BEHAVIOURAL ANALYSIS OF MULTI CELL PRESTRESSED BRIDGE DECK

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Abstract: Now a day's bridges are the main components of the road transportation. There are different kinds of bridges out of which the prestressed bridges are becoming prominent due their structural advantages .This paper mainly studies about the behavioural analysis of the multi cell(2,3,4) with varying depth of girders as 2m,1.8m,1.6m to provide the efficient section . The main criteria of the analysis are the bending moment, shear force and the reaction on the sub structure and the seismic analysis of the sections. The sections are designed and analysed as per the codal recommendations of the IRC: 112-2011. The loadings for which the decks were analysed are self-weight, super imposed dead load, pre stressed load, moving load of IRC class A vehicle, and other load combinations. The result of the exercise show that among the (2,3,4) multi cell bridge decks with varying depth of 2m,1.8m,1.6m, the section with 2 cell and 1.6m depth provides the most efficient section in all the aspects of the analysis done. The analysis is done in the MIDAS CIVIL software which is a finite element analysis.

Keywords: Pre-stressed Concrete, Box-girder, and IRC loading, Midas Civil.

INTRODUCTION:

Box girders, have gained wide acceptance in freeway and bridge systems due to their structural efficiency, better stability, serviceability, economy of construction and pleasing aesthetics. Long span girder bridges with more than 25m, with wider deck, suffers longitudinal and transverse distortion of cross section under eccentric load. Hence such girder bridges require high torsional rigidity to keep the effect of distortion of the deck to be minimum. As span increases, dead load increases. To reduce the dead load, unnecessary materials near the center of gravity. A box girder is formed when two web plates are joined by a common flange at both the top and the bottom. The box girder normally comprises either prestressed concrete, structural steel, or a composite of steel and reinforced concrete. It is typically rectangular or trapezoidal in cross section. Nowadays these box girders are used in flyovers, elevated metro bridges, casted by segmental construction or integral one.

Advantage of box girder

- In case of long span bridges, large width of deck is available to accommodate prestressing cables at bottom flange level. The maintenance of box girder is easier in interior space is directly accessible without use of scaffolding.
- It has high structural efficiency which minimizes the prestressing force required to resist a given bending moment, and its great torsional strength with the capacity this gives to re-center eccentric live loads, minimizing the prestress required to carry them
- They could be cast in smaller segments and could be integrated into one unit by prestressing to achieve longer span

The box girder often is more advantageous than t-beam due to its high bending stiffness combined with a low dead load, yielding a favorable ratio of dead load to live load. Its high torsional stiffness which allows freedom in the selection of both the supports and bridge alignment, Analysis and design of box-girder bridges are very complex because of its three dimensional behaviors consisting of torsion, distortion and bending in longitudinal and transverse directions.

PROBLEM DEFINITION:

In this exercise the modeling of the multi cell bridge decks containing 2,3,4 cells with various depths of 2m,1.8m,1.6m.is modeled as the regulations of the IRC:112-2011 with the following parameters.

- Support condition:- simply supported
- Span length:- 30 m
- Width of carriageway:- 8.5m
- Width of foot path:- 1.5m
- Total width of segment:- 12m
- Moving load :- IRC class A loading

Description of Model:

Thickness of web: - (As per IRC: 18 – 2000):

The thickness of the web shall not be less than d/36 plus twice the clear cover to the reinforcement plus diameter of the duct hole where"d" is the overall depth of the box girder measured from the top of the deck slab to the bottom of the soffit or 200 mm plus the diameter of duct holes, whichever is greater.

Thickness of the web in model = 300 mm (for the girders where anchorage is done) > permissible value (hence safe)

Thickness of the web in model =275 mm (for the internal segment girders) > permissible value (hence safe)

Thickness of Bottom Flange (As per IRC: 18 – 2000):

The thickness of the bottom flange of box girder shall be not less than 1/20th of the clear web spacing at the junction with bottom flange or 200 mm whichever is more.

Thickness of the bottom flange in model = 250 mm > permissible value (hence safe**)**

Thickness of Top Flange (As per IRC: 18 – 2000):
The minimum thickness of the deck slab including that at cantilever tips be 200 mm. For top and bottom flange having pre-stressing cables, the thickness of such flange shall not be less than 150 mm plus diameter of duct hole.Thickness of the Top Flange in model = 300 mm > permissible value (hence safe)

Cross section specifications:
2,3,4,multi cell Concrete Box-Girder with two traffic lanes
Vertical side walls
Top slab thickness = 300 mm
Bottom Slab thickness = 250 mm
External wall thickness = 300 mm, 275 mm(internal segments)
Internal Wall thickness = 300 mm , 275 mm(internal segments)
Wearing coat = 80mm

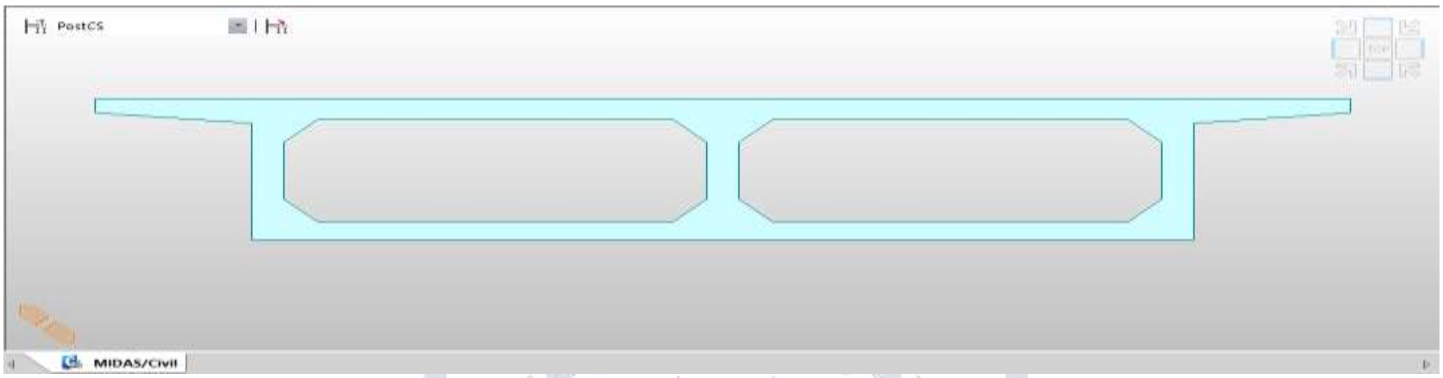


Fig.1. view of 2 cell psc box girder

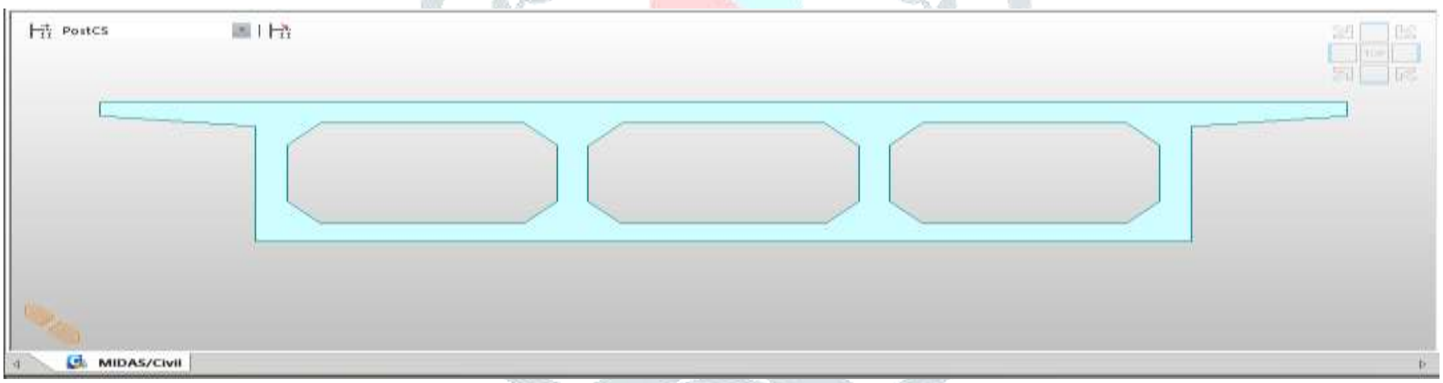


Fig.2. view of 3 cell psc box girder

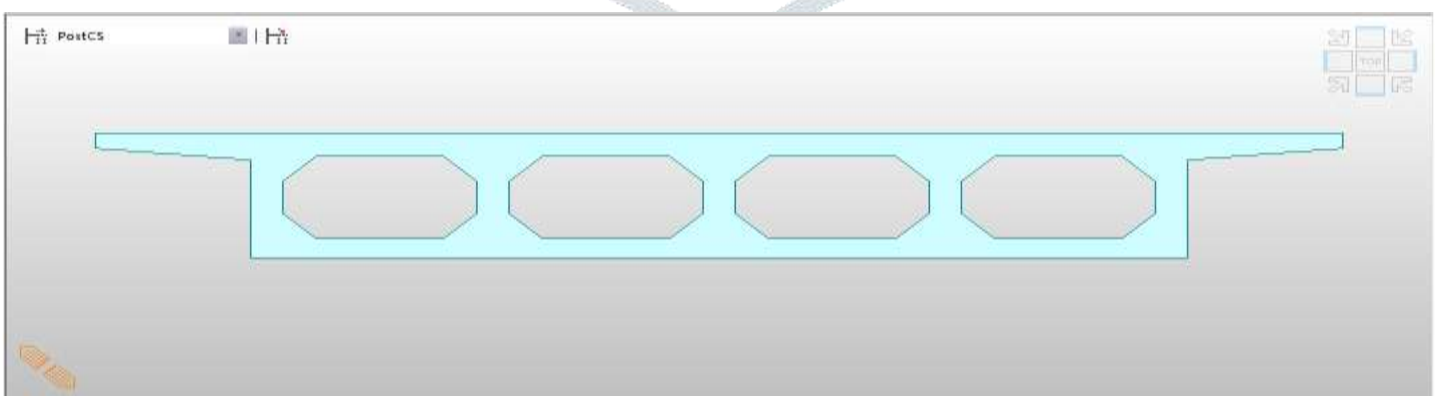


Fig.3**.** view of 4 cell psc box girder

LOADING CRITERIA:
The first and major step in any bridge analysis is selection of type of loading, they are dead load, live load, impact effect, wind load, longitudinal force due to tractive effort of vehicles, longitudinal force due to braking of vehicle, seismic effects, earth pressure, vehicle collision forces etc. Out of these loads live load plays a major role.

