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Optimizing Bridge Design for Economy: A Comparative Study of Concrete, Steel and Prestressed Girders in Sap2000

Dhairya Kathore[1], Prof. Sanjay Limbodiya[2], Prof. Priyanka Rajput[3]

[1]Masters Student, Department of Civil Engineering, SAGE University Indore
[2,3]Assistant Professor, Department of Civil Engineering, SAGE University Indore

Abstract
This project presents a comparative structural analysis of cable-stayed bridges utilizing different deck configurations: **steel, concrete, and prestressed concrete girders**. Using **SAP2000** software, the study evaluates a 120m multi-span bridge (20m - 80m - 20m) to determine the influence of material choice and construction methodology on structural performance.
The investigation focuses on two primary construction scenarios: **un-supported (unshored)** and **supported (shored)** spans. In the un-supported case, the initial deflection and stresses are analyzed during the pre-composite stage, whereas the supported case considers the full composite action resisting total loads upon the removal of temporary supports. Key performance indicators, including **maximum flexural stresses, shear forces, and bending moments**, are compared across the different materials.
Furthermore, the study reviews the economic viability of various girder shapes (T-beam vs. Box girder) and the impact of deck skewness on analysis methods, noting that finite element method (FEM) is required for skews exceeding 25°. The findings aim to provide a technical and economic basis for selecting optimal bridge deck systems based on span requirements, life-cycle costs, and construction constraints as per **IRC: 6-2000** and **AASHTO LRFD** standards.

Keywords: Cable-stayed bridge, SAP2000, Composite construction, Prestressed concrete, Structural analysis, Shored vs. Unshored construction.

1. Introduction

General Introduction

The bridge is a structure used for providing a passway two roads, rivers, pipelines, railway, valley to provide a required passage for vehicles, pedestrians without any obstacle from one point to another and reduces the traffic congestions and timing for way from one point to another , different types of bridges are used for different purposes as per the load is on the bridge coming and on the span on which we have to construct the bridge. In this project we studied about the cable stayed bridge using Sap Software. the different structural components of bridge are as follows:

- The deck (or stiffening girder)
- The cable system supporting the deck
- The pylons (or towers) supporting the cable system

- The anchor blocks (or anchor piers) supporting the cable system vertically and horizontally, or only vertically, at the extreme ends.

Prestressed deck girder:

The prestressed girder are used now a days in which prestressing forces are applied using the prestressed tendons ,there are two types of deck girder in prestressed deck girder are as:

- Pre tensioned prestressed deck girder
- Post tensioned deck prestressed girder

Methodology

This study is performed to compare the Cable stayed bridges designed using steel , concrete and pre-stressed deck girder with same loading and span for bridge .Two cases of span supported and un-supported during construction are considered for comparison. Maximum stresses , shear forces ,bending moment are compared for 120.0m span concrete, steel and prestressed bridge girder . Let the dimensions of girder section are as given below:

Let the dimensions of girder section are as given below:

Left span l1 = 20m

Middle span length l2 = 80m

Right span length l3 = 20 m

Deck width = 3m

Column height h1, = 5m

Top slab thickness = 0.305

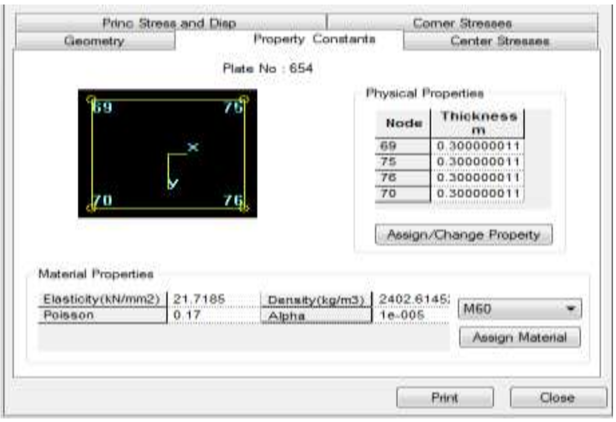
Two types of spans of the bridge have been considered for design

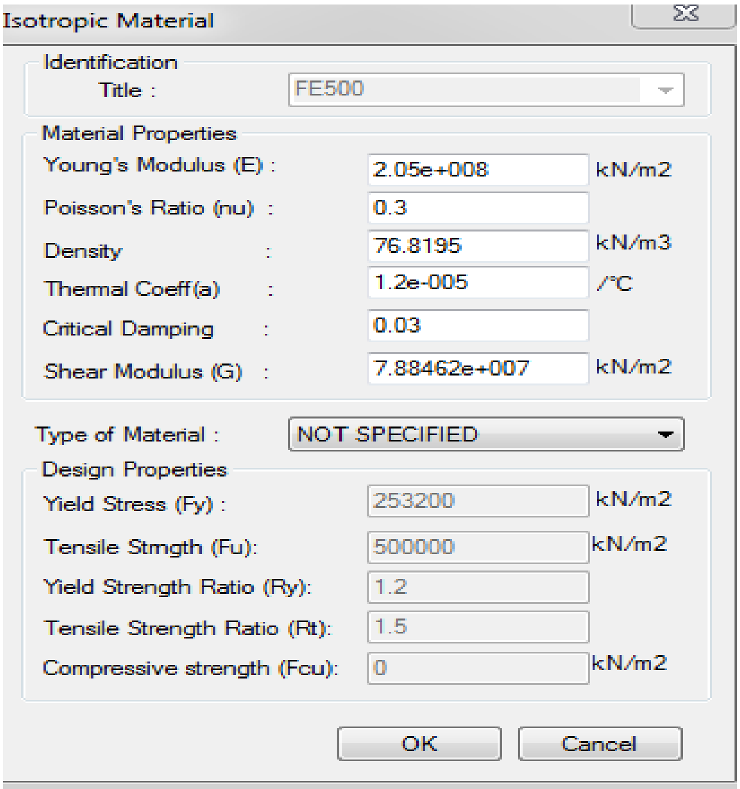
Un-supported span: In the unsupported span it has been assumed that site conditions are such that it is not possible to support the bridge during construction. Therefore, the steel girder will deflect when it is launched, then it will further deflect under the load of shuttering and bridge deck slab concrete. After hardening of the deck slab concrete, the composite action of the steel girder and RCC deck slab will start. Therefore, under live load conditions the composite section will be available to take up the load.

