Cost Optimization of Extradosed Bridge by varying Cable Position

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Abstract - *There is a significant improvement in the area of construction methods of the bridges. Because of higher knowledge in area of prestressed concrete in recent decades' new structural system have emerged and have been used in construction of bridges and viaduct. An example of this development is the case of bridge known as extradosed. An extradosed bridge employs a structure which combines the main elements of both a prestressed box girder bridge and a cable-stayed bridge. From 1988 several extradosed bridge were built worldwide, with different deck cross-section and extradosed cables arrangement. In this paper the extradosed bridge is analyzed using MIDAS civil software by varying the cable distance to get the optimum solution. And the effect of cable positions on the bridge deck and ultimately on the cost of the bridge is presented in this paper. And it is concluded that by increasing the cable distance the cost of the bridge decreases.*

Key Words: extradosed bridge, optimization, cable distance, MIDAS, cost of the bridge

1. INTRODUCTION

The selection and characterization of a bridge structural system is complex task and should be accomplished through a careful study, considering all critical factors such as spans ration, number of supports, aesthetics, cost, the surrounding landscape integration and all technical constraints which must be considered. Extradosed bridges have been widely used in urban areas, near airports where there are restrictions on towers height or in rural areas where it is desired an aesthetically pleasing solution but with reduced impact on surrounding landscape.

Extradosed bridge is first proposed by French Engineer J.Mathivat in 1988, the word "extrados" defines upper surface of an arch, and thus the term "extradosed" was conceived. French Engineer J.Mathivat in 1988 used this designation to describe innovative cable arrangement that he proposed for Arret-Darre viaduct (France, fig 1), in which prestressing cables were placed outside the deck with large eccentricity over the piers, as opposed to tendons in interior section of the girder as in cantilever constructed box- girder bridge.

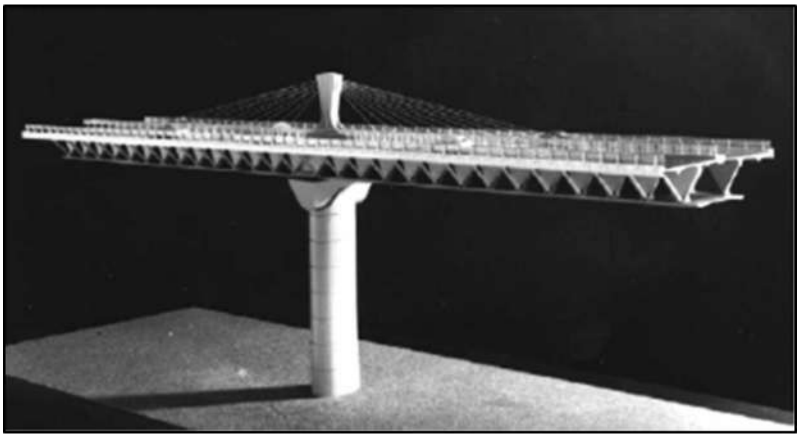


Fig-1: Arret-Darre viaduct, France

Mathivat was inspired by the design used by Swiss engineer Christian Menn for the Ganter Bridge (Switzerland, figure1.2) which was completed in 1980. The entire design was based on cable stayed bridges, but it represents clearly the first example of an extradosed deck. Therefore, it can be said that Mathivat finished the Menn's initial concept, naming the tendon "extradosed prestressing" as opposed to stay-cables.

Extradosed bridge mainly constructed with tower, beam girder, cable and pier, characterized by lower tower height, rigid beam girder and concentrated cable layout and classified as "statically indeterminate" structure.

The extradosed bridge form is mostly suited to medium-length spans between 100 meters (330 ft.) and 250 meters (820 ft.), and over fifty such bridges had been constructed around the world to 2012. The live loads produce small stress variation on the extradosed cables, these can be deviated at the piers by means of saddles, allowing for more compact tower. They have frequently been adopted when overall height, navigation clearance, or aesthetic requirements have made the cable-stayed or girder alternatives less feasible.

Extradosed bridge have two different structural system, the cable suspension system and stiff deck bending system. One can choose which of the two will have a greater influence on bridge structural behavior, by varying the ratio between the stiffness of each system. By reducing the deck stiffness, the bridge has behavior like cable-stayed bridge; on the other hand, by increasing the stiffness it will behave more like traditional box-girder bridge. It was estimated that an extradosed bridge has a stiffness ratio of around 30%.

