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Seismic Analysis of Cable Stayed Bridge Under Moving Loads Using IRC & AASTHO Methods with Different Shapes of Pylons

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Abstract: This study presents a detailed seismic analysis of a cable-stayed bridge subjected to moving vehicular loads using both IRC (Indian Roads Congress) and AASHTO (American Association of State Highway and Transportation Officials) loading standards. The structural behavior of the bridge was evaluated using SAP2000 software, with a specific focus on the influence of different pylon shapes on the dynamic performance of the structure under combined imposed and seismic loading conditions.

The analysis reveals that the diamond-shaped pylon offers superior performance compared to other geometries. It exhibits up to 17% lower natural time period, leading to reduced natural frequency and thereby minimizing fatigue-related displacement. The base shear is also observed to be 22% lower than that of the single-shaped pylon, contributing to better energy dissipation during seismic events. In terms of displacement, the diamond pylon demonstrates a 22% reduction, confirming its stability under both lateral and vertical loads.

Comparing the two loading standards, displacement values under AASHTO loading are approximately 7% lower than those under IRC, highlighting the impact of load definitions on bridge response. Additionally, axial forces and bending moments in the pylons are significantly reduced with the diamond shape—16% and 19% lower respectively under IRC, and 12% and 16% lower under AASHTO—further indicating the structural advantages of this geometry. The distribution of tensile forces in the stay cables also aligns with expectations, with higher forces in outer cables and 10% to 7% lower forces under IRC and AASHTO, respectively, for the diamond-shaped pylon compared to the single shape.

The study concludes that the diamond-shaped pylon configuration enhances structural performance and resilience, making it a favorable choice for seismic-prone and high-traffic regions when evaluated under both IRC and AASHTO standards.

Keywords: *Cable-stayed bridge, Seismic analysis, Pylon shapes, Moving loads, IRC and AASHTO standards, SAP2000*

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I.INTRODUCTION:

A bridge is a structure which provides a passage over an obstacle without closing the way beneath. There are six basic forms of bridge structures: beam bridges, truss bridges, arch bridges, cantilever bridges, suspension bridges and cable stayed bridges.

Man's achievements in structural engineering are most evident in the World's largest Bridge spans. With the rate of increase of development of India's economic, the bridge spans increase day by day. The cable-stayed bridge is one of the popular styles of the long-span bridges. Compared with the suspension bridge, cable-stayed bridge is preferable in rigidity, economy, wind resistant stability, erection and so on. Even though they are gaining more popularity because the design of cables stayed bridges is governed not only by financial, practical and technical requirements but also by a great extent, by aesthetical appearance and architectural considerations. It is an important element in a transportation system, as its capacity governs the capacity of the system, its failure or defective performance will result in serious disruption of traffic flow, and also the cost of the bridge structure. Therefore, it is very predominant to devote the special attention in design of such bridges to ensure adequate strength and durability, consistent with safety and cost.

The rapid growth of the modern Cable Stayed Bridge throughout the world afterwards is due to the many advances in bridge engineering leading towards better understanding of the behavior and performance. The cable stayed bridge is especially suited in the span range of 200 m. to 900 m. Many cable stayed bridges have been successfully built around over the world in only last two decades of the 20th century. Due to their highly appreciable appearance & significantly utilized structural materials, cable stayed bridges have been taken as one of the most popular type of bridges in last decades. With increasing span length, the modern cable stayed bridges are more acceptable & flexible strong enough to the effect of wind as compare to ever. The cable stayed bridge is one of the modern bridges which were built for the longer spans and for better enhancement of the work in the field of aesthetic appearance and durability. The design of long span cable stayed bridges always possesses a challenge to the ingenuity and to the perseverance of the designer. Every long span bridge brings new problems in design concepts and in new construction details. The designer chose his solution with full freedom of decision, but with full responsibility for the success of work.