Supported span: In the supported span case, it is assumed that it is possible to erect temporary support to the bridge span. Therefore, there will not be any deflection of the steel girder or the deck slab until the supports are removed after hardening of the deck slab concrete. Thus, the composite sections will resist all the loads after removal of the support.

Material considered:

For concrete deck girder M 60 grade of concrete is used in design of cable stayed bridge





For design of steel girder bridges FE 500 is used in design of cable stayed bridge

Loads Considered

Dead load: self weight of members and cables are taken in dead load

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	DL
Primary	2	IRC: SLS CLASS AA LOADING N8: DISP X
Primary	3	IRC: SLS CLASS AA LOADING N8: DISP Y
Primary	4	IRC: SLS CLASS AA LOADING N8: DISP Z
Primary	5	IRC: SLS CLASS AA LOADING N8: DISP R
Primary	6	IRC: SLS CLASS AA LOADING N8: DISP R
Primary	7	IRC: SLS CLASS AA LOADING N8: DISP R
Primary	8	IRC: SLS CLASS AA LOADING N9: DISP X
Primary	9	IRC: SLS CLASS AA LOADING N9: DISP Y
Primary	10	IRC: SLS CLASS AA LOADING N9: DISP Z
Primary	11	IRC: SLS CLASS AA LOADING N9: DISP R
Primary	12	IRC: SLS CLASS AA LOADING N9: DISP R
Primary	13	IRC: SLS CLASS AA LOADING N9: DISP R
Primary	14	IRC: SLS CLASS AA LOADING N253: DISF
Primary	15	IRC: SLS CLASS AA LOADING N253: DISF
Primary	16	IRC: SLS CLASS AA LOADING N253: DISF
Primary	17	IRC: SLS CLASS AA LOADING N253: DISF
Primary	18	IRC: SLS CLASS AA LOADING N253: DISF
Primary	19	IRC: SLS CLASS AA LOADING N253: DISF
Primary	20	IRC: SLS CLASS AA LOADING N254: DISF
Primary	21	IRC: SLS CLASS AA LOADING N254: DISF
Primary	22	IRC: SLS CLASS AA LOADING N254: DISF
Primary	23	IRC: SLS CLASS AA LOADING N254: DISF
Primary	24	IRC: SLS CLASS AA LOADING N254: DISF
Primary	25	IRC: SLS CLASS AA LOADING N254: DISF

Live load : In Live load vehicular loads and temperature variation load are taken