Although differentiated from cable-stayed bridges in several areas, the principal and defining extradosal characteristic is the low height of the main towers or pylons, expressed as a proportion of the main span length. Classic cable-stayed designs employ a tower-height to main-span ratio of around 1:5 (or 0.20). In comparison, extradosed bridges have towers with height: span ratios of between 1:8 and 1:15 (0.125 to 0.067), with around 1:10 (0.10) being most common. This lower tower height results in a much flatter cable angle, typically ~ 15° to the horizontal, and a correspondingly much higher axial compression force within the bridge superstructure due to the greater horizontal force component within each cable stay.

Their hybrid nature can lead to significant additional complexity in their design, as the response of the bridge to applied loads is determined by the interactions between

- The flexural stiffness of the deck/girder superstructure;
- The axial stiffness of the cable stays;
- The height and longitudinal stiffness of the towers/pylons;
- The lengths of adjacent spans and back-spans;
- The degree of fixity between the superstructure, the towers and the substructure;
- The flexural stiffness of the main support piers.

India's first extradosed bridge was built by Larsen & Toubro Ltd. for the Second Vivekananda Bridge Toll Corporation (figure1.4) over river Hooghly, Kolkata. This bridge is 880 meters long, with a span of 110 meters. A new bridge that bears a similarity to the famous Golden Ears Bridge in Vancouver, Canada, will soon be constructed across Narmada River in Bharuch. This will be the first "extradosed bridge" to be built in Gujarat and the "longest" in the country. This will be the first extradosed bridge in Gujarat. Presently, three such structures exist in India. But the span of 144m for the Extradosed Bridge in Gujarat on Narmada will be the longest in India.

Fig-2: Second Vivekananda Brid

2. Literature Review

Rohini R. Kavathekar and Dr. N.K.Patil (2018) has studied the characteristics of extradosed and cable stayed bride. In this paper spans of 100m, 150m, 200m, 250m, and 300m are considered for analysis. Different parameters are studied for extradosed and cable stayed bridge which includes response of deck, deck moment, study of pylon, how the response of bridge varies span wise, from aesthetics point of view feasible bridge structure, pylon height and span length to thickness of girder ratio. The parameters of extradosed bridge are compared with cable-stayed bridge.

S.L. Stroh (2015) given the proportioning and design considerations for extradosed prestressed bridges. It says that Extradosed prestressed bridges can provide an economical bridge solution for spans in the transition range from conventional girder bridges and cable stayed bridges. Proportioning guidelines are discussed for items such as applicable span ranges, depth ratios for the deck, tower height, bridge width, efficient span ranges, and stay layouts. Author recommended the span ranges for various bride types. The paper also addresses strength and fatigue design guidelines for the stay cables that are specific to the extradosed bridge type. Author examined 29 existing extradosed structures that have sufficient data available to examine different parameters. The paper also provides discussion on stay cable design requirements following the PTI specifications related to strength and fatigue considerations, (PTI 2006).

Vijay Parmar and K. B. Parikh (2015) discussed the effect of pylon height on cable stayed bridge. In this paper, different height of pylon was studied for cable-stayed bridge. Cable stayed bridges are now a day's main option for long span bridges. To know the behavior of cable stayed bridge all the parameters were kept constant except pylon height and cable inclination; this study is required. Some criteria for pylon height was given i.e. Span/5 to Span/4. Pylon is a column that is connected to all cables and transmits cable's forces to foundation. By changing the height of column, it will also change the inclination of cable. In this paper, different height of pylon was taken to study which height of pylon is more effective. To observe behavior of bridge by these changes, other parameters were kept constant like span (80), width of deck (20m) and cable connections (at 20m). Analysis was done in computer aided software. Different height of pylons was considered and results for Cable axial force, Pylon Axial Force, deck axial force, Deck shear force and deck moment was determined.

Xiaolei Wang et al. (2014) explained that the optimization methods which commonly used are based on the cable-stayed bridge and not entirely suit for the extradosed cable-stayed bridge. The paper puts forward a new optimization method, which applies the unknown coefficient functions aided by MIDAS/CIVIL, it takes the reasonable feasible range of dead moment solved by stress balanced method as the constraint condition, makes the square of unknown coefficients as objective function, and solves the cable force based on the effect matrix method thus to determine the cable force in reasonably completion state. This article has discussed different existing methods of how to determine the cable force in reasonably finished state of extradosed cable stayed bridge. Cable force solved with different objective function and that solved by new method are compared in this paper. And finally, the result shows better cable force obtained under the method which is used in this paper compared with the cable force under the other constraint and objective function.

