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Behavior of Asymmetric Cable Stayed Bridge for Long Span

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Abstract: *In the recent years cable stayed bridges have received more attention than any other bridges. As one of the most competitive bridge in modern times, the cable stayed bridge is ideally suitable for long span. Asymmetric cable stayed bridges are the upgrade of conventional cable stayed bridges. Analytical investigation is an important in the study of asymmetric cable stayed bridge. The response of the bridge deck under moving traffic load is very important in the analysis process. Even the slightest deflection may result in the collapse of the bridge structure. Recent reports states that the cable stayed bridges are subjected to wave like vibrations when subjected to moving loads. So the bridge must be analyzed in such a way that its deflections are well under the permissible limits. The parameters like displacements, shear forces, bending moments and percentage of reinforcements were studied in long span asymmetric cable stayed bridge. The asymmetric cable bridge was modeled using SAP2000 software.*

Keywords: Bending Moments, Displacements, Long Span Asymmetric Cable Bridge, Moving Loads, Shear Forces, SAP 2000.

I. INTRODUCTION

Cable stayed bridges are more popular than any other bridges mainly in the United States, Japan and Europe as well as in third world counties due to their ability to cover large spans. Cable stayed bridges can cross above one kilometer. Recently lots of cable stayed bridges are constructed in many countries about more than one kilometer. As one of the most competitive bridge in modern times these bridges are more effective in cost and behavior for long span. There is still place for innovation in cable stayed bridge structure. Asymmetric cable stayed bridges are the well upgrade of conventional cable stayed bridge. The combined of single plane cable, two plane cable and three plane cable are provide depends on number of traffic lanes.

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Currently these kind of bridges are preferable than conventional structures due to their aesthetic purpose. Consequently, the reliability of the overall structure and the complexity of the dynamic characteristics should be fully taken into consideration when the cable stayed bridge structure is designed. Modal analysis is an important for the study of analytical investigation of asymmetric cable stayed bridge.

II. TYPES OF CABLE STAYED BRIDGE

Cable-stayed bridges can be distinguished by the number of spans, number of towers, girder type, number of cables, etc. Cable-stayed bridges can also be categorized according to the construction material used for major structural components, configurations of stay cables and tower. For example, different types of construction materials used for the main components like girders in cable bridges: steel, concrete, and hybrid cable stayed bridge.

Contemporarily the asymmetric cable stayed bridges are classified as cable based asymmetric bridge and pylon based asymmetric bridge. These types of bridges are more preferable in recent times for aesthetic reasons. In this paper the cable base asymmetric bridge is investigated for long span. In this bridge single plane cable is provided at one side and two plane cable at its opposite side to create asymmetric model.

III. OBJECTIVES OF THE PROJECT

- To study the behaviour of asymmetric cable stayed bridges for different loading conditions.
- To create the model of long span conventional and asymmetric Cable stayed bridge for two cable plane and four cable plane arrangements using SAP2000 software.
- To analyse the conventional and asymmetric cable plane system for two cable plane and four cable plane arrangements.
- To investigate the response of asymmetric Cable stayed bridge under all condition of loads mainly in moving loads and the comparative study will be carry out between conventional and asymmetric cable bridges.
- To propose the construction of asymmetric cable bridge design instead of conventional cable bridge design.

IV. SPECIFICATIONS OF CONVENTIONAL AND ASYMMETRIC CABLE STAYED BRIDGE

The specifications of conventional and asymmetric cable stayed bridge for two cable plane arrangements are shown in Table- I.

Table- I: Specifications of two cable plane bridges

Name	Description	
	Conventional cable stayed bridge	*Asymmetric cable stayed bridge*
Total length	1000 m	1000 m
Span arrangement	2 cable plane	2 cable plane
Main span	500 m	500 m
Side span	250 m	250 m
Pylon height	100 m	100 m
Pylon type	Inverted Y-type	Single pylon
Cable system	Fan type	Fan type
Number of cables (each side span)	44 no's & 44 no's	22 no's & 44 no's
Cable diameter	0.06 m	0.06 m
Girder type	Box girder	Box girder
Girder depth	3 m	3 m
Girder width	24 m	24 m
Traffic	Four lanes	Four lanes

The specifications of conventional and asymmetric cable stayed bridge for four cable plane arrangements are shown in Table- II.