II.OBJECTIVE

The main objectives of this study are –

1. To determine the behavior of Cable Stayed bridge using different shapes of Pylons.
2. To evaluate the behavior of such system with different shapes of Pylons under the effect of vehicular loading as per different standard codes.
3. To study the combined effect of vehicular loading and lateral loading under seismic condition for the cable stayed bridge with different shapes of Pylons

III.MODELLING APPROACH

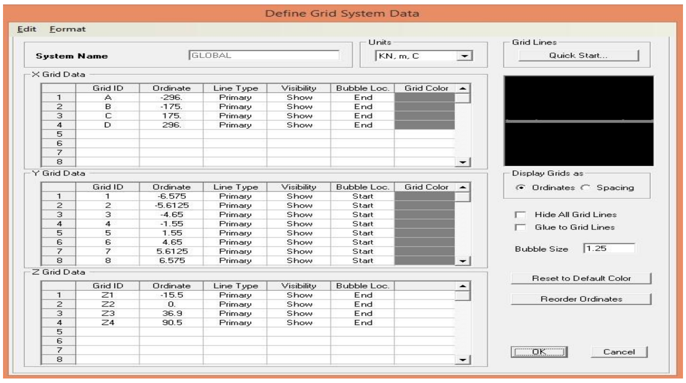
3.1Modeling Procedure -

In recent years, several cable-stayed bridges have been constructed with different shapes of pylons which results in a great demand to evaluate the effects of different shapes of pylon on cable stayed bridges under the consideration of vehicular and wind effects. Therefore, there is a need to study the behaviour of the bridge system having conventional pylons under vehicular and wind loading. It can be done by the computational analysis of bridges using finite element programmes.

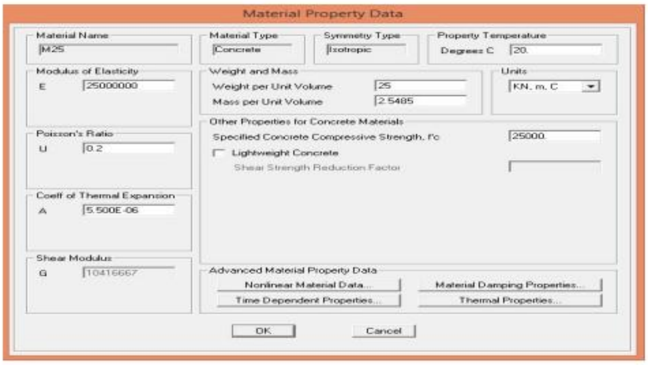
SAP 2000 is a finite element based program and is recognized by international community for the research purpose. The modeling of cable stayed bridge in SAP is prepared as per following procedure in SAP2000:

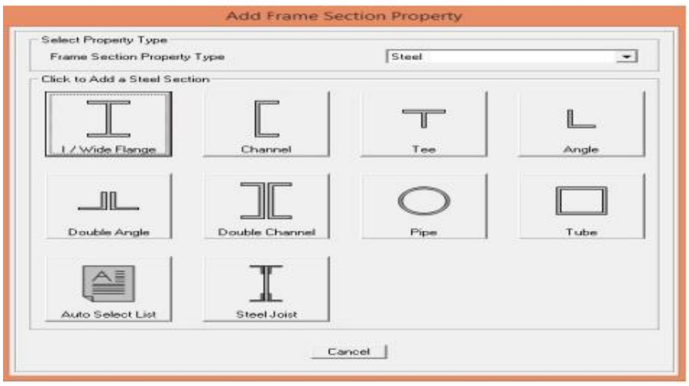
Modelling Procedure on SAP

a.Draw the geometry of the bridge either by inserting coordinates or by linking the nodes through member length.



b.Define the materials and sections for the members.





c.Define the loading values and load combinations to be applied on the structures.

d.Now assign the defined section as the members.

e.Assign the loads to the joints or members as per the case.

f.After assigning everything, set the analysis to be carried out and press run analysis.

SAP program will generate the various results like joint displacements, joint forces, joint reactions, base reactions, deck force, forces in cables and pylons, mode shapes etc.