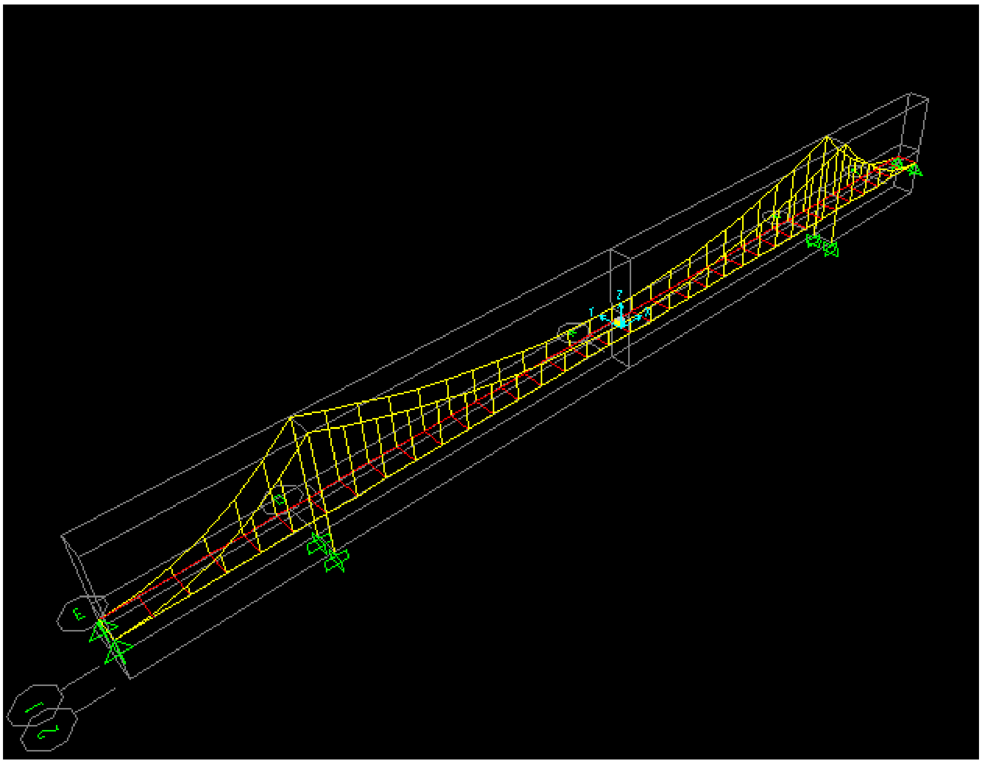


Fig 3.2: 3 D view of cable stayed bridge

Results and Discussion

The models of cable stayed bridge of same span and same loading condition with different deck girder materials are analysed using sap software and the results are computed below in tables and graphs in terms of stresses, shear forces and moments and the variation of stresses are also shown through contour diagrams below:

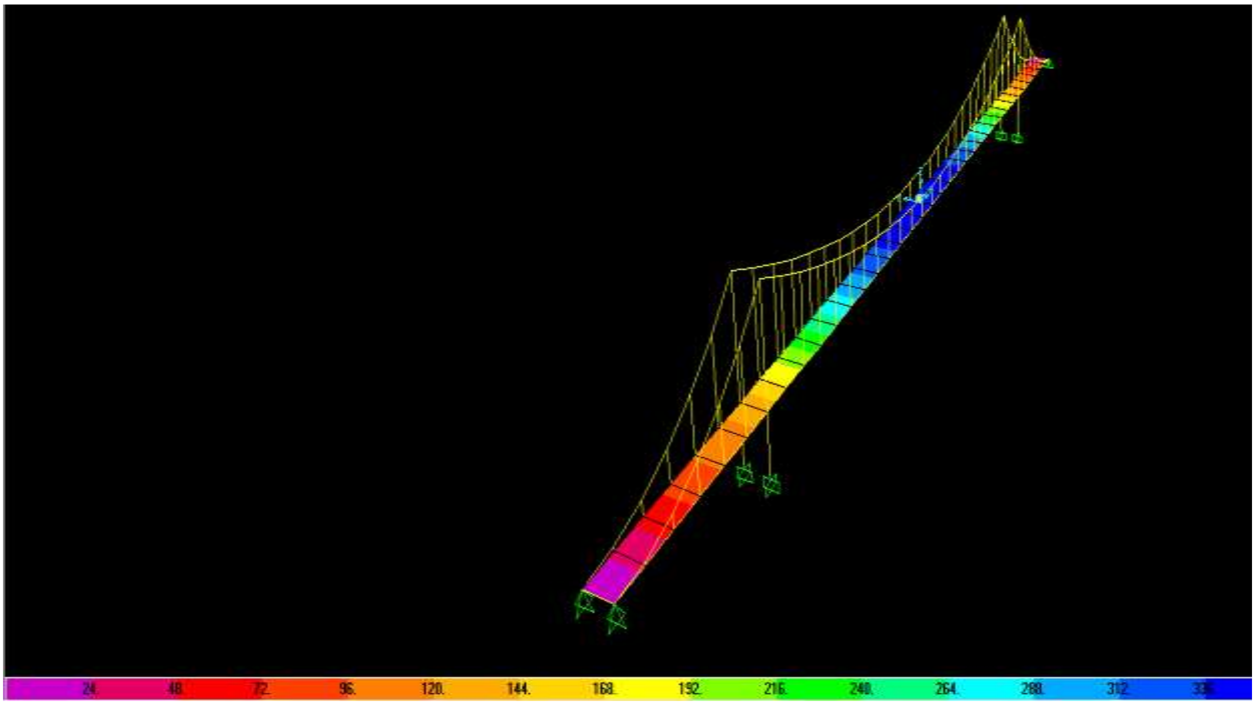


Fig 4.1: M max of concrete deck girder of cable stayed bridge

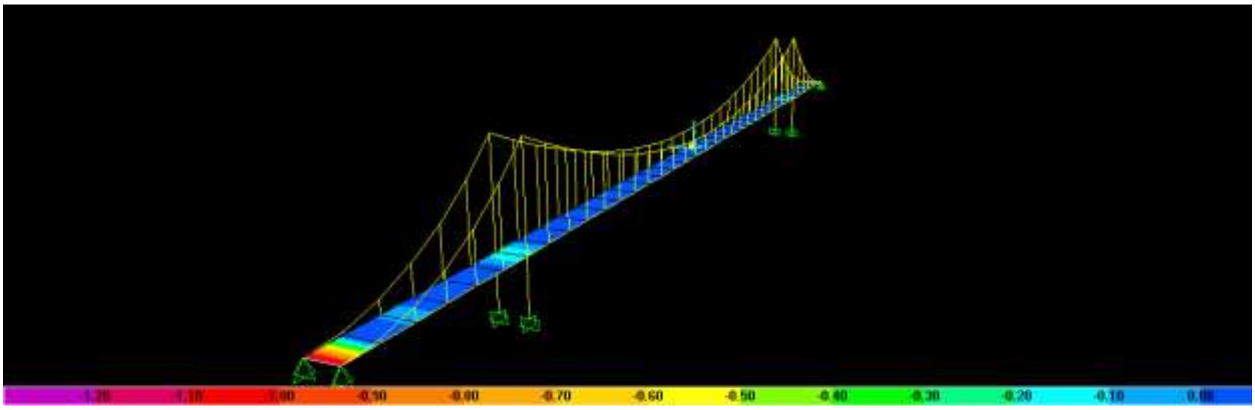


Fig 4.2: M min of concrete deck girder of cable stayed bridge

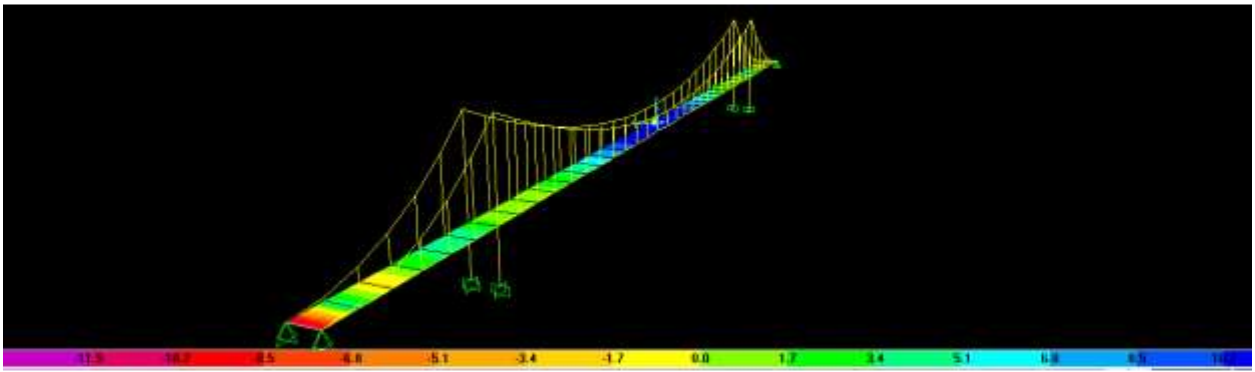


Fig 4.3: F max of concrete deck girder of cable stayed bridge

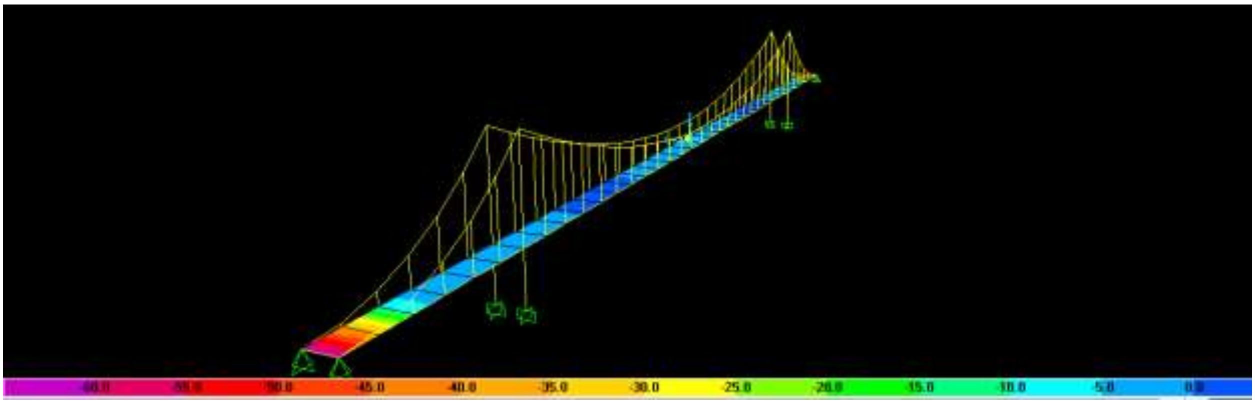


Fig 4.4: F min of concrete deck girder of cable stayed bridge

TABLE: Element Forces - Frames					
Frame	V2	V3	T	M2	M3
Text	KN	KN	KN-m	KN-m	KN-m
1	-0.577	0.000003267	0.000004905	-9.154E-06	-0.2989
1	-0.42	0.000003267	0.000004905	-0.00001071	-0.0616
1	-0.264	0.000003267	0.000004905	-0.00001227	0.1013
1	-0.108	0.000003267	0.000004905	-0.00001382	0.1898
1	0.049	0.000003267	0.000004905	-0.00001538	0.2038
1	0.205	0.000003267	0.000004905	-0.00001693	0.1434
1	0.361	0.000003267	0.000004905	-0.00001849	0.0086
1	0.518	0.000003267	0.000004905	-0.00002004	-0.2007
2	-1.217	-0.00003476	0.000004856	0.00002104	-0.9706
2	-0.67	-0.00003476	0.000004856	0.00007917	0.6072
2	-0.123	-0.00003476	0.000004856	0.0001373	1.27
3	-67.902	-0.00001095	-0.000007797	-0.00002763	-14.2564
3	-67.902	-0.00001095	-0.000007797	-0.00002611	-4.8255
3	-67.902	-0.00001095	-0.000007797	-0.00002459	4.6053
4	-0.577	-0.000003267	-0.000004905	9.154E-06	-0.2989
4	-0.42	-0.000003267	-0.000004905	0.00001071	-0.0616
4	-0.264	-0.000003267	-0.000004905	0.00001227	0.1013
4	-0.108	-0.000003267	-0.000004905	0.00001382	0.1898
4	0.049	-0.000003267	-0.000004905	0.00001538	0.2038
4	0.205	-0.000003267	-0.000004905	0.00001693	0.1434
4	0.361	-0.000003267	-0.000004905	0.00001849	0.0086
4	0.518	-0.000003267	-0.000004905	0.00002004	-0.2007
5	-1.217	0.00003476	-0.000004856	-0.00002104	-0.9706
5	-0.67	0.00003476	-0.000004856	-0.00007917	0.6072
5	-0.123	0.00003476	-0.000004856	-0.0001373	1.27
6	-67.902	0.00001095	0.000007797	0.00002763	-14.2564
6	-67.902	0.00001095	0.000007797	0.00002611	-4.8255
6	-67.902	0.00001095	0.000007797	0.00002459	4.6053
7	-0.492	-1.477E-18	-3.643E-17	0.00002216	-0.248
7	-0.328	-1.477E-18	-3.643E-17	0.00002216	-0.0429
7	-0.164	-1.477E-18	-3.643E-17	0.00002216	0.0802
7	1.049E-14	-1.477E-18	-3.643E-17	0.00002216	0.1212
7	0.164	-1.477E-18	-3.643E-17	0.00002216	0.0802
7	0.328	-1.477E-18	-3.643E-17	0.00002216	-0.0429