Table- II: Specifications of two cable plane bridges

Name	Description	
	Conventional cable stayed bridge	*Asymmetric cable stayed bridge*
Total length	1000 m	1000 m
Span arrangement	4 cable plane	4 cable plane
Main span	250 m	250 m
Side span	125 m	125 m
Pylon height	50 m	50 m
Pylon type	Inverted Y-type	Single pylon
Cable system	Fan type	Fan type
Number of cables (each side span)	44 no's & 44 no's	22 no's & 44 no's
Cable diameter	0.06 m	0.06 m
Girder type	Box girder	Box girder
Girder depth	3 m	3 m
Girder width	24 m	24 m
Traffic	Four lanes	Four lanes

V. ANALYTICAL INVESTIGATION

The model was created in SAP2000 software. Here the analysis of conventional and asymmetric cable stayed bridge for two cable plane and four cable plane arrangements are carried out for dead load, live load, moving load, wind load and seismic forces.

The modeling of conventional cable bridge for two cable plane is shown in Fig. 1.

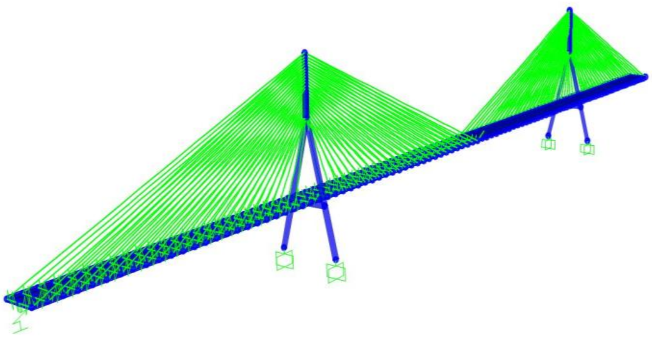

Fig. 1. Conventional cable stayed bridge for two cable plane

The modeling of asymmetric cable bridge for two cable plane is shown in Fig. 2.

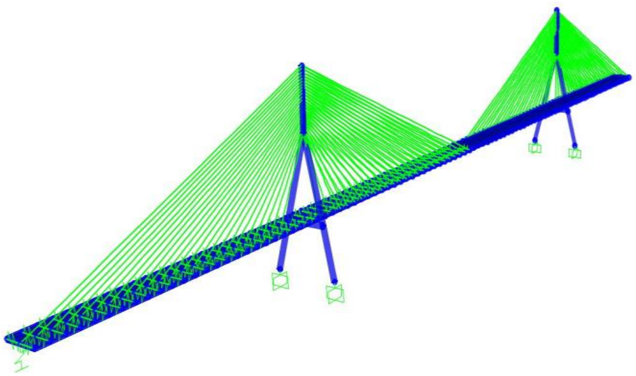

Fig. 2. Asymmetric cable stayed bridge for two cable plane

The modeling of conventional cable bridge for four cable plane is shown in Fig. 3.

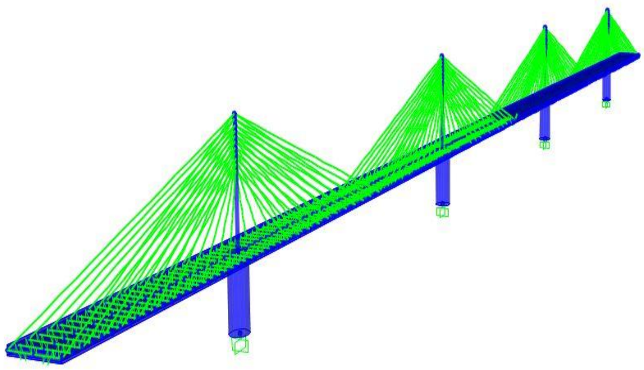

Fig. 3. Conventional cable stayed bridge for four cable plane

The modeling of asymmetric cable bridge for four cable plane is shown in Fig. 4.