Dead load:
Dead load of the bridge deck is important factor that should be consider for the analysis. The dead load is calculated by adding all the self-weight of the bridge components
Super Imposed Dead load:
All the loads other than the dead loads which act upon the structure for about the whole of the structure is considered as the super imposed dead loads. These loads comprises of the loads from crash barrier, median, foot path. All these loads are considered for the analysis of the bridge deck

Vehicle Live Loads:
Vehicle live loads are categorized based on their conFiguration and intensity as IRC Class 70R, IRC Class AA (tracked and wheeled type), IRC Class A and IRC Class B loading. As per the recommendations of the IRC and the criteria of the carriage way the CLASS A loading is made to be acted upon.
Load combinations:
For the analysis of the bridge deck different load combination are used that are recommended by IRC 112-2011 There are:
A. 1.25 G + 2 SG + 2.5 Q---under moderate conditions
B. 1.5 G + 2 SG + 2.5 Q--- under severe exposure conditions.(**Load Combination-1**)
Where
G- dead load of the structure
SG-imposed dead load
Q-quasi permanent loads
Other loads combinations are used for the analysis which includes the serviceability aspect that considers the effect of creep and shrinkage
The load combinations are
1.0 G+1.0SIDL+1.0WC+1.5MVC+1.0PS+1.0DW+1.0CREEP+1.0SRINKAGE+1TENDON STRESS
(**Load Combination-2**)

The load combination including the seismic loading
1.35G+1.35SIDL+1.75WC+1.5(XRS)+0.45(YRS)+0.2MVC+1PS+1.35DW+1.35CREEP+1.35SRINKAGE+1TENDON STRESS (**Load Combination-3**)
MVC-moving vehicle combination
WC-wearing coat
XRS-seismic force in the x-direction
YRS- seismic force in the y-direction
PS- Prestress
DW-Dead load
`Seismic loading:
The seismic loading is analysed through the response spectrum method and the seismic analysis is done through the MIDAS CIVIL software. The loading criteria is done as per the recommendations of the IS: 1893 part 2

VALIDATION OF RESULTS:
The bending moment, shear force and the reaction on the pier results are obtained by using MIDAS CIVIL. The bending moment and shear force and reactions are obtained by considering different loading conditions consisting of dead load, super imposed dead load live load and seismic load. The results are shown below for the 2,3,4 multi cell bridge deck with the depths of 2m,1.8m,1.6m.

Table -1 results of 2 cell (1.6m depth)

ANALYSIS CRITERIA	SELF WEIGHT	SIESMIC FORCE (X-DIRETION)	SIESMIC FORCE (Y-DIRETION)	MOVING LOAD	L.C-1	L.C-2	L.C-3
BENDING MOMENT (KN-M)	**187612.6**	**377.73**	**106.65**	**3259.11**	**37754.2**	**32824.2**	**41182.1**
SHEAR FORCE (KN)	**2506.14**	**61.28**	**179.84**	**456.99**	**1371.36**	**822.81**	**137.7**
REACTION FORCE ON PEIRS (KN)	**1253.7**	**30.07**	**35.97**	**293**	**2709.68**	**3043.19**	**3639.32**

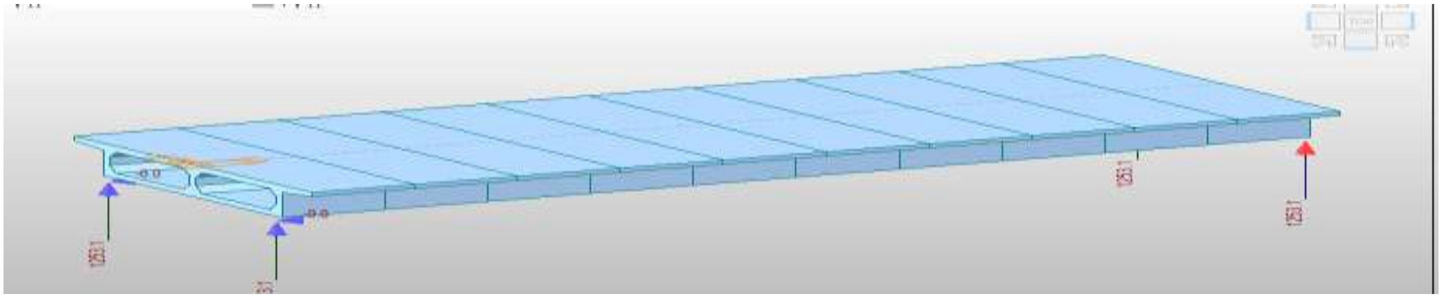


Fig.4. reaction on the pier

Table -2 results of 2 cell (1.8m depth)

ANALYSIS CRITERIA	SELF WEIGHT	SIESMIC FORCE (X-DIRETION)	SIESMIC FORCE (Y-DIRETION)	MOVING LOAD	L.C-1	L.C-2	L.C-3
BENDING MOMENT (KN-M)	19202.29	347.69	915.33	3259.12	38413.73	33922.41	43903.35
SHEAR FORCE (KN)	2565.62	66.13	184.18	456.99	5185.9	3973.52	5351.8
REACTION FORCE ON PEIRS (KN)	1282.807	33.7537	40.81	293.035	2754.299	3102.66	3727.3

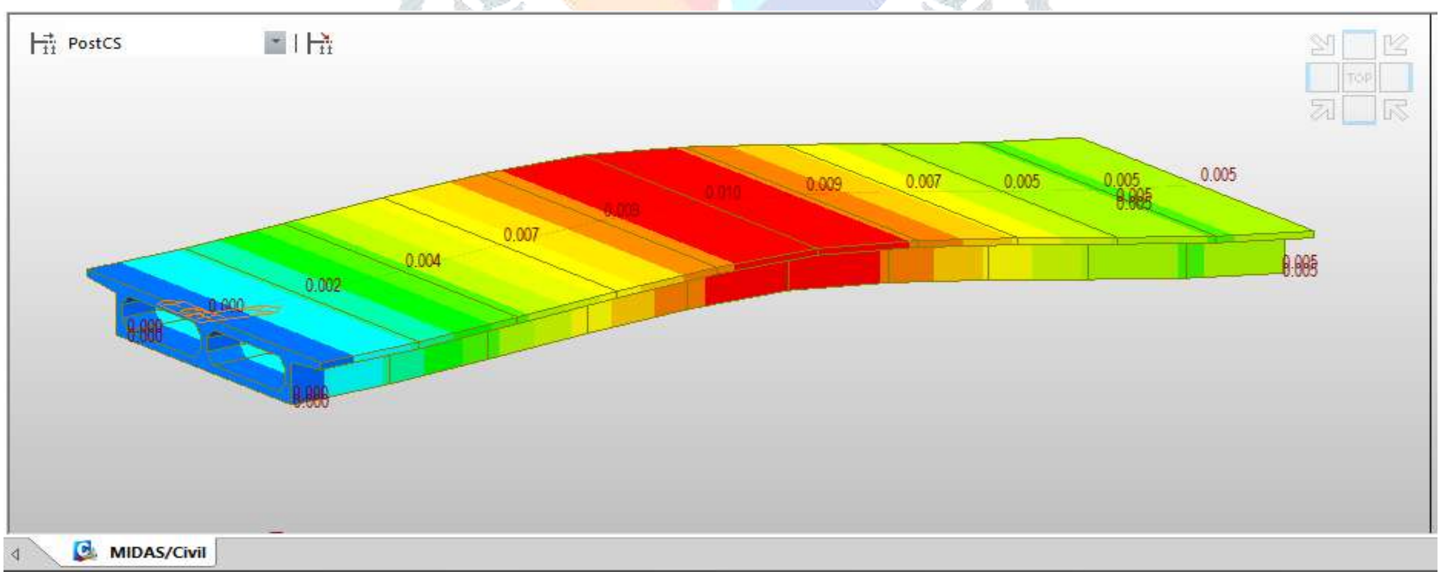


Fig.5. deflection due to pre stress force

Table -3 results of 2 cell (2.0 m depth)

ANALYSIS CRITERIA	SELF WEIGHT	SIESMIC FORCE (X-DIRETION)	SIESMIC FORCE (Y-DIRETION)	MOVING LOAD	L.C-1	L.C-2	L.C-3
BENDING MOMENT (KN-M)	19641.96	460.9	937.55	3259.11	29462.94	37092.47	45893.79
SHEAR	2625.09	71.15	188.55	456.99	3937.63	4069.97	5489.54

FORCE (KN)							
REACTION FORCE ON PEIRS (KN)	1312.5435	37.474037	45.76175	293.03959	1968.8153	3150.89644	3800.217

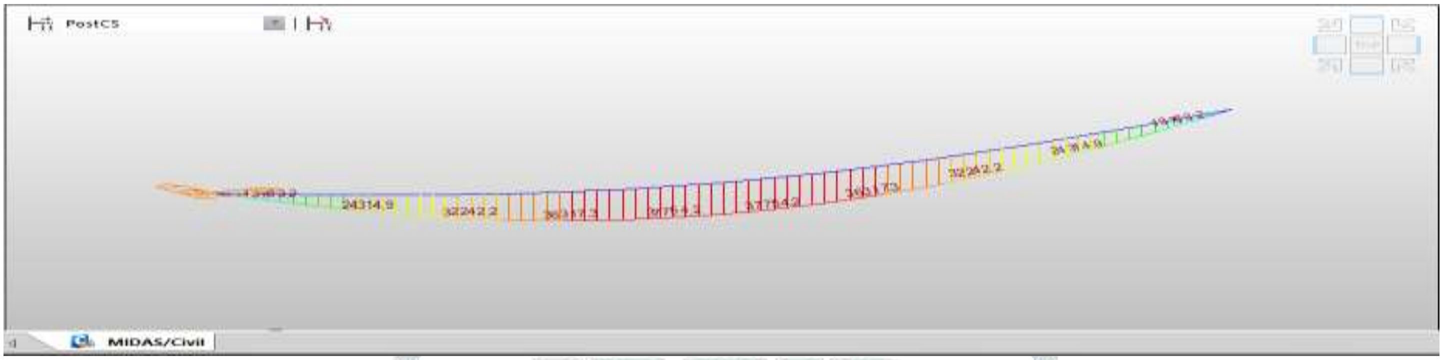


Fig.6. bending moment due to severe load combination

Table -4 results of 3 cell (1.6 m depth)