7	0.492	-1.477E-18	-3.643E-17	0.00002216	-0.248
8	-0.573	-0.000003443	0.000005008	-1.867E-06	-0.1918
8	-0.417	-0.000003443	0.000005008	-2.271E-07	0.044
8	-0.261	-0.000003443	0.000005008	1.412E-06	0.2055

Table 4.1: Element Forces – Frames of steel girders

Table 4.2:Joint Reactions of steel girders

TABLE: Joint Reactions						
Joint	F1	F2	F3	M1	M2	M3
Text	KN	KN	KN	KN-m	KN-m	KN-m
1	132.859	14.167	13952.941	0	0	0
4	132.859	-14.167	13952.941	0	0	0
143	-132.859	14.167	13952.941	0	0	0
144	-132.859	-14.167	13952.941	0	0	0
145	9.463	-0.001715	11571.752	0.0029	15.4382	-2.274E-09
146	9.463	0.001715	11571.752	-0.0029	15.4382	2.274E-09
147	-9.463	-0.001715	11571.752	0.0029	-15.4382	2.274E-09
148	-9.463	0.001715	11571.752	-0.0029	-15.4382	-2.274E-09

Table 4.3: Joint Displacements of steel girders

TABLE: Joint Displacements						
Joint	U1	U2	U3	R1	R2	R3
Text	m	m	m	Radians	Radians	Radians
1	0	0	0	2.116E-07	0.003538	-5.037E-08
2	-6.839E-07	-6.036E-08	-0.011779	2.415E-06	0.003525	2.336E-08
3	0.000828	-7.327E-07	-0.011787	2.426E-06	0.003423	-2.684E-07
4	0	0	0	-2.116E-07	0.003538	5.037E-08
5	-6.839E-07	6.036E-08	-0.011779	-2.415E-06	0.003525	-2.336E-08
6	0.000828	7.327E-07	-0.011787	-2.426E-06	0.003423	2.684E-07
7	-8.827E-07	1.085E-09	-0.023468	4.664E-06	0.003485	3.806E-09
8	0.003298	-5.232E-06	-0.023507	4.748E-06	0.003163	-0.000000711
9	-8.827E-07	-1.085E-09	-0.023468	-4.664E-06	0.003485	-3.806E-09
10	0.003298	5.232E-06	-0.023507	-4.748E-06	0.003163	0.000000711
11	-8.94E-07	3.461E-10	-0.034986	0.00000658	0.003422	-3.496E-09
12	0.007456	-0.000017	-0.035062	6.754E-06	0.003164	-0.000001369
13	-8.94E-07	-3.461E-10	-0.034986	-0.00000658	0.003422	3.496E-09
14	0.007456	0.000017	-0.035062	-6.754E-06	0.003164	0.000001369
15	-8.567E-07	4.626E-09	-0.046262	8.246E-06	0.00334	4.842E-09
16	0.013233	-0.000037	-0.046407	8.591E-06	0.003191	-0.000002143
17	-8.567E-07	-4.626E-09	-0.046262	-8.246E-06	0.00334	-4.842E-09
18	0.013233	0.000037	-0.046407	-8.591E-06	0.003191	0.000002143
19	-8.026E-07	5.73E-09	-0.057234	9.615E-06	0.003241	-3.817E-09
20	0.020389	-0.00007	-0.057386	0.00001	0.002638	-0.000003009
21	-8.026E-07	-5.73E-09	-0.057234	-9.615E-06	0.003241	3.817E-09
22	0.020389	0.00007	-0.057386	-0.00001	0.002638	0.000003009