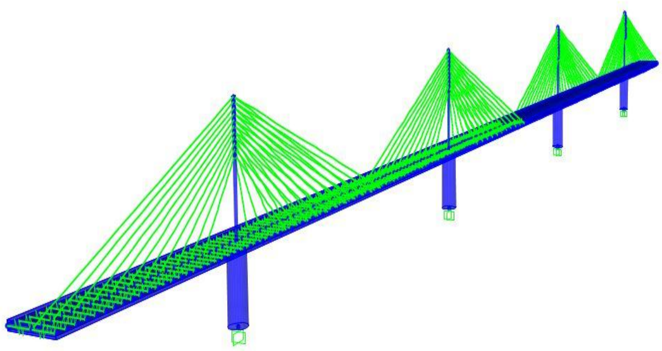

Fig. 4. Asymmetric cable stayed bridge for four cable plane

A. Material properties

The material properties were used in the conventional and asymmetric bridge modeling is shown in Table- III.

Table- III: Material properties

S.No.	Component	Material Properties
1	Cable	Fe345
2	Girder	M40 & HYSD500
3	Pylon	M40 & HYSD500

B. Sectional properties

The sectional properties were used in the conventional and asymmetric bridge modeling is shown in Table IV.

Table- IV: Sectional properties

S.No.	Component	Material	Shape	Dimensions
1	Cable	Steel	Circular	0.06m
2	Girder	Concrete	Rectangular	Depth=3m Width=24m T_f=0.7m T_w=0.8m
3	Pylon	Concrete	Circular	2m,5m &10m

C. Load case details

The following load case details were applied in the conventional and asymmetric cable stayed bridge for both two cable plane and four cable plane arrangements.

- *Dead load:* In the dead load due to self-weight of structural elements and other materials are automatically calculated by SAP2000 software. It included unit weight of cable, unit weight of pylon, unit weight of girder and rebar.
- *Live load:* The live load is applied as 4kN/m as per IS 875 part II throughout the girder in cable stayed bridge.
- *Moving load:* The response of the bridge deck under moving traffic load is very important. Even the slightest deflection may result in the collapse of the bridge structure. Recent reports state that the cable stayed bridges are subjected to wave like vibrations when subjected to moving loads. So the bridge must be designed in such a way that its deflections are well under the permissible limits. IRC class 'A' truck loadings are considered for moving load analysis which is shown in below Figure. Vehicle is moving forward in lane 1 & lane 2 whereas, other vehicles are moving backward in lane 3 & lane 4.
- *Wind load:* The wind load is applied as per IS 875 part III to both X and Y directions. The wind load parameters are listed as follows.

  Wind exposure parameters
  - Windward co-efficient = 0.8
  - Leeward co-efficient = 0.5

  Wind co-efficient
  - Wind speed, V_b = 55 m/s

  (Maximum wind speed given in IS 875-1987)
  - Terrain category = 2
  - Structure class = B
  - Risk co-efficient, k_1 = 1.08
  - Topography factor, k_2 = 1
- *Seismic forces:* Seismic forces were applied in X and Y directions to get maximum response of the structure during an earthquake. The following are the parameters of seismic forces.
  - Seismic zone factor, Z = 0.36
  - Importance factor, I = 1.5
  - Soil type = II
  - Response reduction, R = 5

The load case details for analytical investigation are shown in Table- V.

Table- V: load case details

S.No.	Load details	Description
1	Dead load	Auto calculated by software
2	Live load	As per IS 875 Part II
3	Moving load	IRC class 'A' vehicle
4	Wind load	55m/sec
5	Seismic force	Zone 5

VI. RESULTS AND DISCUSSION

The following results were obtained from SAP2000 software. The results are based on the ultimate limit state combination of loads.

Ultimate limit state combination of load is 1.1 D.L+1.4 L.L+1.4 M.L+ 0.5 W.L+ 0.5 EQ. This combination of load is well effective to investigate the behavior of asymmetric cable stayed bridge for long span condition.

The deck displacements of conventional and asymmetric cable stayed bridge for two cable plane arrangements are shown in Fig. 5.

