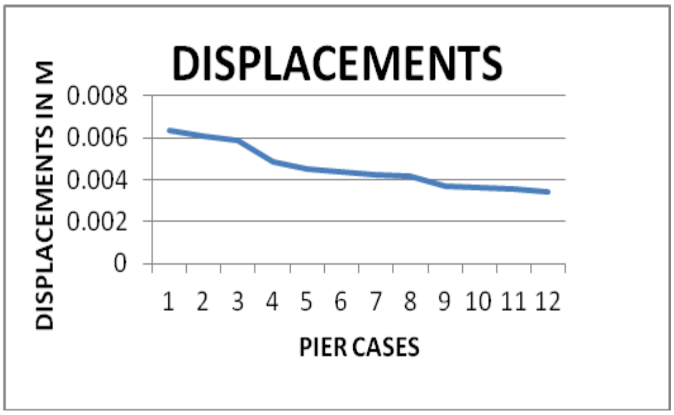

Fig 4-Variation of displacements for different pier cases

From the above graph it is clear that as cross sectional area goes on increasing displacements goes on decreasing displacement is maximum for section (3.6X0.9)m & minimum for section (4.8X1.5)m.

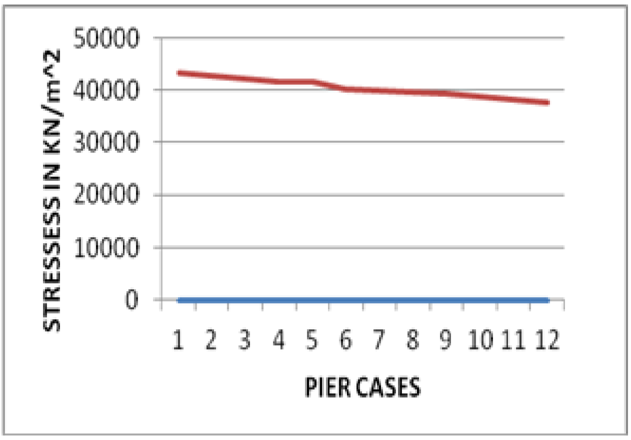

Fig 5- Variation of stresses for different pier models.

The above graph shows that variation in stresses due to change in cross section of piers. As the cross sectional area of pier increases stress goes on decreases. The stress decreases linearly from pier case 1 to pier case 12.

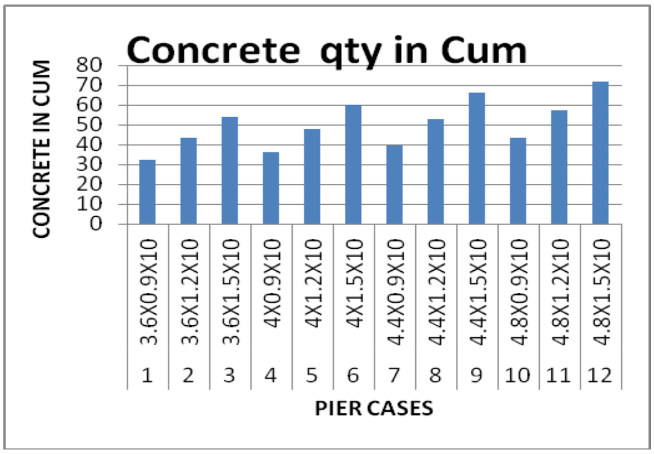

Fig 6-Variation in concrete quantity for different pier models.

From the above graphical results it is concluded that the quantity of steel & quantity of concrete for case-1 i.e section (3.6X0.9) is less as compared to other sections. So the section (3.6X0.9) i.e case-1 pier is economical.

5. CONCLUSIONS

In this study the displacement & stress of the reinforced concrete pier are analyzed by using Midas software. Also studied which section is economical one. All pier models are analyzed & compared to succeeding models as per width & thickness changed. After compiling & analyzing the results from each analysis the following conclusions are made.

1. As we see the results, the most economical section is (3.6X0.9) m. Because it has less stiffness as compared to all other cases & amount of steel required as compared to other cases is also less. Hence it is economical one.

2. By referring the plots of load Vs height of pier, we come to the conclusion that as stiffness of member increases the force in integral structure is also get increases.

3. As the stiffness of member increases there is increase in the forces of member. Hence to design the integral structure optimum stiff member has to select.

4. Displacement increases linearly from pier case 12 to pier case 1.Displacement is maximum for case no.1 shown in Fig 4 & Table 3

5. Here is variation in stresses are occurred due to change in width & thickness of pier models shown in Fig 5 & Table 3

6. Quantity of concrete increases with respect to increment of pier section shown in Fig 6 & Table 4

7. Quantity of steel increases with respect to increment of pier section shown in table 4

8. Percentage of steel increases with respect to increment of pier section shown in Table 4.

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