Chang-Huan Kou Lin et al. (2014) proposed an experimental design method to solve structural optimization problem of extradosed bridge including following steps: (1) generate experimental design, (2) Implement experimental design, (3) Construct a response variable model, (4) Define optimization problem, (5) Solve optimization problem. Response variable model of alternative structure analysis software was created. This model is a set of regular and simple functions. Neural network was used for construction of the model in this article. The reason to employ neural network instead of traditional regression analysis was that the relationship between internal forces and displaced cross section dimension of the structure are often nonlinear model. Neural network is a non-linear system that gives itself the greatest advantage to accurately construct a non-linear model. Artificial Neural Network is a computational system consisting of software and hardware. Case study based on extradosed bridge in china is also discussed in this article and evaluated the feasibility of above method. And the paper finally concluded that layout of cable force in extradosed bridge and corresponding tower height will have crucial impact on the structural performance. Therefore, when adjusting stayed cable's initial tension, it is necessary to optimize the tower height at the same time.

Hongtao Bi &Yan Li (2013) proposed an optimization model to investigate the effect of the non-stayed cable segment length on the performance of a low-pylon cable-stayed bridge. Based on the structural analysis of the cable-stayed bridges, the proposed model aims to adjust the structural internal force by changing the non-stayed cable segment length. The girder's moment in mid-span and maximum displacement were taken as the main optimization index for length beside pylon. The most reasonable length of non-stayed cable segment was obtained by the optimization analysis. If the ratio of between the non-stayed cable segment length beside pylon and the main span located in the range of 0.13~0.17, the mid-span girder's loading considered as reasonable.

Young Jin Kim et al. (2013) developed an optimal structural system for the hybrid cable-stayed bridge and expected to have a durable lifetime of 200 years. The major structural members were made of ultra-high performance concrete (UHPC) with 200 MPa-class compressive strength. This innovative cable-stayed bridge system made it possible to reduce each of the construction and maintenance costs by 20% compared to the conventional concrete cable-stayed bridge by improving significantly the weight and durability of the bridge. Therefore, detail design was carried out considering a real 800 m cable-stayed bridge and the optimal structure of the hybrid cable-stayed bridge is proposed and verified.

Venkat Lute et al. (2011) have done optimum design of cable stayed bridge which depends on number of parameters. The huge number of design variables were considered. During problem formulation, most of the practical design variables and constraints are considered. Total material cost of bridge was taken as objective function and optimum design was carried out in this article. They have considered the Genetic Algorithm (GA) which is suitable for optimizing cable stayed bridges with huge number of design variables and practical constraints. Using genetic algorithms some parametric studies such as effect of geometric nonlinearity, effect of grouping of cables, effect of practical site constraints on tower height and side span, effect of bridge material, effect of cable layout, effect of extra-dosed bridges on optimum relative cost have been presented. Stiffness method was used for analysis of radiating type of cable stayed bridge using MATLAB. Also, cable grouping method was included. Finally, the result shows that genetic algorithm can handle more number of variables easily. As cable grouping concept was included in this optimization approach, reduction in the relative cost was observed.

Miguel Joao da Silva Barbara (2011) presented the study of extradosed prestressed concrete bridges. The influence of geometrical parameters, such as the height of towers, girders depth and size of piers in the structural behavior and in the design and construction of an extradosed bridges were also analyzed it is intended to get a critical sense of how each component of an extradosed bridge affects its structural behavior.

The paper also discusses the main factors that define the design of an extradosed bridge. From its setting in vast world of bridge with different solutions to some critical details that must be considered in the final design. Many of these issues are generally relevant to any bridges with medium to large main span, as they represent important consideration for the design process of any prestressed concrete bridge.

Finally, this paper intends to provide enough technical information about extradosed decks, so that a structural engineer can understand the key steps concerning the design and construction of bridge of this type.

Fathy Sadd presented the structural optimization of extradosed bridges. Nonlinear FE model was adopted and considered the geometric nonlinearity of the system and the effect of material nonlinearity, mainly due to cracking of r/c deck towers. The model was adopted to introduce the structural optimization of extradosed bridge; concerned the cable layout i.e. distribution of cables over the span, the retaining condition of the deck/ tower joint and the form of tower.

A simplified analysis model for the load distribution between bending action of deck and membrane action of the stay cables was introduced. The influence of cables arrangements over the deck and shape of tower i.e. single tower and Y-shaped tower in addition to retaining condition on the structural behavior of extradosed bridges were considered. A geometric and material nonlinear FE model was developed to rest this estimation study.

José Benjumea (2010) et al. In this paper the structural behavior and design criteria's of extradosed bridge are explained. The influence of principal structural elements and design criteria proposed by researchers are presented in this paper. In this paper few design criteria's like deck depth and pylon height, length supported by cables, side span length, cables allowable stress in serviceability limit state are also given. Finally it is concluded that structural behavior in such bridges depends on the interaction among each structural element involved, provided that they share some morphological and constructive similarities with cable stayed and prestressed box-girder bridges.