ANALYSIS CRITERIA	SELF WEIGHT	SIESMIC FORCE (X-DIRETION)	SIESMIC FORCE (Y-DIRETION)	MOVING LOAD	L.C-1	L.C-2	L.C-3
BENDING MOMENT (KN-M)	20092.92	410.91	957.58	3259.12	39749.67	34124.76	43159.28
SHEAR FORCE (KN)	2685	66.9	192.89	456.99	5364.98	3532.9	4995.9
REACTION FORCE ON PEIRS (KN)	1342.501	33.449671	38.622763	336.05569	2951.3902	4264.96053	38934.68

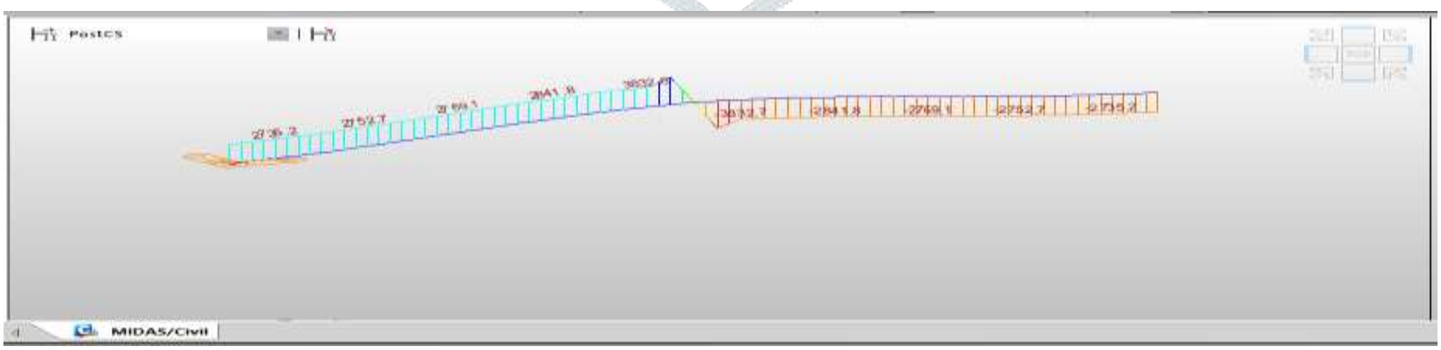


Fig.7. shear force due to pre stress force

Table -5 results of 3 cell (1.8 m depth)

ANALYSIS CRITERIA	SELF WEIGHT	SIESMIC FORCE (X-DIRETION)	SIESMIC FORCE (Y-DIRETION)	MOVING LOAD	L.C-1	L.C-2	L.C-3

BENDING MOMENT (KN-M)	20476	454	912	3259	40324	33622	46018
SHEAR FORCE (KN)	2737.27	72.19	198.71	456.99	5443.39	3637.44	5145.01
REACTION FORCE ON PEIRS (KN)	1368.636	36.106274	43.702941	336.0635	2990.6134	3338.86815	3972.468

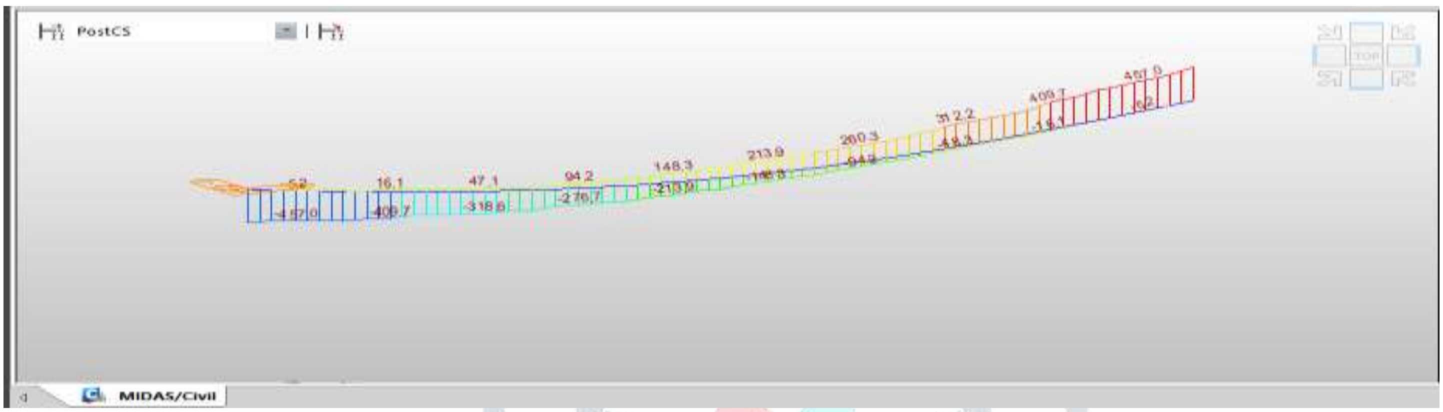


Fig.8. bending moment due moving load

Table -6 results of 3 cell (2.0 m depth)

ANALYSIS CRITERIA	SELF WEIGHT	SIESMIC FORCE (X-DIRETION)	SIESMIC FORCE (Y-DIRETION)	MOVING LOAD	L.C-1	L.C-2	L.C-3
BENDING MOMENT (KN-M)	21265.36	508.1	942.41	3259.12	41508.34	40165.03	50030.43
SHEAR FORCE (KN)	2843.59	80.29	204.53	456.99	5602.87	3850.08	5441.03
REACTION FORCE ON PEIRS (KN)	1421.797	40.143612	49.662289	336.07075	3070.372	3445.19967	4124.754

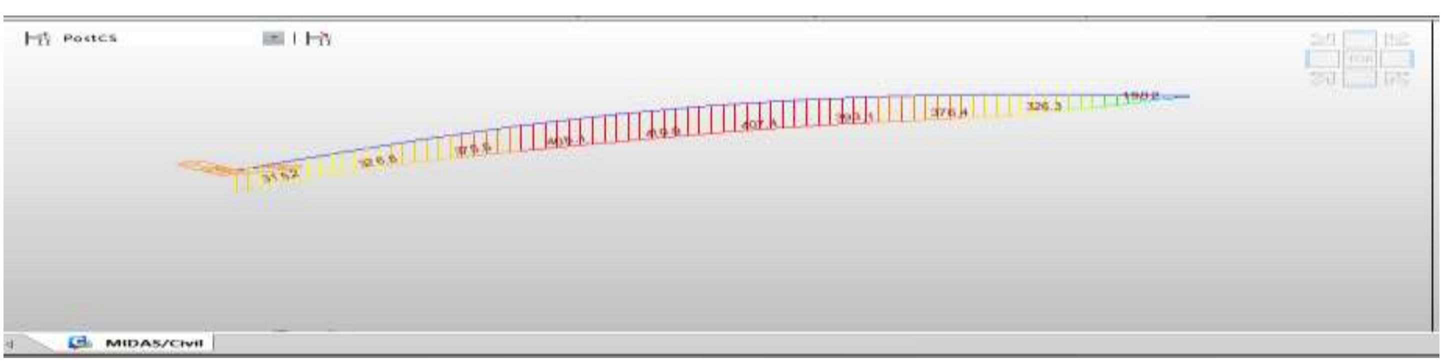


Fig.9. bending moment due seismic load in x- direction

Table -7 results of 4 cell (1.6 m depth)

ANALYSIS CRITERIA	SELF WEIGHT	SIESMIC FORCE (X-DIRETION)	SIESMIC FORCE (Y-DIRETION)	MOVING LOAD	L.C-1	L.C-2	L.C-3
BENDING MOMENT (KN-M)	21757.73	444.75	1040.32	3259.12	42246.89	36218.89	43311.91
SHEAR FORCE (KN)	2901.03	72.68	209.14	456.99	5689.03	3285.55	4908.45
REACTION FORCE ON PEIRS (KN)	1450.515	36.3383	41.809305	336.02394	3113.3324	3502.56	4190.438

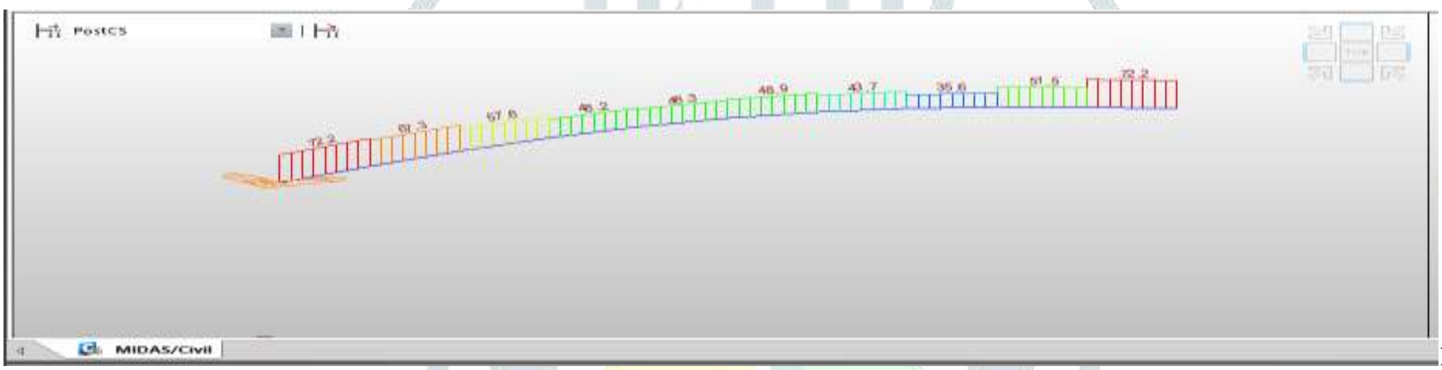


Fig.10. shear due seismic load in y- direction

Table -8 results of 4 cell (1.8 m depth)