Table 4.4: Element Stresses - Area Shells of steel girders

Graphs

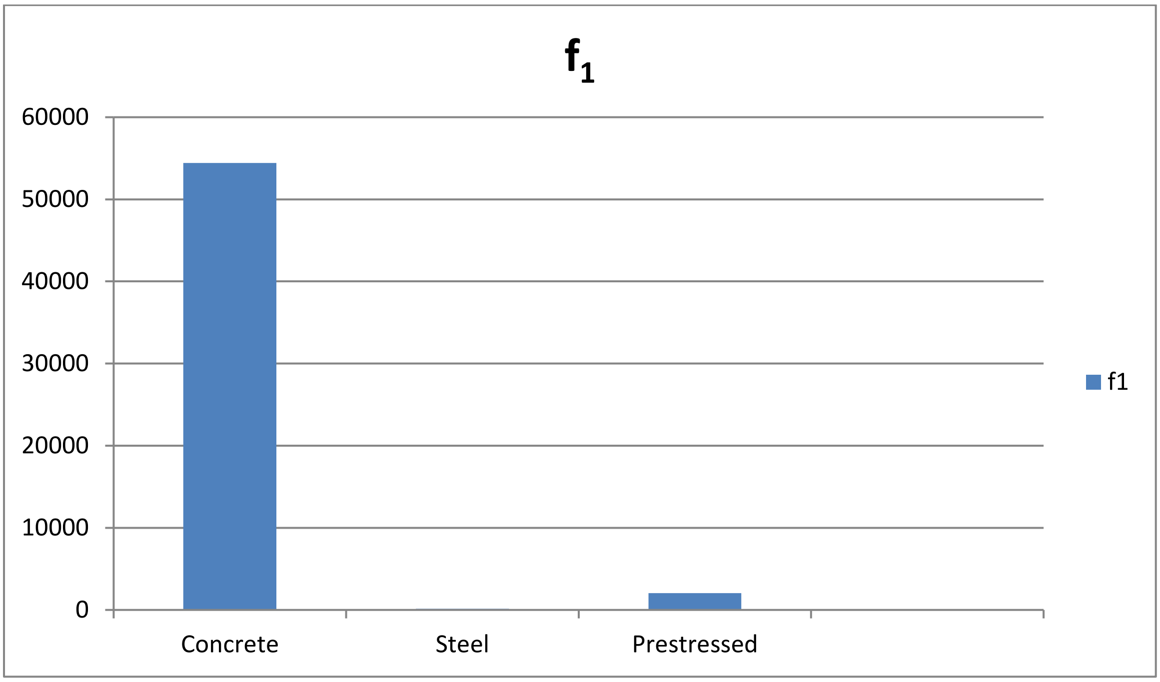


Fig 4.21: F1 variation of concrete ,steel and prestressed deck girder of cable stayed bridge

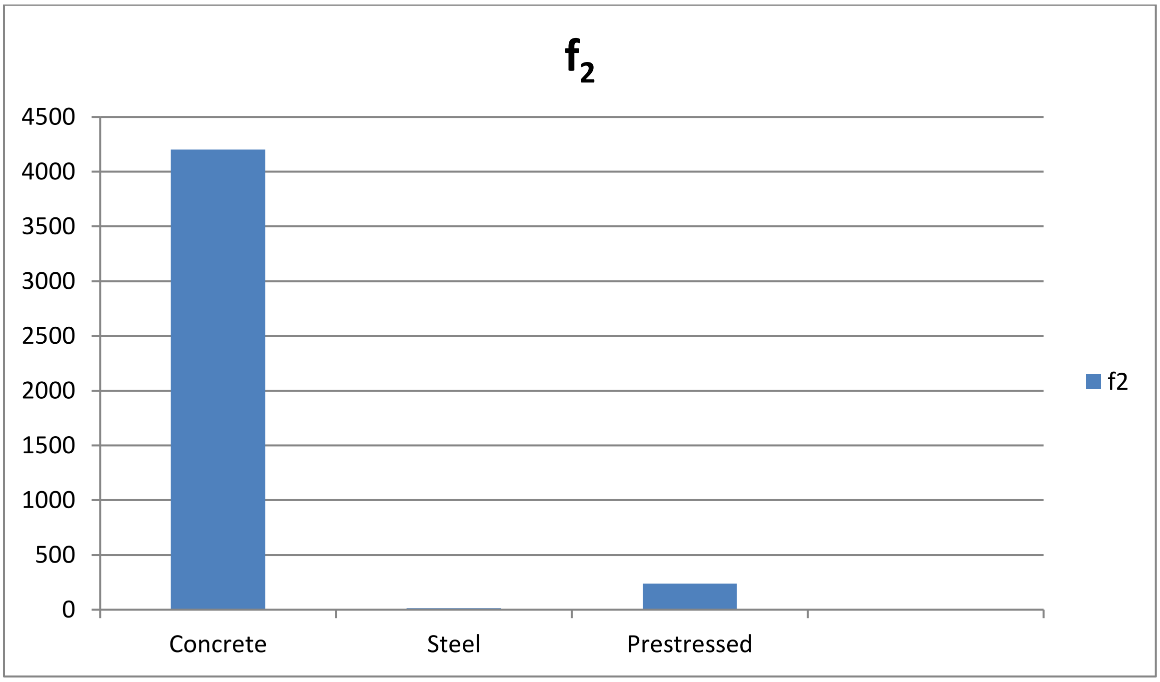


Fig 4.22: F2 variation of concrete ,steel and prestressed deck girder of cable stayed bridge