Konstantinos Kris Mermigas (2008) presented the behavior and design of extradosed brides in this paper. How different geometric parameters such as tower height, girder depth, and pier dimensions influence the structural behavior, cost and feasibility of an extradosed bridge has studied. A study of 51 extradosed bridges shows the variability in proportions and use of extradosed bridges, and compares their material quantities and structural characteristics to girder and cable-stayed bridges. The strategies and factors that must be considered in the design of an extradosed bridge are discussed. Two cantilever constructed girder bridges, an extradosed bridge with stiff girder, and an extradosed bridge with stiff tower are designed for a three span bridge with central span of 140 m. The structural behavior, materials utilization, and costs of each bridge are compared. Providing stiffness either in the girder or in the piers of an extradosed bridge are both found to be effective strategies that lead to competitive designs.

M. Pircher et al. (2003) described a unit force method for optimization of cable tensioning in cable stayed bridges. The paper described a novel solution to the problem of derivation of an optimal sequence for the tensioning of the stay cables. This method considered all relevant effects for the design of cable stayed bridges, including construction sequence, second order theory, large displacement, cable sag and time dependent effects, such as creep and shrinkage or relaxation of prestressing tendons, information about the implementation of this method into a computer was given. The method is not restricted to the design of cable stayed bridges and well used for other structural application in the future. A method to find the optimal tensioning strategy for the construction of cable stayed bridges has been derived. This paper explains the unit load method and explains how nonlinear and time-dependent effects are relevant for the design of bridges was included. The unit load computed the correct final tensioning forces for the stay-cables under the dead load condition, which led exactly to a predetermined moment distribution within the deck and pylon. The method was implemented into bridge-design software package and used in practical application of the analysis of the Udevella Bridge in Sweden.

L.M.C. Simoes and J.H.J.O. Negrao (2000) presented the study on optimization of cable-stayed bridge with box-girder decks. The deck was modelled through the assembly of planes of plate-membrane elements. A multi criteria approach was considered for the optimization itself with constraints on maximum stress, minimum stresses in stays and deflection under dead load condition. An integrated analysis optimization application for this type of structures was developed by the authors, in which the required adaptations were implemented at the code level. The program was named cable stayed bridges integrated analysis and optimization. (CIAO). The program was tested in investigation of some relevant aspects that affects the design of cable-stayed bridges. The research model on shape and sizing optimization of cable-stayed bridges started by using a 2D finite element model for the analysis. The problem was extended to three-dimensional analysis and consideration of erection stages under static loadings. A sensitivity analysis algorithm derived from modal-spectral approach about the complete quadratic combination method was described. The illustrative examples were also given.

L. M. C. Simoes and J. H. O. Negrao (1993) described method which sets still cable- stayed bridge design in multi-objective optimization context with goals of minimum cost and stress. The cable anchored positions on main girder and pylon and the cross-sectional size of the structural members were dealt with as design variables. The Pareto solution was found by means of an entropy based optimization algorithm. Significance of dealing with cable anchor positions as design variable was shown with the help of illustrative examples for both the fixed and variable geometry problems. In this paper, the cable-stayed design problem is posed in multi-objective optimization format with goals of minimum cost and stress and a Pareto solution is sought. The proposed design method was applied to a three-span steel cable-stayed bridge under variable design condition. The influence of the correction sequence in optimum solution is also emphasized. Optimization of cable-stayed bridge can be done efficiently by the proposed entropy-based algorithms were shown in this article. This work has only touched the surface of optimizing the design of cable-stayed bridges, nevertheless it has shown that there was potential savings to be made using optimization.

3. Problem Formulation

The bridge discussed is an extradosed cable-stayed bridge. Three-dimensional models are prepared using finite element software MIDAS Civil 2017. MIDAS Civil is selected because in this software any complex and unusual bridge sections can be modelled and analyzed. Optimization of the extradosed bridge will be done by the parametric study. Summary of models for the study

1) The models are prepared for Spans 80m, 100m, 120m, and 140m.
2) For each span the structure is modelled for cable distance 5m, 6m, 7m, and 8m
3) The height of substructure is kept constant at 12m with single pier structure for all the models.
4) Single plane stay configuration is used.
5) Superstructure used is multi-cell box girder.