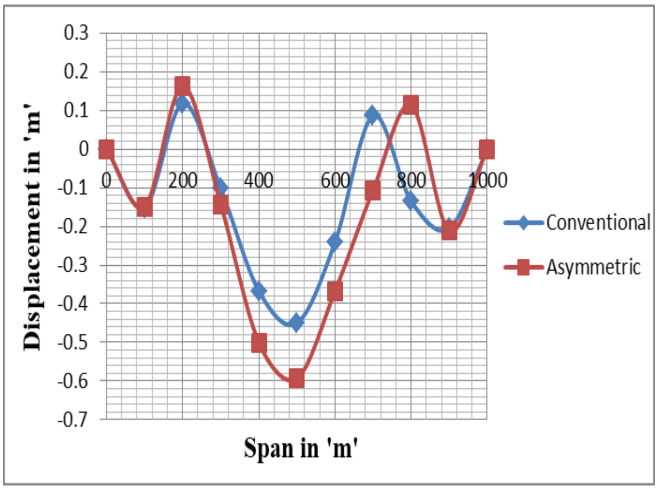

Fig. 5. Span vs. displacement curve of conventional and asymmetric cable stayed bridge for two cable plane

The maximum deck displacement of conventional cable bridge for two cable plane is 0.44 m and maximum deck displcament of asymmetric cable bridge is 0.59 m.

The deck shear forces of conventional and asymmetric cable stayed bridge for two cable plane arrangements are shown in Fig. 6.

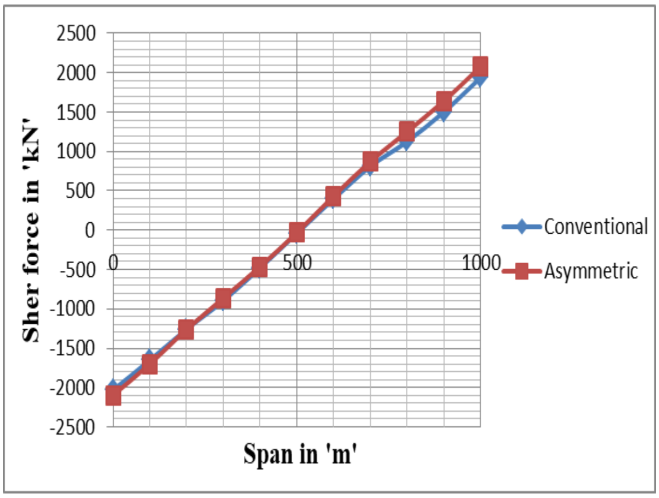

Fig. 6. Span vs. shear force curve of conventional and asymmetric cable stayed bridge for two cable plane

The maximum deck shear force of conventional cable bridge for two cable plane is 2059.395 kN and maximum deck shear force of asymmetric cable bridge is 2078.805 kN.

The deck bending moments of conventional and asymmetric cable stayed bridge for two cable plane arrangements are shown in Fig. 7.

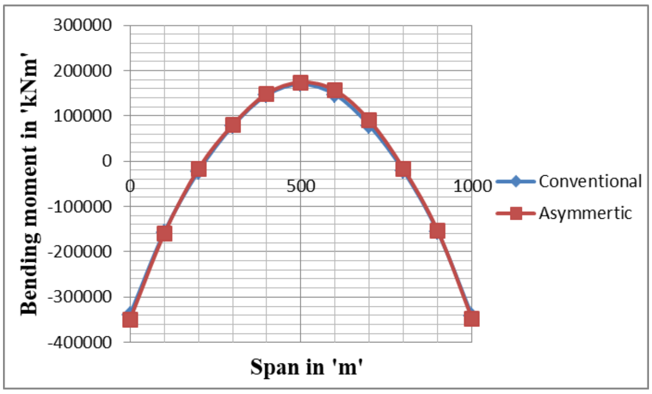

Fig. 7. Span vs. bending moment curve of conventional and asymmetric cable stayed bridge for two cable plane

The maximum deck bending moment of conventional cable bridge for two cable plane is 3.41×10^5 kNm as a negative value and maximum deck bending moment of asymmetric cable bridge is 3.49×10^5 kNm as a negative value.