3.2 Modelling of Bridge

MODEL 1 – DIAMOND SHAPED PYLON UNDER IRC VEHICULAR LOADING

MODEL 2 – DIAMOND SHAPED PYLON UNDER AASHTO VEHICULAR LOADING

MODEL 3 – SINGLE SHAPED PYLON UNDER IRC VEHICULAR LOADING

MODEL 4 - SINGLE SHAPED PYLON UNDER AASHTO VEHICULAR LOADING

MODEL 5 – H SHAPED PYLON UNDER IRC VEHICULAR LOADING

MODEL 6 – H SHAPED PYLON UNDER AASHTO VEHICULAR LOADING

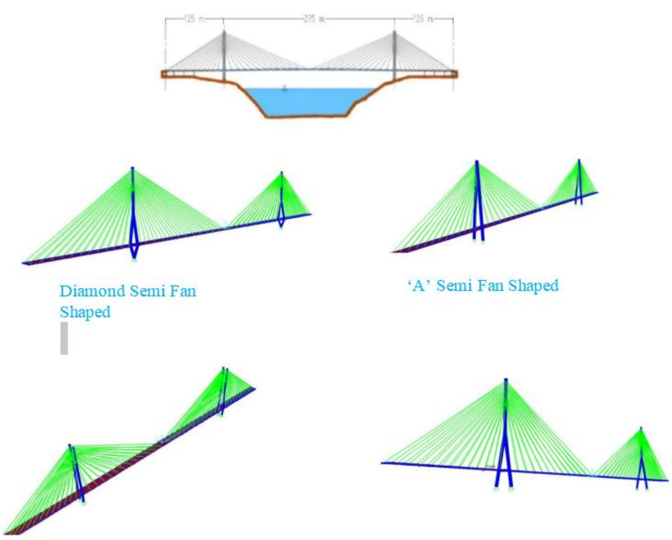
MODEL 7 – INVERTED Y SHAPED PYLON UNDER IRC VEHICULAR LOADING

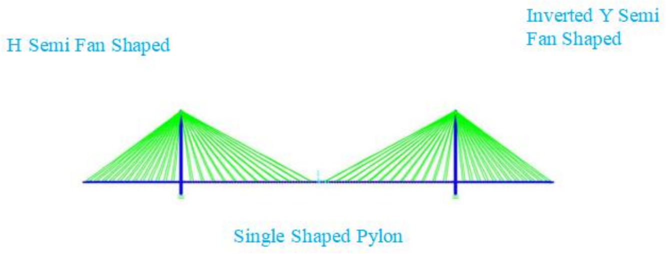
MODEL 8 – INVERTED Y SHAPED PYLON UNDER AASHTO VEHICULAR LOADING

MODEL 9 – A SHAPED PYLON UNDER IRC VEHICULAR LOADING

MODEL 10 – A SHAPED PYLON UNDER AASHTO VEHICULAR LOADING

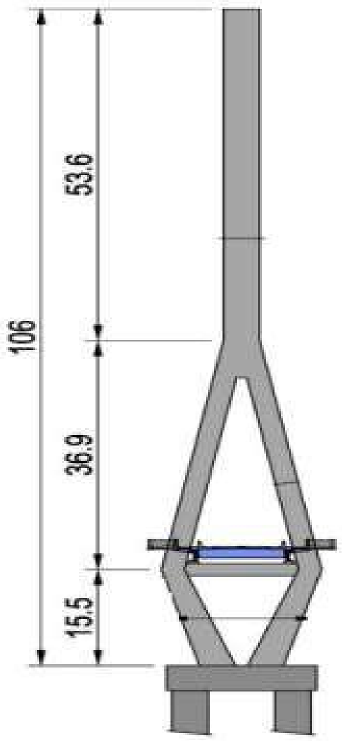
Typical Bridge Span Configuration



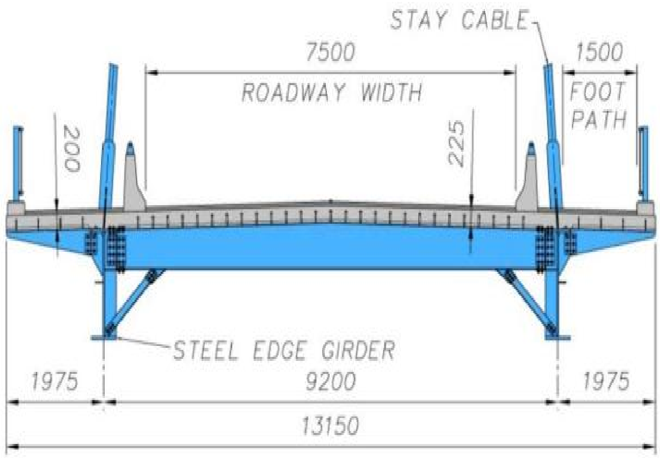


Different 3D models of Cable Stayed Bridge with different types of Pylons

PYLON GEOMETRY



MAIN SPAN SECTION –



Details of the components of cable stayed bridge

S. No.	Component	Material	Shape	Dimension (in m.)
1.	Cable	Steel	Circular	0.40
2.	Deck at Side Span	Concrete	Rectangular	Depth- 0.225 Length- 125
	Deck at Main Span	Concrete	Rectangular	Depth- 0.225 Length- 275
3.	Side Span End Cross Beams	Steel	I-Section	1 x 0.5 Tf= 0.15 Tw= 0.15