ANALYSIS CRITERIA	SELF WEIGHT	SIESMIC FORCE (X-DIRETION)	SIESMIC FORCE (Y-DIRETION)	MOVING LOAD	L.C-1	L.C-2	L.C-3
BENDING MOMENT (KN-M)	22155.98	491.67	1059.09	3259.12	42844.26	39391.02	49753.92
SHEAR FORCE (KN)	2962.98	78.04	213.22	456.99	5781.95	3409.46	5083.77
REACTION FORCE ON PEIRS (KN)	1481.49	39.022125	47.154304	336.06609	3159.9003	3564.57918	4282.34

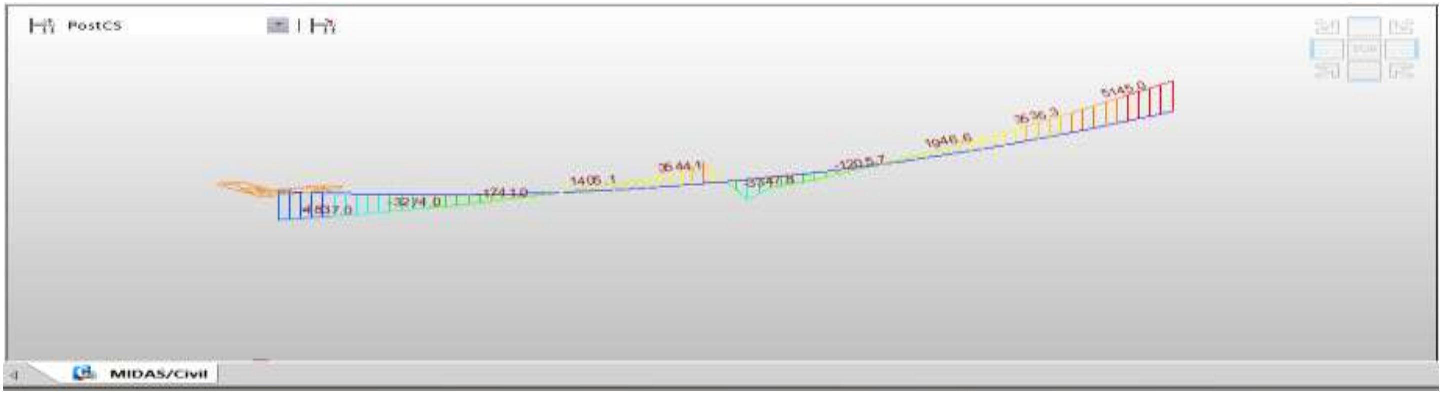


Fig.11. bending moment due to lc-3

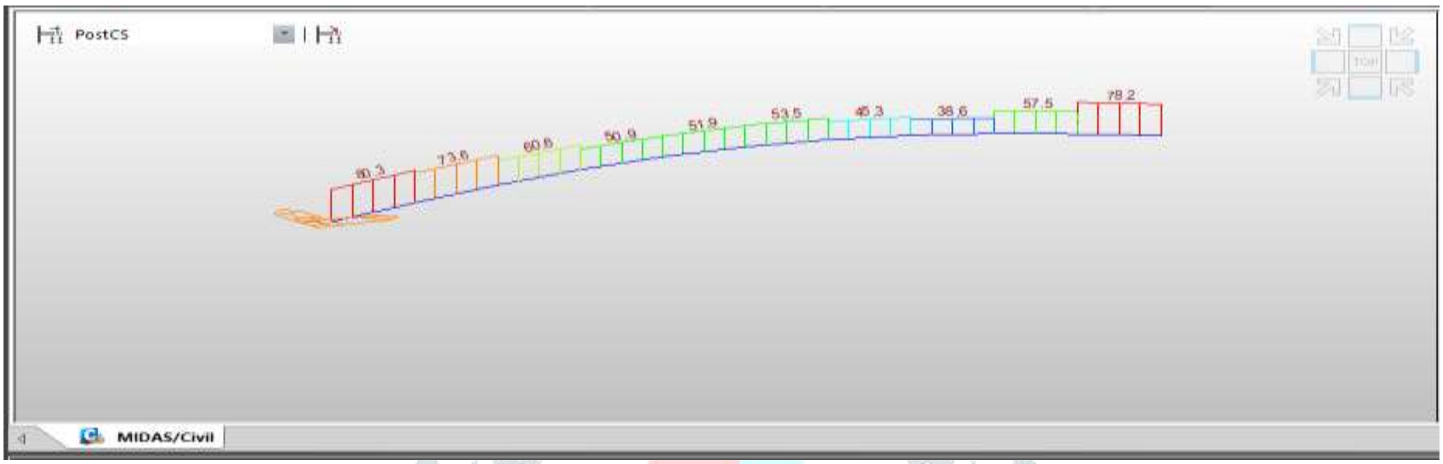


Fig.12. shear force due to seismic load in y direction

Table -9 results of 4 cell (2.0 m depth)

ANALYSIS CRITERIA	**SELF WEIGHT**	**SIESMIC FORCE (X-DIRETION)**	**SIESMIC FORCE (Y-DIRETION)**	**MOVING LOAD**	**L.C-1**	**L.C-2**	**L.C-3**
BENDING MOMENT (KN-M)	**22888.76**	**517.84**	**1608.6**	**3259.11**	**43945.07**	**51073.38**	**64228**
SHEAR FORCE (KN)	**3059**	**85.37**	**187.08**	**456.54**	**5924.86**	**1303.42**	**5214.43**
REACTION FORCE ON PEIRS (KN)	**1531.05**	**41.335854**	**48.371801**	**343.93306**	**3254.01**	**3675.61**	**4416.882**

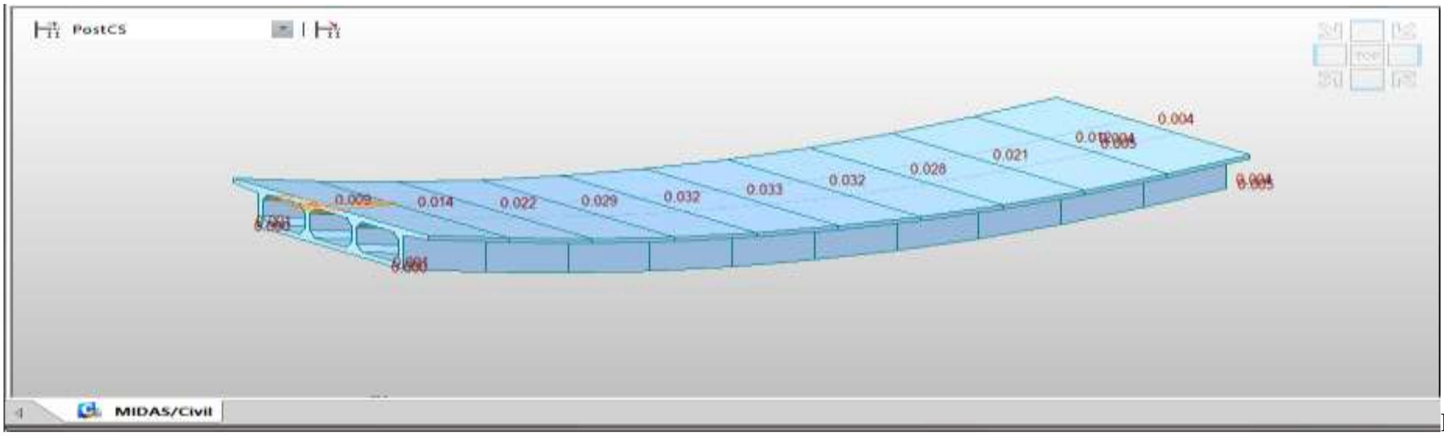


Fig.13. deflected shape due to load combination -3

COMPARISON OF RESULTS:

The results of all the segments in aspects of bending moment and shear force and reactions due to the self-weight, moving loads, and the different load combinations. The graphical representation shows the comparisons.