The pylon shear forces of conventional and asymmetric cable stayed bridge for two cable plane arrangements are shown in Fig. 8.

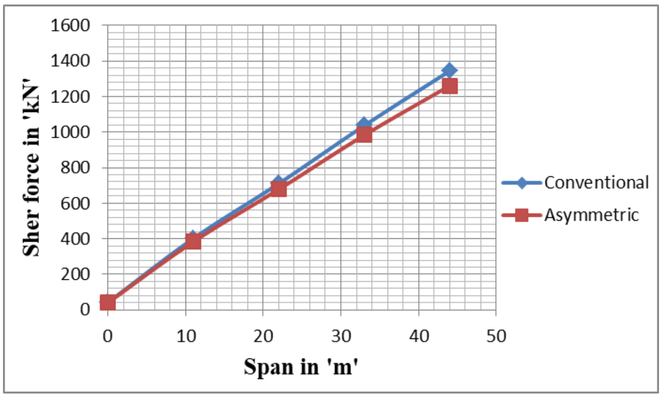

Fig. 8. Height vs. shear force curve of conventional and asymmetric cable stayed bridge for two cable plane

The maximum shear force in pylon of conventional cable bridge for two cable plane is 1344.103 kN and maximum shear force in pylon of asymmetric cable bridge is 1261.039 kN.

The pylon bending moments of conventional and asymmetric cable stayed bridge for two cable plane arrangements are shown in Fig. 9.

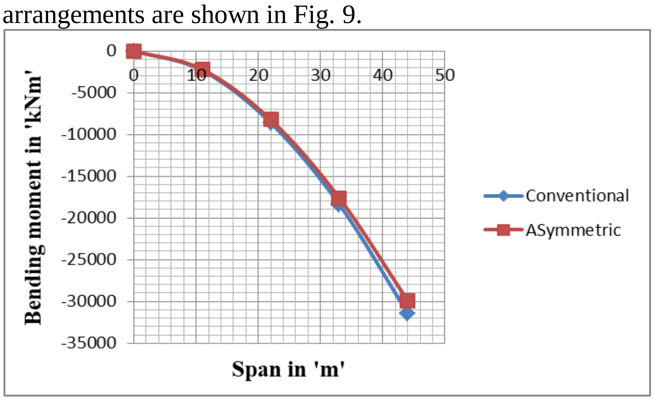

Fig. 9. Height vs. bending moment curve of conventional and asymmetric cable stayed bridge for two cable plane

The maximum bending moment in pylon of conventional cable bridge for two cable plane is 3.14×10^4 kNm as a negative value and maximum bending moment in pylon of asymmetric cable bridge is 2.9×10^4 kNm as a negative value.

The percentage of reinforcement in pylon of conventional and asymmetric cable stayed bridge for two cable plane arrangements are shown in Fig. 10.

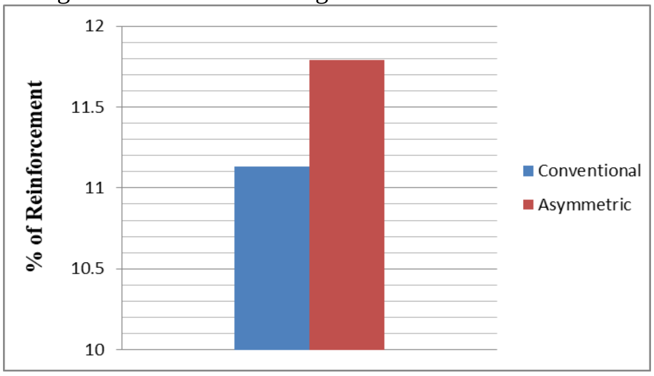

Fig. 10. Percentage of reinforcement in pylon

The percentage of reinforcement in pylon of conventional cable bridge is 11.2% and for asymmetric cable bridge pylon is 11.8%.

The deck displacements of conventional and asymmetric cable stayed bridge for four cable plane arrangements are shown in Fig. 11.