4.	Main Span End Cross Beams	Steel	I-Section	0.9 x 0.5 Tf= 0.15 Tw= 0.15
5.	Side Span Girders	Steel	I-Section	0.7 x 0.3 Tf= 0.1 Tw= 0.1
6.	Main Span Girders	Steel	I-Section	0.6 x 0.2 Tf= 0.1 Tw= 0.1
7.	Pylon Beam	Concrete	Rectangular	Depth- 3 Width- 3.5

Details of cross sectional properties of various components

S. No.	Component	Cross Sectional Area (m^2)	Moment of Inertia (m^4)	Shear Area (m^2)	Torsion Constant
1.	Cable	0.125	6.36×10^{-3}	0.2545	0.0127
2.	End Cross Beams	.225	0.0317	0.15	1.59×10^{-3}
3.	Intermediate Cross Beams	0.1	5.58×10^{-3}	0.07	2.7×10^{-4}
4.	Girders	0.045	1.03×10^{-3}	0.025	3.356×10^{-5}
5.	Pylon Beam	10.5	1.7747	3.667	2.6979

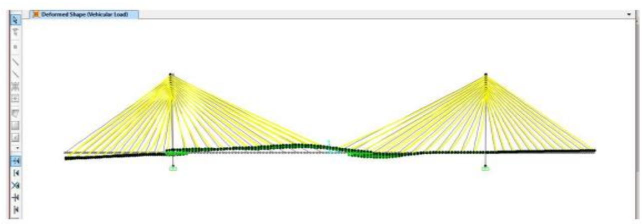
Details of dimensions for different shape of Pylons

S. No.	Pylon Shape	Material	Shape	Dimension (in m.)
1.	'Diamond' Shape	Concrete	Rectangular	(2.5 x 3.5)
2.	'H' Shape	Concrete	Rectangular	
3.	'Inverted Y' Shape	Concrete	Rectangular	
4.	'A' Shape	Concrete	Rectangular	
5.	'Single Pylon' Shape	Concrete	Rectangular	

IV.RESULT AND DISCUSSION

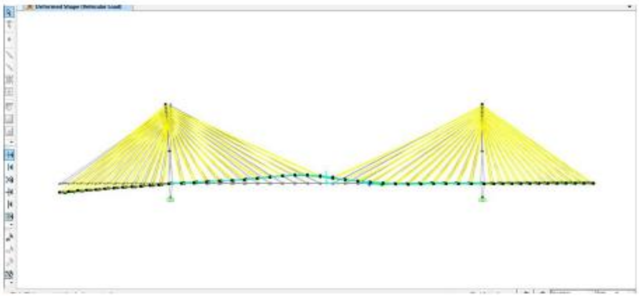
The detailed analysis has been done for the various arrangements of cables and outputs have been carried out in the tabular form and have been plotted. The results which have been plotted give an idea about the suitable arrangement of cable stays.