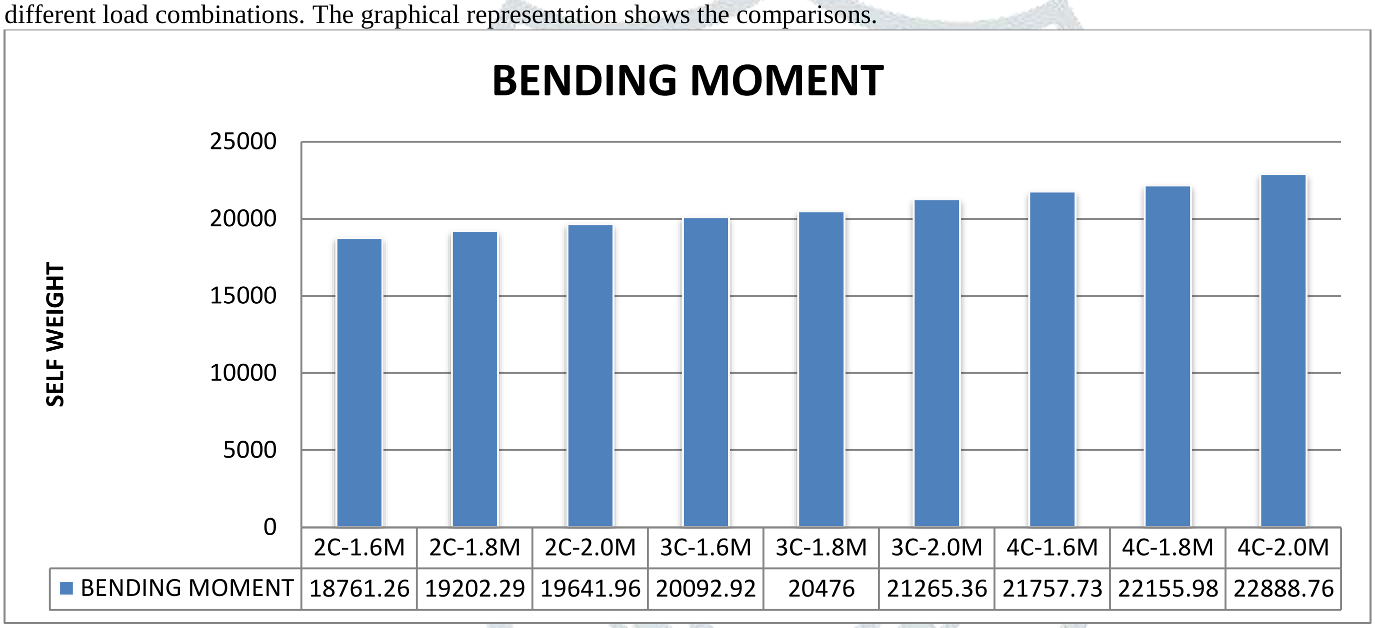


Fig.14. graph showing the bending moment for the self-weight

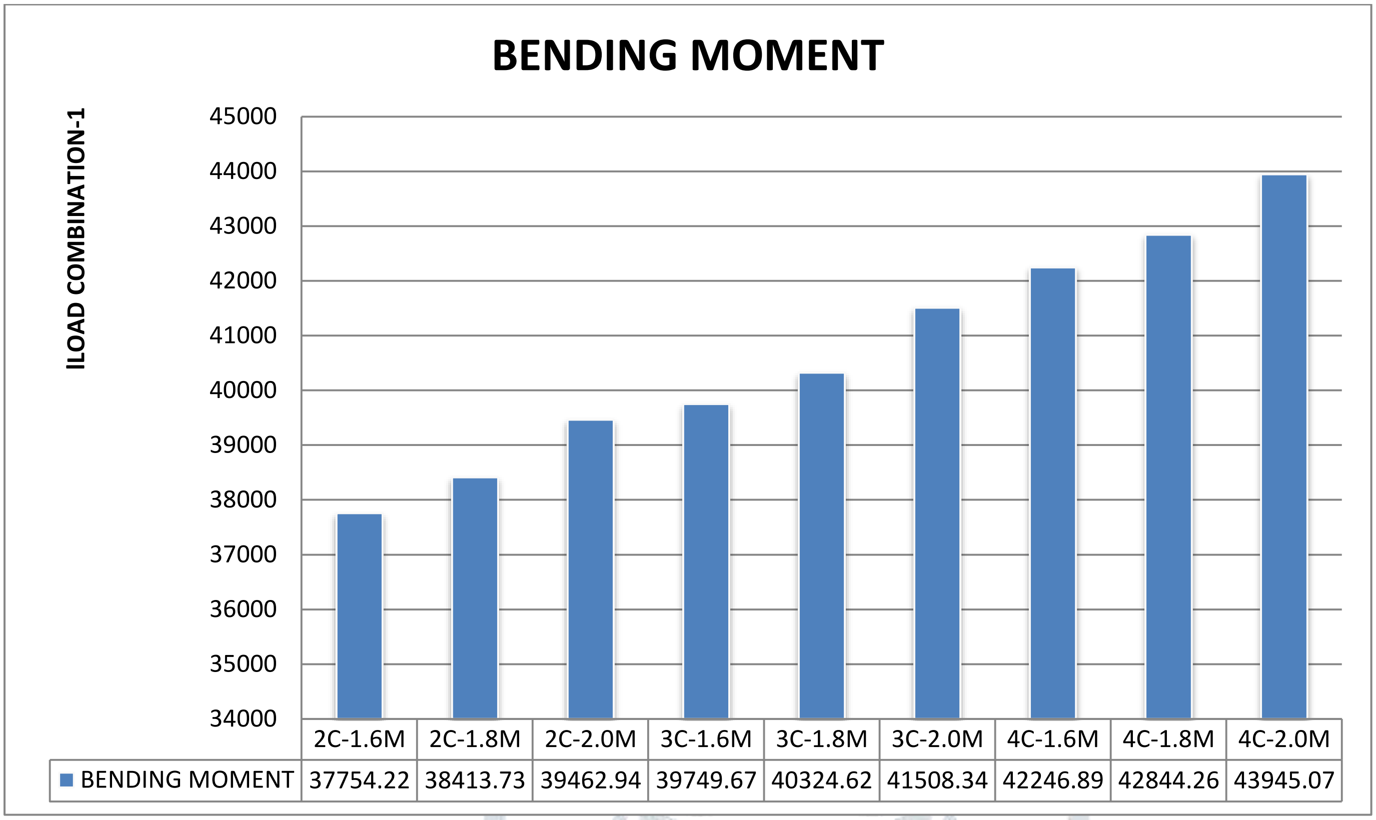


Fig.15. graph showing the bending moment for the load combination-1

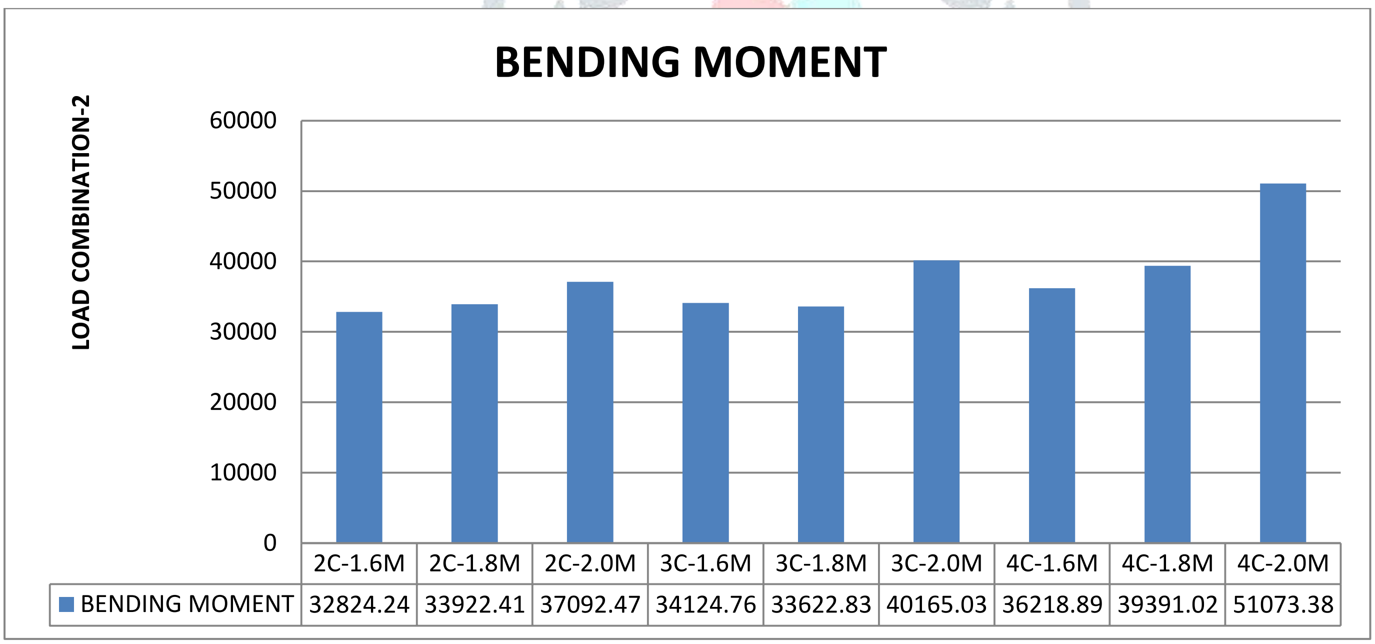
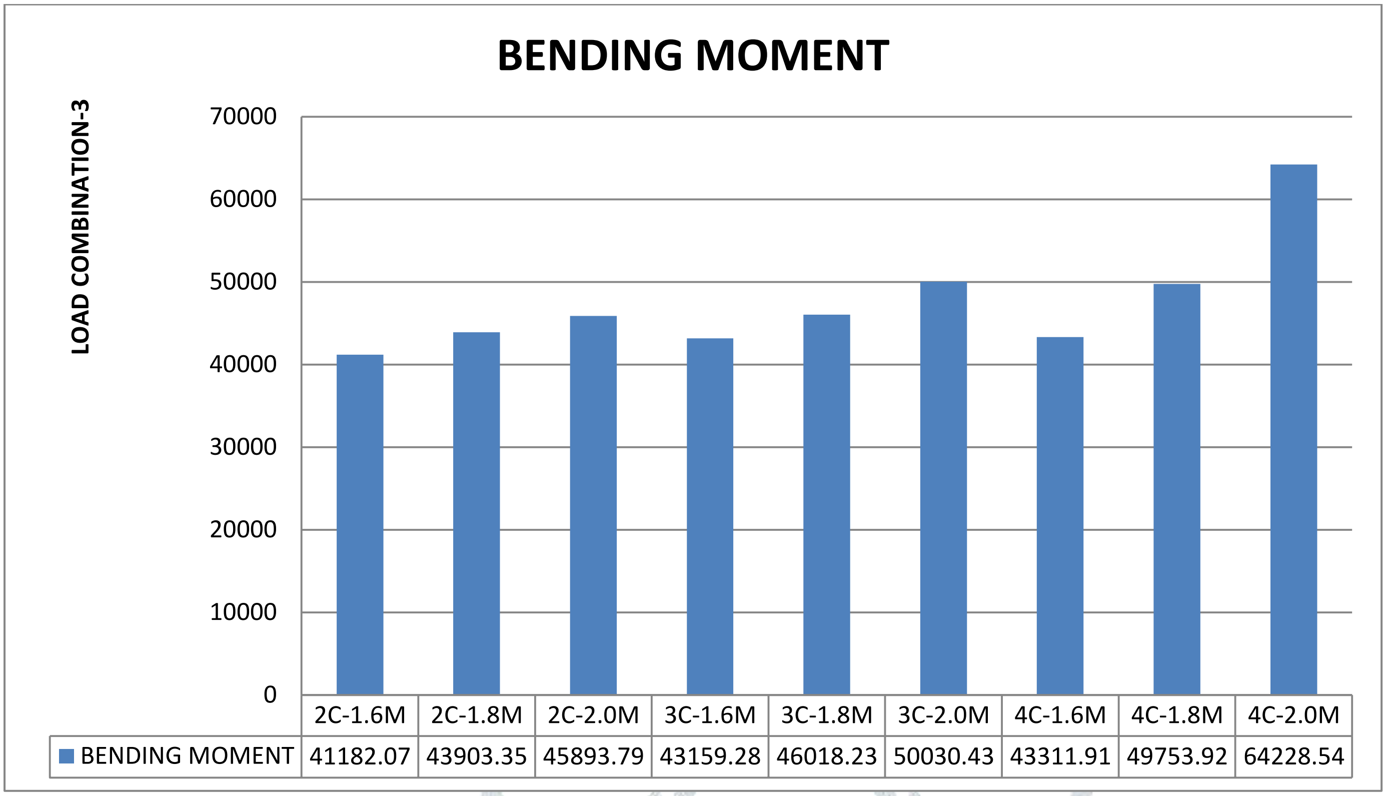