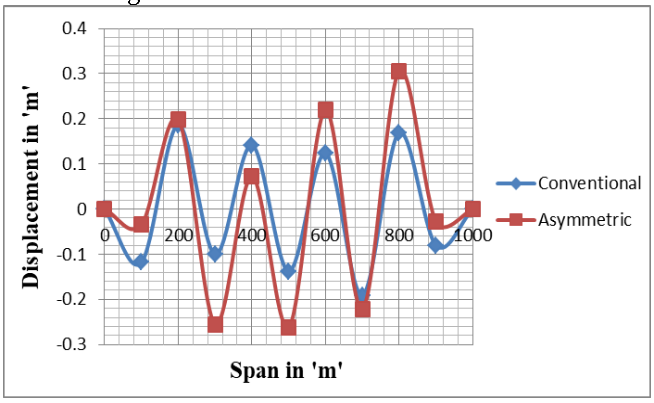

Fig. 11. Span vs. displacement curve of conventional and asymmetric cable stayed bridge for four cable plane

The maximum displacement in deck of conventional cable bridge for four cable plane is 0.24 m and maximum displcament in deck of asymmetric cable bridge is 0.32 m.

The deck shear forces of conventional and asymmetric cable stayed bridge for four cable plane arrangements are shown in Fig. 12.

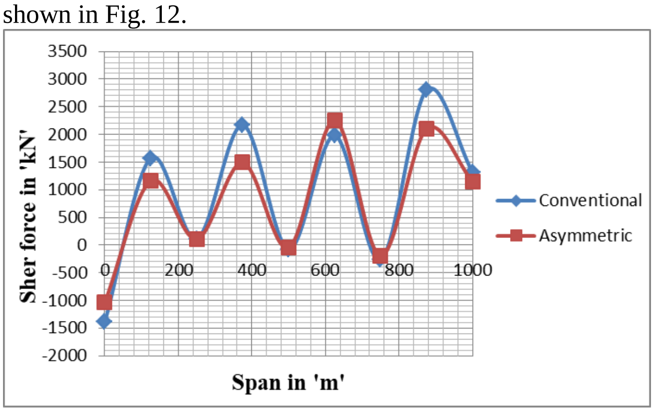

Fig. 12. Span vs. shear force curve of conventional and asymmetric cable stayed bridge for four cable plane

The maximum shear force in deck of conventional cable bridge for four cable plane is 3212.7 kN and maximum shear force in deck of asymmetric cable bridge is 2699.96 kN.

The deck bending moments of conventional and asymmetric cable stayed bridge for four cable plane arrangements are shown in Fig. 13.

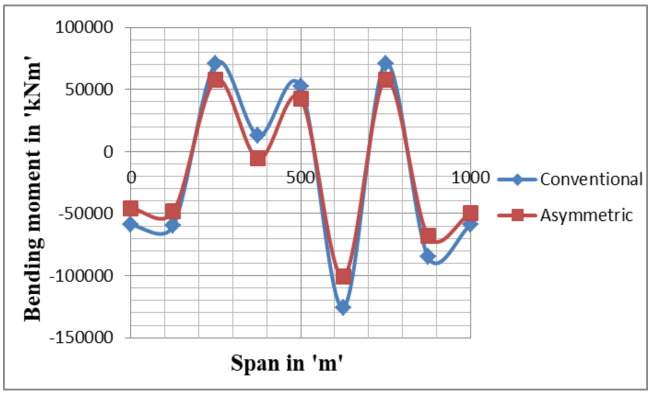

Fig. 13. Span vs. bending moment curve of conventional and asymmetric cable stayed bridge for four cable plane

The maximum bending moment in deck of conventional cable bridge for four cable plane is 1.31×10^5 kNm as a negative value and maximum bending moment in deck of asymmetric cable bridge is 1.07×10^5 kNm.

The pylon shear forces of conventional and asymmetric cable stayed bridge for four cable plane arrangements are shown in Fig. 14.