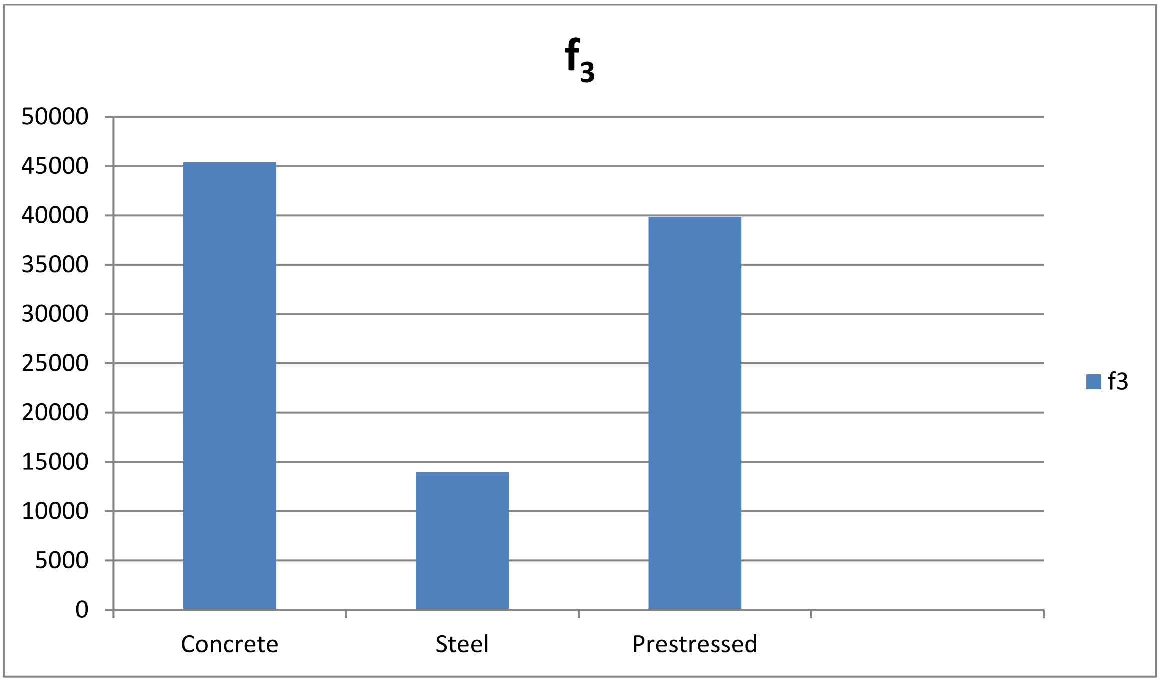


Fig4.23: F3 variation of concrete ,steel and prestressed deck girder of cable stayed bridge

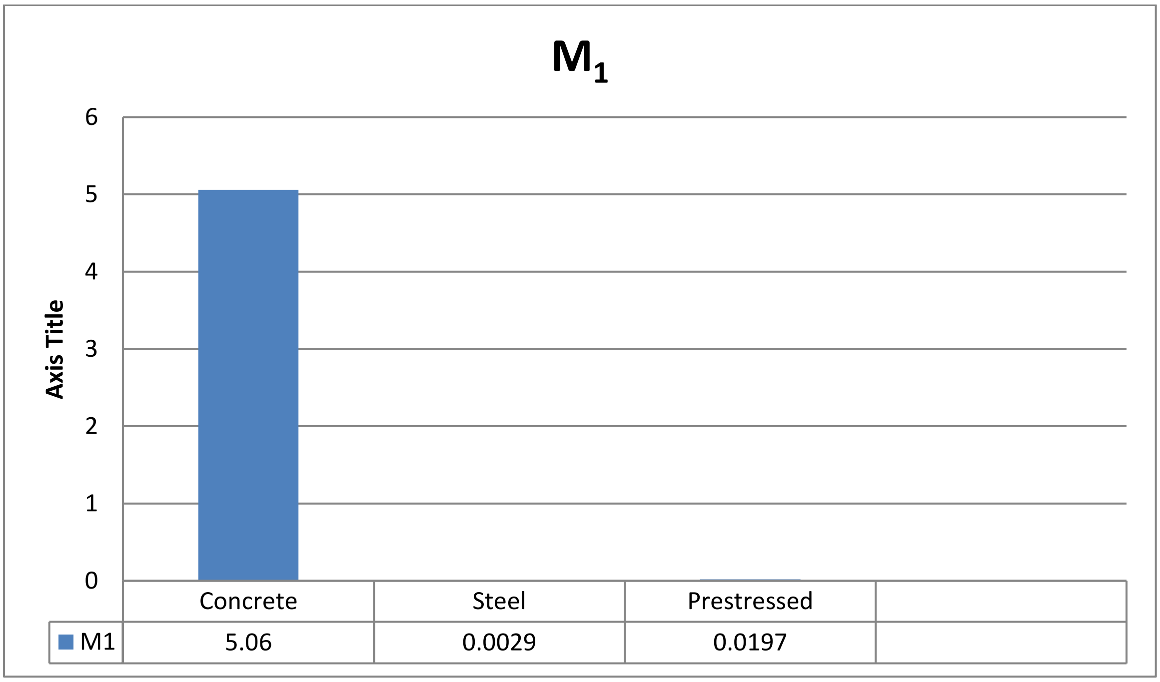


Fig4.24: M1 variation of concrete ,steel and prestressed deck girder of cable stayed bridge