DEFLECTED SHAPES OF CABLE STAYED BRIDGE WITH DIAMOND SHAPED PYLON R IRC LOADING

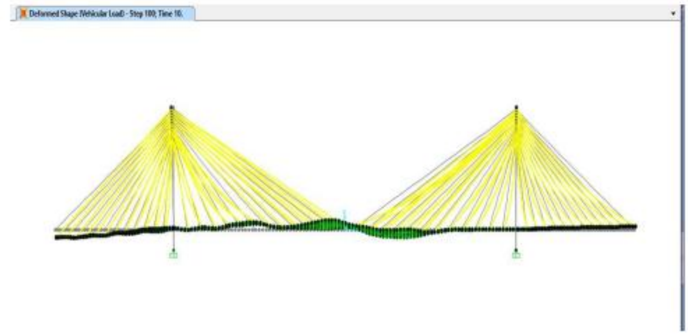


FO

FOR AASHTO LOADING

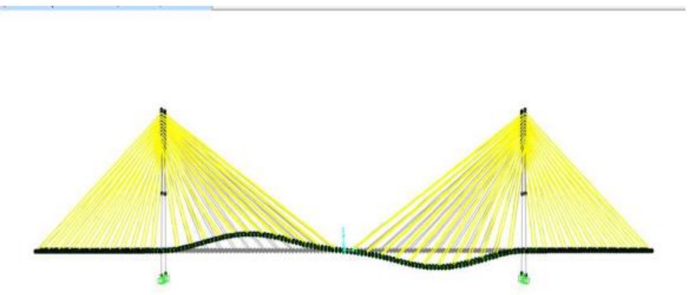


DEFLECTED SHAPES OF CABLE STAYED BRIDGE WITH SINGLE SHAPED PYLON FOR IRC LOADING

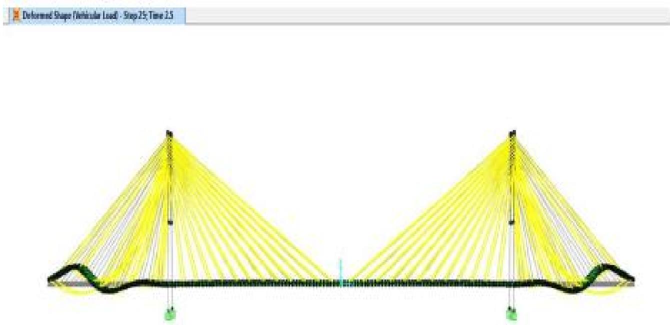


DEFLECTED SHAPES OF CABLE STAYED BRIDGE WITH H SHAPED PYLON

FOR IRC LOADING

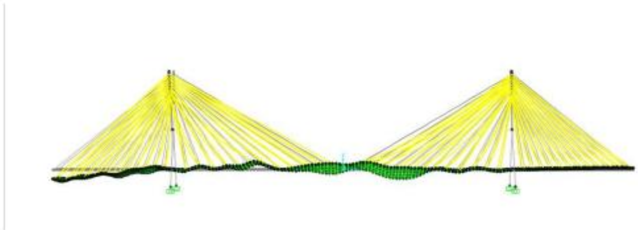


FOR AASHTO LOADING

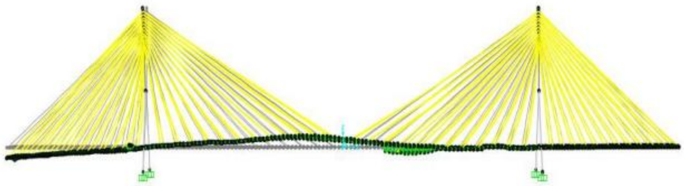


DEFLECTED SHAPES OF CABLE STAYED BRIDGE WITH INVERTED Y SHAPED PYLON

FOR IRC LOADING

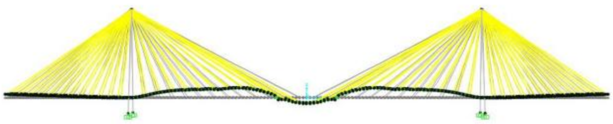


FOR AASHTO LOADING

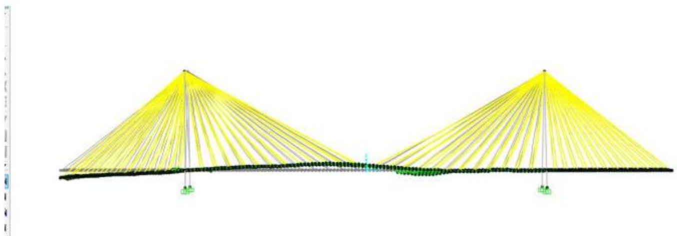


DEFLECTED SHAPES OF CABLE STAYED BRIDGE WITH A SHAPED PYLON

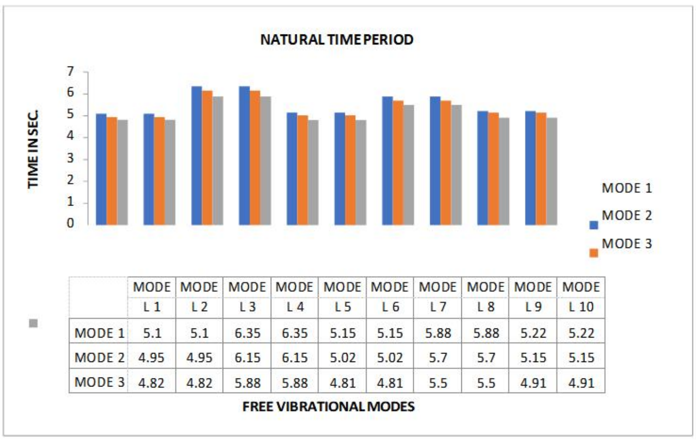
FOR IRC LOADING



FOR AASHTO LOADING

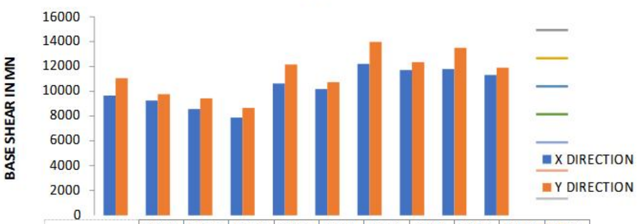


TIME PERIOD –



	MODE L 1	MODE L 2	MODE L 3	MODE L 4	MODE L 5	MODE L 6	MODE L 7	MODE L 8	MODE L 9	MODE L 10
MODE 1	5.1	5.1	6.35	6.35	5.15	5.15	5.88	5.88	5.22	5.22
MODE 2	4.95	4.95	6.15	6.15	5.02	5.02	5.7	5.7	5.15	5.15
MODE 3	4.82	4.82	5.88	5.88	4.81	4.81	5.5	5.5	4.91	4.91

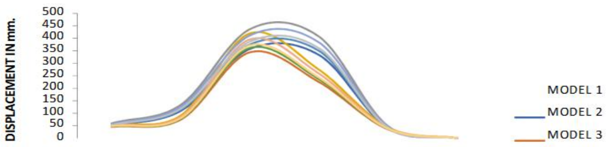
BASE SHEAR –