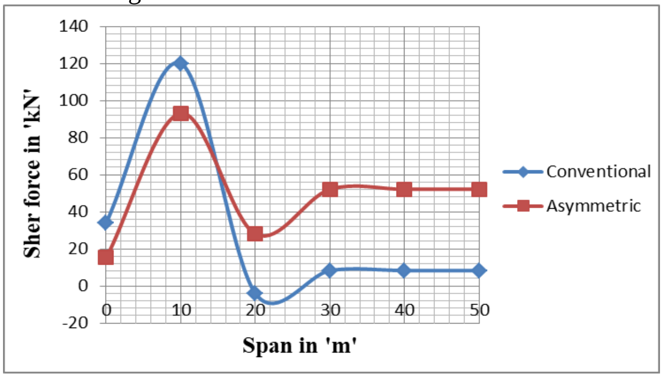

Fig. 14. Span vs. shear force curve of conventional and asymmetric cable stayed bridge for four cable plane

The maximum shear force in pylon of conventional cable bridge for four cable plane is 125.029 kN and maximum shear force in pylon of asymmetric cable bridge is 102.205 kN.

The pylon bending moments of conventional and asymmetric cable stayed bridge four cable plane arrangements are shown in Fig. 15.

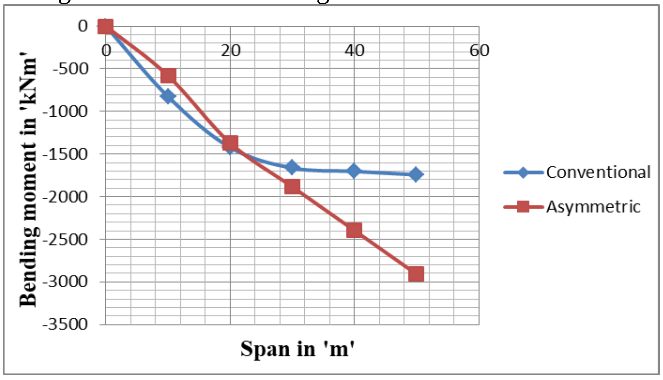

Fig. 15. Span vs. shear force curve of conventional and asymmetric cable stayed bridge for four cable plane

The maximum bending moment in pylon of conventional cable bridge for four cable plane is 1743.154 kNm as a negative value and maximum bending moment in pylon of asymmetric cable bridge is 2910 kNm as a negative value.

The percentage of reinforcement in pylon of conventional and asymmetric cable stayed bridge for four cable plane arrangements are shown in Fig. 16.

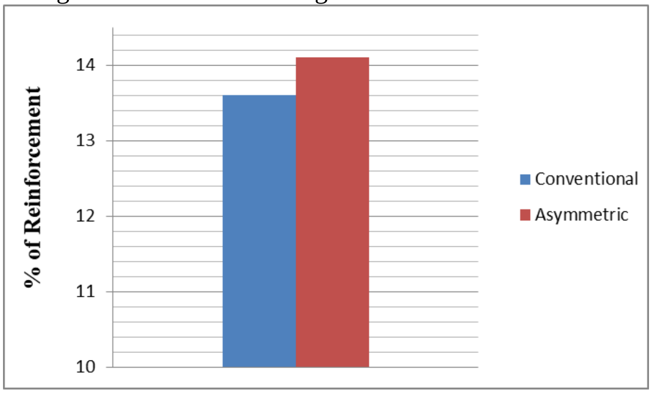

Fig. 16. Percentage of reinforcement in pylon

The percentage of reinforcement in pylon of conventional cable bridge is 13.6% and for asymmetric cable bridge pylon is 14.1%.

VII. CONCLUSION

From the results and discussion we have come to following conclusion.

In this study the linear analysis is done by using SAP 2000 software.

The Engineering properties like displacements, shear force, bending moment in deck and shear force, bending moment in pylons are considered for the present study have the small difference in behavior between conventional and asymmetric cable bridge for two and four cable plane arrangements.

The percentage of reinforcements in pylon for conventional and asymmetric cable bridge is changed. The change in percentage of reinforcemnt is due to reduced in number of cables.

The numbers of cables are partially reduced in asymmetric cable bridge than conventional cable bridge. Therefore the weights of the cables are greatly reduced along the length of the bridge.

Hence we can construct asymmetric cable bridge instead of conventional cable bridge because of its behavior similar to conventional cable bridge and aesthetic improvisation.

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