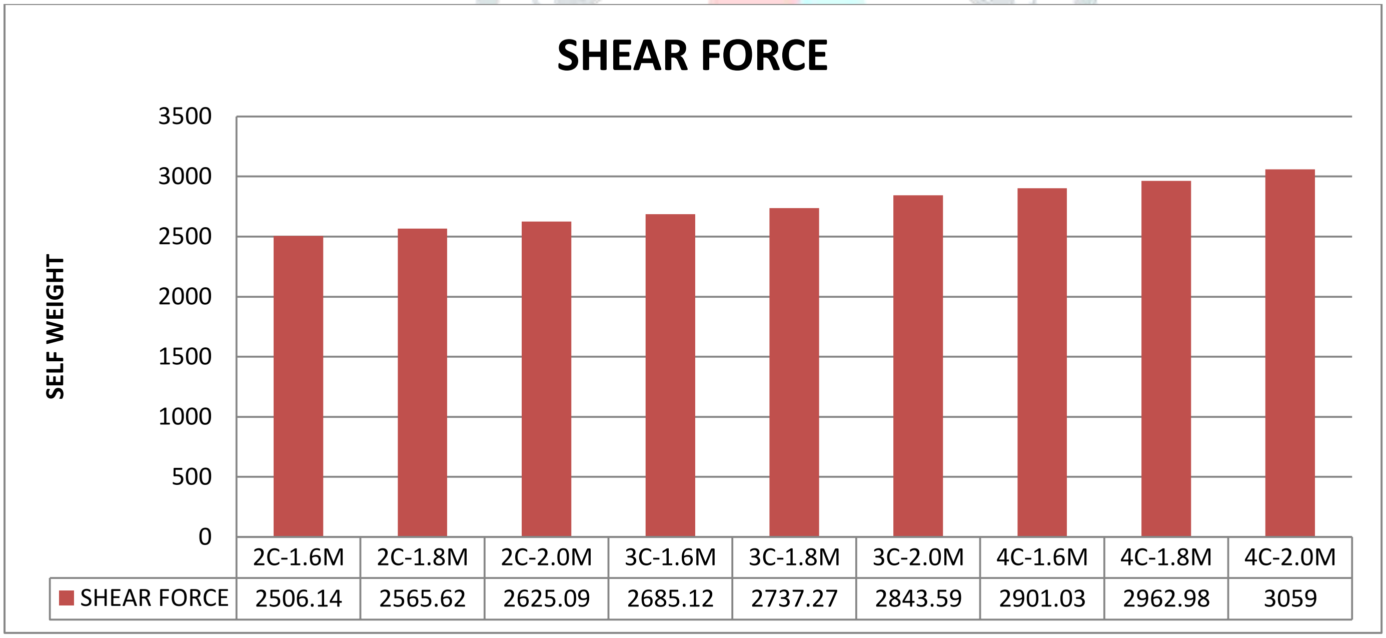
Fig.16. graph showing the bending moment for the load combination-2



	2C-1.6M	2C-1.8M	2C-2.0M	3C-1.6M	3C-1.8M	3C-2.0M	4C-1.6M	4C-1.8M	4C-2.0M
BENDING MOMENT	41182.07	43903.35	45893.79	43159.28	46018.23	50030.43	43311.91	49753.92	64228.54

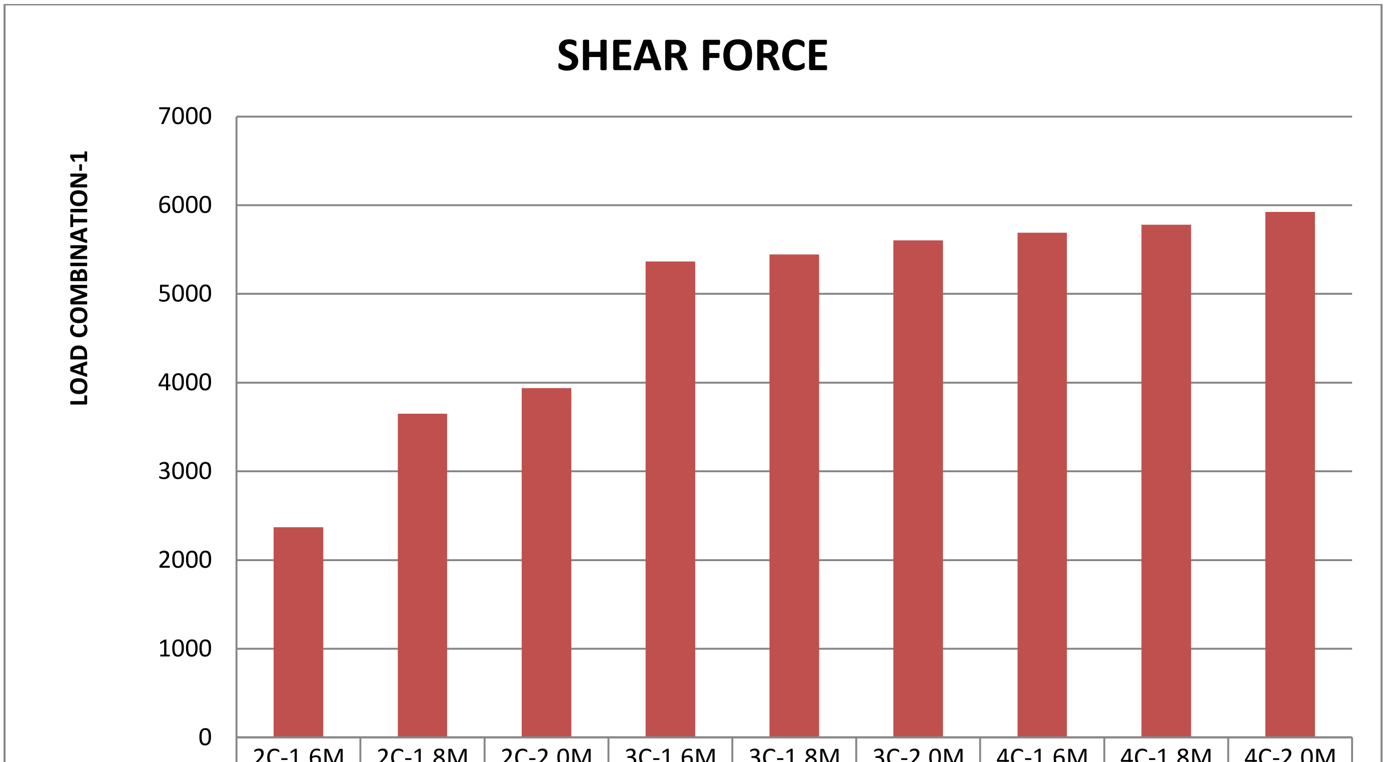
Fig.17. graph showing the bending moment for the load combination-3

SHEAR FORCE COMPARISONS:



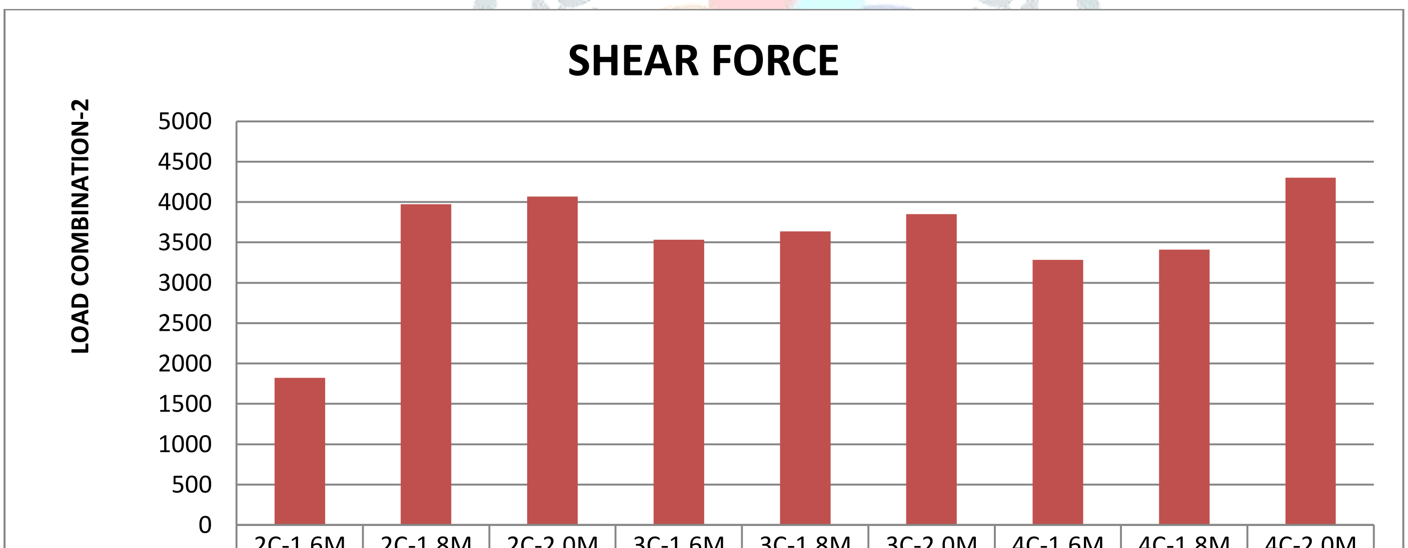
	2C-1.6M	2C-1.8M	2C-2.0M	3C-1.6M	3C-1.8M	3C-2.0M	4C-1.6M	4C-1.8M	4C-2.0M
SHEAR FORCE	2506.14	2565.62	2625.09	2685.12	2737.27	2843.59	2901.03	2962.98	3059