	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9	MODEL 10
X DIRECTION	9650	9254	8560	7875	10615	10179	12207	11706	11783	11299
Y DIRECTION	11052	9755	9426	8672	12157	10731	13981	12340	13494	11911

Different Types of Pylon with different specifications

DISPLACEMENT CURVE IN X DIRECTION –



	TOP	80	60	35	15	0
MODEL 1	49	110	359	334	39	0
MODEL 2	45	75	345	225	35	0
MODEL 3	59.78	134.2	437.98	407.48	47.58	0
MODEL 4	54.9	91.5	420.9	274.5	42.7	0
MODEL 5	51.45	115.5	376.95	350.7	40.95	0
MODEL 6	47.25	78.75	362.25	236.25	36.75	0
MODEL 7	56.35	126.5	412.85	384.1	44.85	0
MODEL 8	51.75	86.25	396.75	258.75	40.25	0
MODEL 9	52.92	118.8	387.72	360.72	42.12	0
MODEL 10	48.6	81	372.6	243	37.8	0

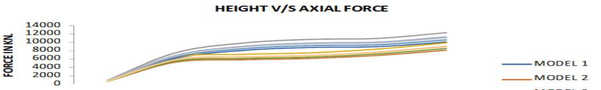
PYLON HEIGHT IN m.

DISPLACEMENT CURVE IN Y DIRECTION –

	TOP	80	60	35	15	0
MODEL 1	88	225	415	386	78	0
MODEL 2	72	160	390	370	70	0
MODEL 3	107.36	274.5	506.3	470.92	95.16	0
MODEL 4	87.84	195.2	475.8	451.4	85.4	0
MODEL 5	92.4	236.25	435.75	405.3	81.9	0
MODEL 6	75.6	168	409.5	388.5	73.5	0
MODEL 7	101.2	258.75	477.25	443.9	89.7	0
MODEL 8	82.8	184	448.5	425.5	80.5	0
MODEL 9	95.04	243	448.2	416.88	84.24	0
MODEL 10	77.76	172.8	421.2	399.6	75.6	0

PYLON HEIGHT IN m.