Name	RCC and Steel	RCC and Prestressed	Steel and Prestressed
F1	0.24248213531237942	3.7401032386	0.6481390552
F2	0.3369022127	5.6626219367	5.94957983193

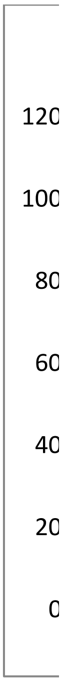


Fig4.25: M2 variation of concrete ,steel and prestressed deck girder of cable stayed bridge

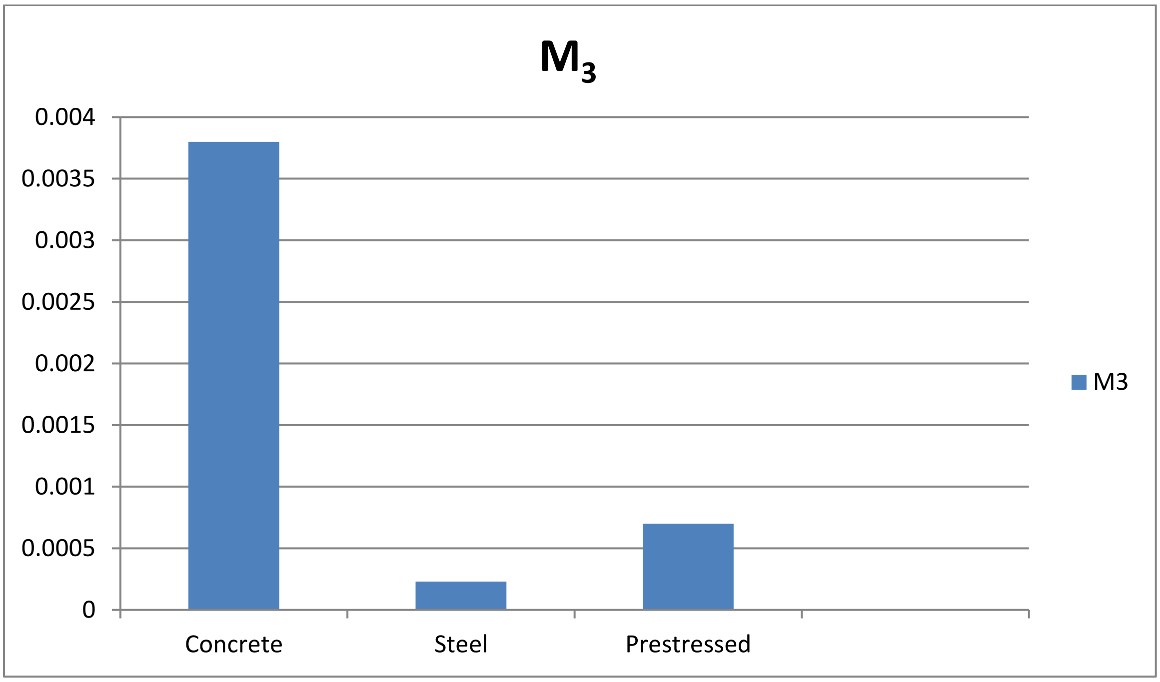


Fig4.26: M 3 variation of concrete ,steel and prestressed deck girder of cable stayed bridge

DISCUSSIONS:

The percentage variation of (Rcc deck girder and steel deck girder)and(rcc deck girder and presstressed girder)and (Steel and Prestressed girder) are shown in table below:

F3	30.752953623	21.3	14.408162422
M1	0.05731225296	0.38932806324	45.6852791878
M2	24.9241201162	172.74782047	14.42803738317757
M3	6.05263157894	18.421052631	32.85714285714286
Smax	0.6067551266	4.574547647768396	7.989874218811803
Smin	2.1055424528301887	11.96933962264151	17.59113300492611
S angle TOP	99.9888	99.98	100
S Vm Top	28.41429529558302	19.7	14.408146607847327
S max Batten	28.17974539236177	19.5	14.408681543946917
S min Batten	0.26207729468599034	2.03743961352657	12.863070539419086
S angle Batten	44.13463162041988	46.8385208532673	94.22721045927564
S Vm Batten	28.414316370324954	19.7	14.408129954919945
V2	17.197866311051843	13.12	13.114830508474578
V3	0.8979057591623035	6.282722513089005	14.291666666666666
T	0.0057755555	43.074074074	0.013408426483233019
M2	0.11240386511	0.7848550581	14.321608040201005
M3	27.630563862	19.165	14.417025441463736

Conclusions

The models of cable stayed bridge with same span and loading conditions are analysed using sap software and results are computed in table above and the comparative graphs are made between the structures of bridges with concrete,steel and prestressed deck girder and which girder is suitable for construction is drawn from the conclusions below:

- The forces in steel girder are lesser than prestressed and concrete deck girder in cable stayed bridge
- The moment and shear for concrete are more than steel and prestressed deck girder cable stayed bridge
- Svm of prestressed deck girder is more than steel and concrete deck girders
- Torsion is also more in concrete deck bridges than steel and prestressed bridges.

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