Fig.18. graph showing the shear force for the self-weight



	2C-1.6M	2C-1.8M	2C-2.0M	3C-1.6M	3C-1.8M	3C-2.0M	4C-1.6M	4C-1.8M	4C-2.0M
SHEAR FORCE	2371.36	3649.31	3937.63	5364.98	5443.39	5602.87	5689.03	5781.95	5924.86

Fig.19. graph showing the shear force for the load combination-1



	2C-1.6M	2C-1.8M	2C-2.0M	3C-1.6M	3C-1.8M	3C-2.0M	4C-1.6M	4C-1.8M	4C-2.0M
SHEAR FORCE	1822.81	3973.52	4069.97	3532.9	3637.44	3850.08	3285.55	3409.46	4303.42

Fig.20. graph showing the shear force for the load combination-2

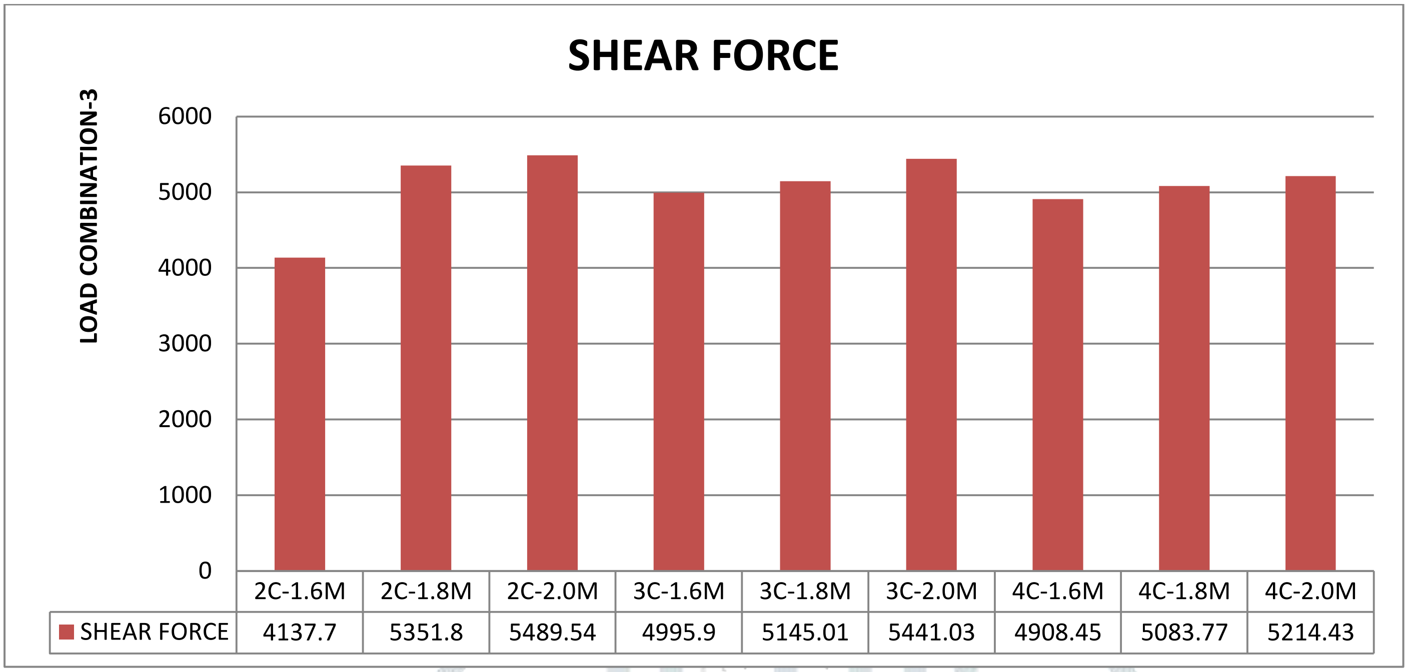


Fig.21. graph showing the shear force for the load combination-3

REACTIONS ON THE GIRDER COMPARISONS:

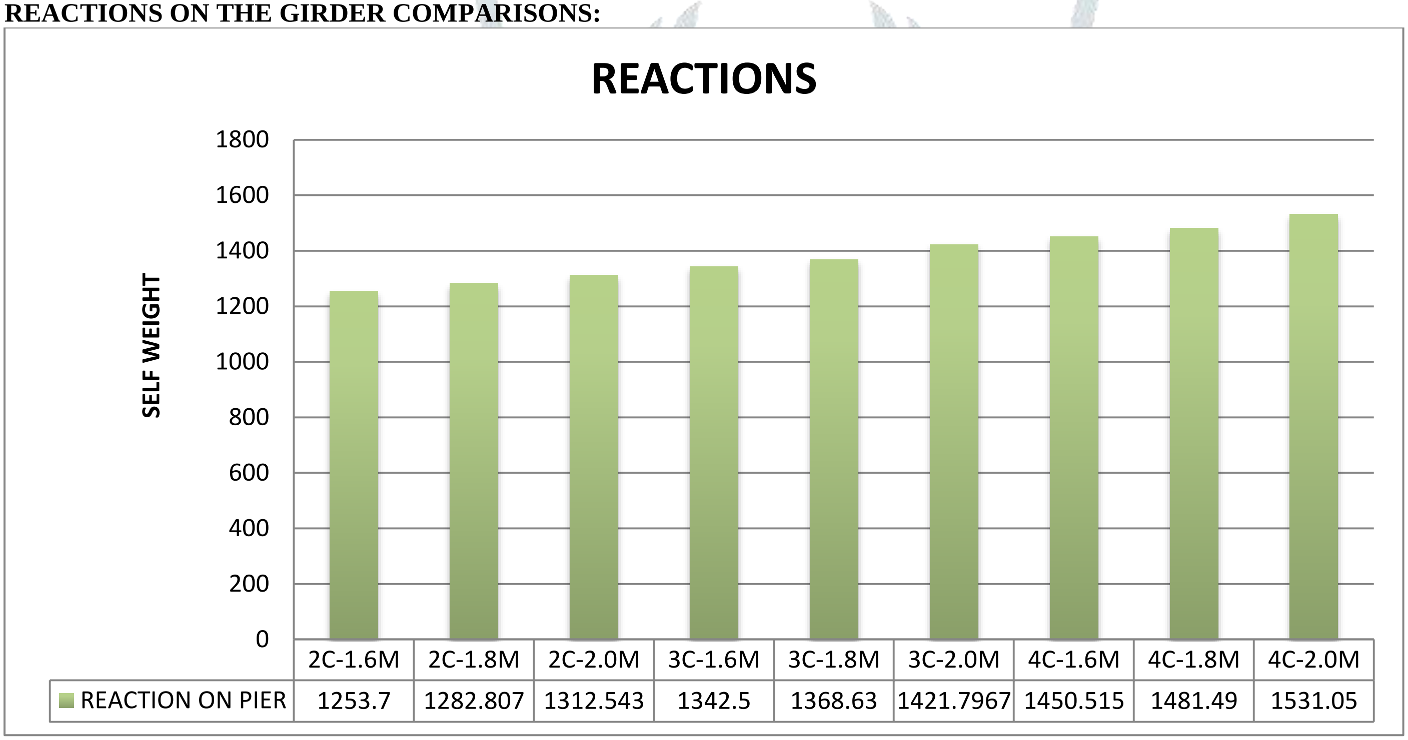


Fig.22. graph showing the reaction for the self-weight

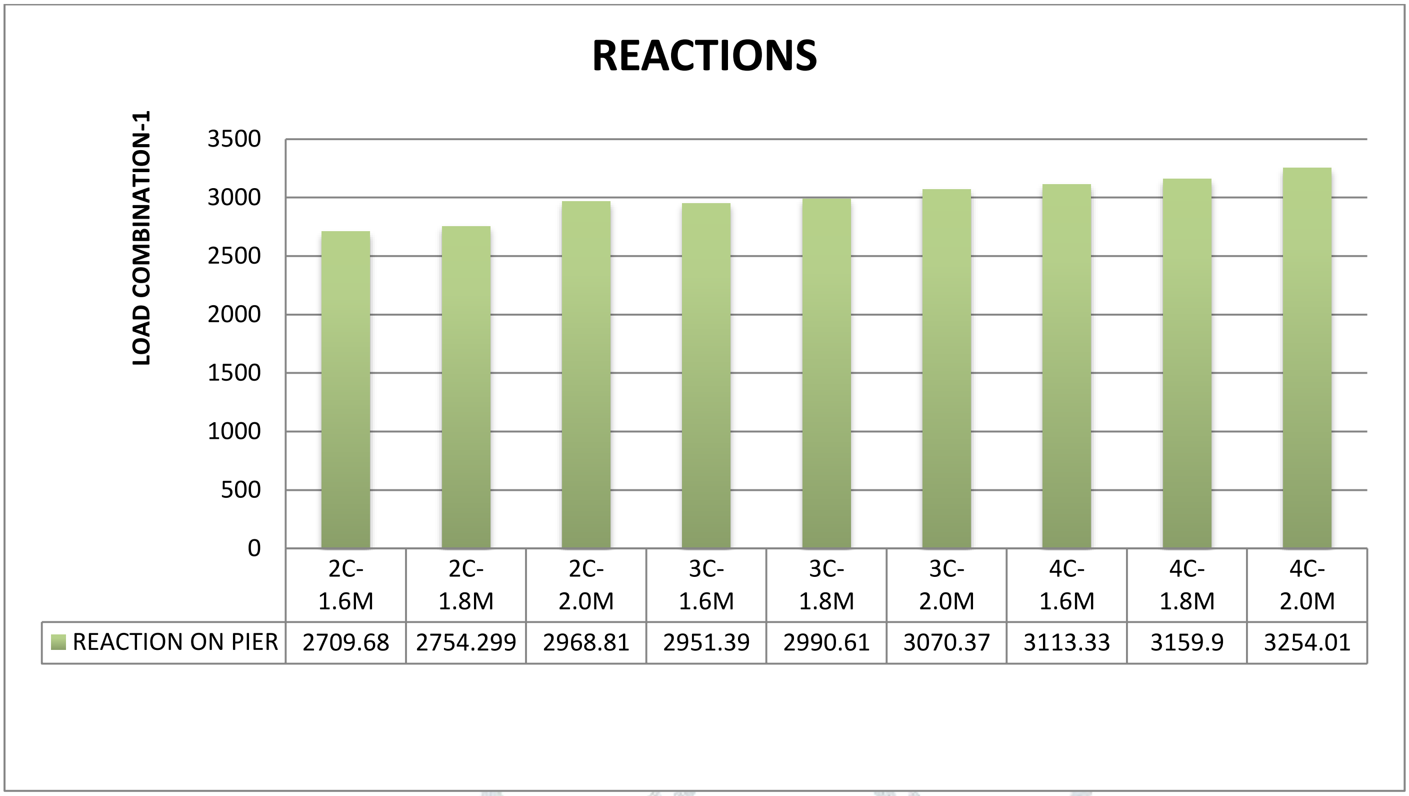


Fig.23. graph showing the reaction for the load comination-1

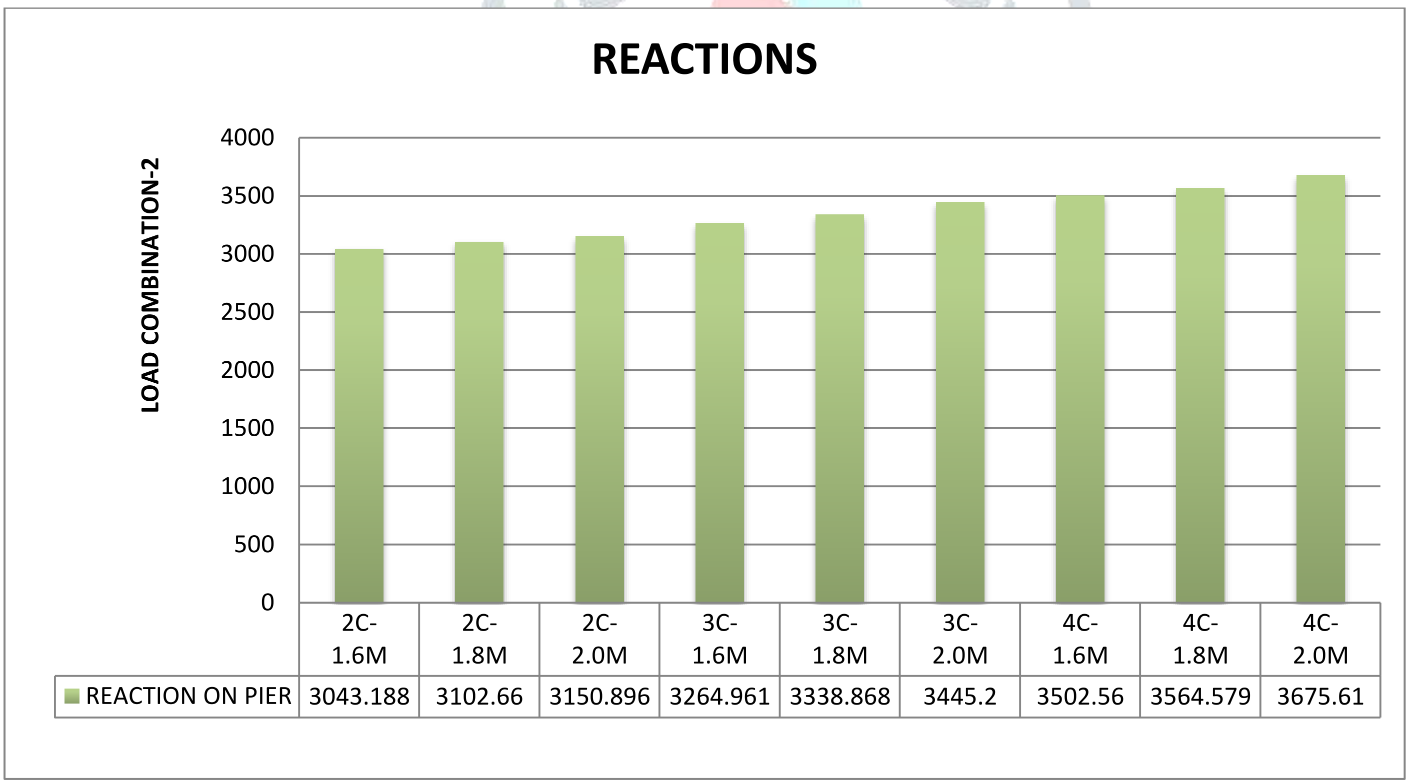


Fig.24. graph showing the reaction for the load comination-2

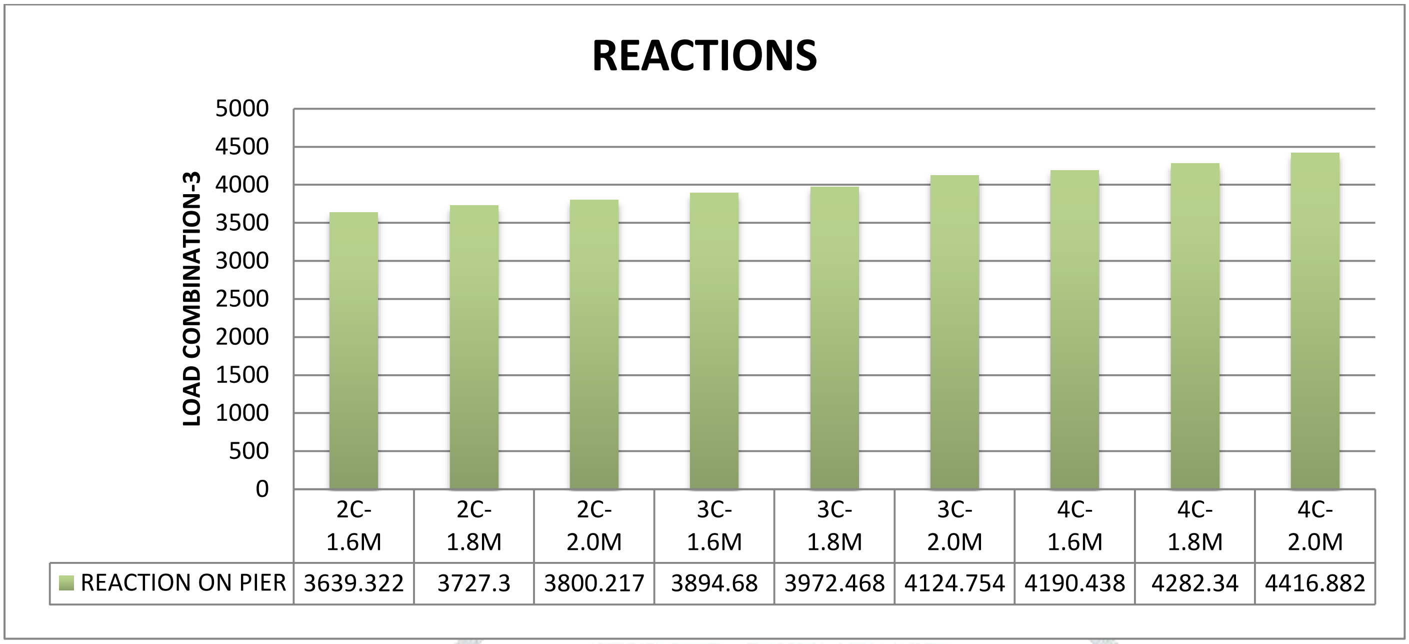


Fig.25. graph showing the reaction for the load comination-3

CONCLUSIONS:

From the analysis made and the results obtained for the 2,3,4, multi cell bridge decks with varying depth of 2m,1.8m,1.6. The following observations are made

- The bending moment due to the self-weight increases with increase in the number of cells and the depth of the section
- The bending moment due the load combination -1 that contains dead load , live load and super imposed dead load also increases with increase in the number of cells and the depth of the section
- The bending moment due the load combination -2 that is without the seismic load also increases with increase in the number of cells and the depth of the section
- The bending moment due the load combination -2 that is along with the seismic load shows the variation from 1.6m depth to 2.0m depth, the bending moment value is high for the section of 2,3,4 cells decks with 2m depth
- The Shear force due to the self –weight increases with increase in the number of cells and the depth of the section
- The Shear force due to load combination -1 that contains dead load , live load and super imposed dead load also increases with increase in the number of cells and the depth of the section
- The Shear force due to load combination -2 which considers the creep and shrinkage effect has variations from 2,3,4 multi cells.
- The Shear force due to load combination -3 increases with increase in the depth of the section
- The reactions due to dead load ,load combinations 1, 2 , 3 are increasing with increase in the number of cells and the depth of the section
- The bending moment and the shear force due to the moving load is same on all the sections
- The 2 cell 1.6m depth section produces lower values bending moment and the shear force for the self-weight and the other load combinations
- The 4 cell 2.0m depth section produces higher values of values bending moment and the shear force for the self-weight and the other load combinations
- The 4 cell 2.0m depth section does not provide efficient results regarding the seismic loading
- The 2 cell 1.6m depth section provides low bending moment and shear values for seismic forces as well.

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