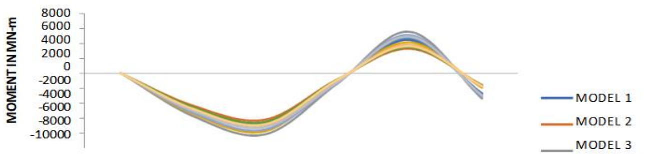
AXIAL FORCE IN PYLON –



	TOP	80	60	35	15	0
MODEL 1	750	6115	8042	8758	8960	10066
MODEL 2	650	5227	5825	6125	6869	8075
MODEL 3	915	7460.3	9811.24	10684.76	10931.2	12280.52
MODEL 4	793	6376.94	7106.5	7472.5	8380.18	9851.5
MODEL 5	787.5	6420.75	8444.1	9195.9	9408	10569.3
MODEL 6	682.5	5488.35	6116.25	6431.25	7212.45	8478.75
MODEL 7	840	6848.8	9007.04	9808.96	10035.2	11273.92
MODEL 8	728	5854.24	6524	6860	7693.28	9044
MODEL 9	825	6726.5	8846.2	9633.8	9856	11072.6
MODEL 10	715	5749.7	6407.5	6737.5	7555.9	8882.5

PYLON HEIGHT IN m.

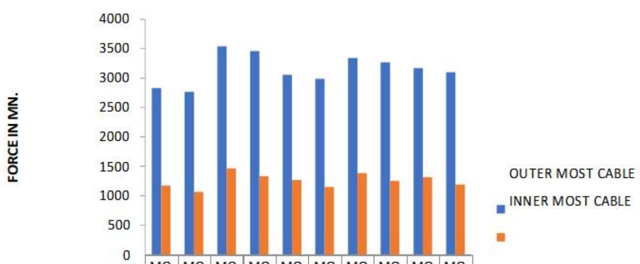
BENDING MOMENT IN PYLON –



	TOP	80	60	35	15	0
MODEL 1	0	-4606	-6562	-1105	4455	-2715
MODEL 2	0	-4356	-6236	-815	3298	-1563
MODEL 3	0	-5757.5	-8202.5	-1381.25	5568.75	-3393.75
MODEL 4	0	-5445	-7795	-1018.75	4122.5	-1953.75
MODEL 5	0	-4836.3	-6890.1	-1160.25	4677.75	-2850.75
MODEL 6	0	-4573.8	-6547.8	-855.75	3462.9	-1641.15
MODEL 7	0	-5296.9	-7546.3	-1270.75	5123.25	-3122.25
MODEL 8	0	-5009.4	-7171.4	-937.25	3792.7	-1797.45
MODEL 9	0	-5066.6	-7218.2	-1215.5	4900.5	-2986.5
MODEL 10	0	-4791.6	-6859.6	-896.5	3627.8	-1719.3

PYLON HEIGHT IN m.

AXIAL FORCE IN CABLES –



	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9	MODEL 10
OUTER MOST CABLE	2831	2768	3539	3460	3057	2989	3341	3266	3171	3100
INNER MOST CABLE	1174	1065	1468	1331	1268	1150	1385	1257	1315	1193

VI.CONCLUSION

In this study the response and conduct of the cable-stayed bridge under the action of imposed and seismic loads is found by analysing the structure using SAP 2000 software.

The Natural time period for the diamond shaped pylon seems to be lesser up to 17% as compared to other shaped pylons, due to which the natural frequency of the structure is low which is much desirable as the higher frequencies have higher displacement of the component which incurs higher fatigue damage to the component.

The Base shear for the diamond shaped pylon is 22% less as compare to single shaped pylon.

The displacement of the cable stayed bridge under the action of the imposed and seismic loads is observed to be found less for diamond shaped pylon as compared to other shapes. The values of displacement is 22% lower for the diamond shaped pylon as compare to single shaped pylon whose displacement values are higher in both directions.

The displacement values for AASHTO Loading is seems to be 7% less than the IRC Loading Models as the loading values for AASHTO is much differ than the values considered in IRC Loading.

The axial force in Pylons is 16% lower in diamond shaped pylon for IRC loading while 12% lower for AASHTO loading as compare to single shaped Pylon.

The Bending Moment is 19% lower in Diamond Shaped for IRC Loading while 16% lower for AASHTO loading when compared to single shaped Pylon

The tensile force / axial force in cables found greater for outer most cables and lower in inner most cables due to the inclination of cables and it seems to be 10% less for IRC Loading values while 7% less for AASHTO loading values as compare to single shaped Pylon.

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