Concept of Work

The extradosed cable-stayed bridge is a new type of bridge developed in recent years. Extradosed bridges would be a midway between a cantilever constructed bridge and cable stayed bridge working part on the bending of the girder and part on the cable suspension of deck and combining some features of each one. Optimum design of extradosed cable stayed bridge depends upon number of parameters. During problem formulation, most of the practical design variables are considered. The extradosed bridge form is mostly suited to medium-length spans between 100 m to 250 m. In this project the span of 80m, 100m, 120m, 140m are considered for analysis. Extradosed cable stayed bridges are the large and sophisticated structures which may greatly benefits from use of structural optimization techniques for preliminary design improvements. Structural optimization has become an important tool, since it allows a better exploitation of material, thus decreasing structures self-weight and saving material costs.

Extradosed prestressed bridges are typically constructed in balanced cantilever and their behavior is similar to a girder bridge constructed in balanced cantilever, but with more efficient external prestressing. The constant sections are appropriate for the short-span extradosed bridges with depth to span ratio ranging from 1:25 to 1:50 as stated by S.L.Stroh. So the depth to span ratio is kept 1:40 for all the models. The spacing of the main cables has critical influence not only on the structural efficiency during construction and in the completed system but also on the appearance of the bridge this is explained by Young Jin Kim et al. in 2013. The cable spacing's 5m, 6m, 7m, and 8m are selected for the modelling.

Table -1: List of Models

Sr No	Span Length(m)	Cable Distance(m)	Pylon Height(m)
1	80	5m	8m (H/L=1/10)
2		6m	8m (H/L=1/10)
3		7m	8m (H/L=1/10)
4		8m	8m (H/L=1/10)
5		6m	9m (H/L=1/9)
6		6m	10m (H/L=1/8)
7	100	5m	10m (H/L=1/10)
8		6m	10m (H/L=1/10)
9		7m	10m (H/L=1/10)
10		8m	10m (H/L=1/10)
11		6m	11m (H/L=1/9)
12		6m	12.5m (H/L=1/8)
13	120	5m	12m (H/L=1/10)
14		6m	12m (H/L=1/10)
15		7m	12m (H/L=1/10)
16		8m	12m (H/L=1/10)
17		6m	13.5m (H/L=1/9)
18		6m	15m (H/L=1/8)
19	140	5m	14m (H/L=1/10)
20		6m	14m (H/L=1/10)
21		7m	14m (H/L=1/10)
22		8m	14m (H/L=1/10)
23		6m	15.5m (H/L=1/9)
24		6m	17.5m (H/L=1/8)

4. Methodology

The analysis of extradosed bridge is done in MIDAS civil 2017. In this study, we are considering live load as per IRC-6-2014. For material properties and permissible stress values the IRC-112-2011 is referred. Total 24 models are generated and analyzed. The models are analyzed by applying dead load, moving load class A and class 70R. Since it is a bridge structure all the loads on the structure are taken from IRC codes.

Table -2: Input parameters for the bridges

Type of structure	Extradosed bridge
Grade of concrete	M60
Density of concrete(prestressed)	25 kN/m^3
Density of concrete (asphalt)	22 kN/ m^3
Density of macadam (binder premix)	22 kN/ m^3
Prestressing steel	12.7 mm 7-ply H.T. strands
Live load classes	Class A, Class 70R
Height of sub structure	12m
Cable diameter	100mm
Depth of girder	Depth/span=1/40
Width of girder	17m
No of lanes	4

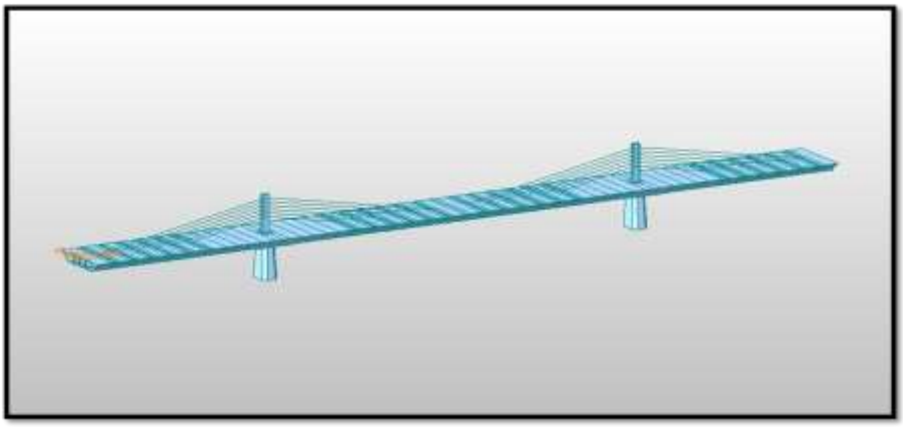


Fig-3: Iso view of the model showing different elements (cable, girder, pylon and pier)

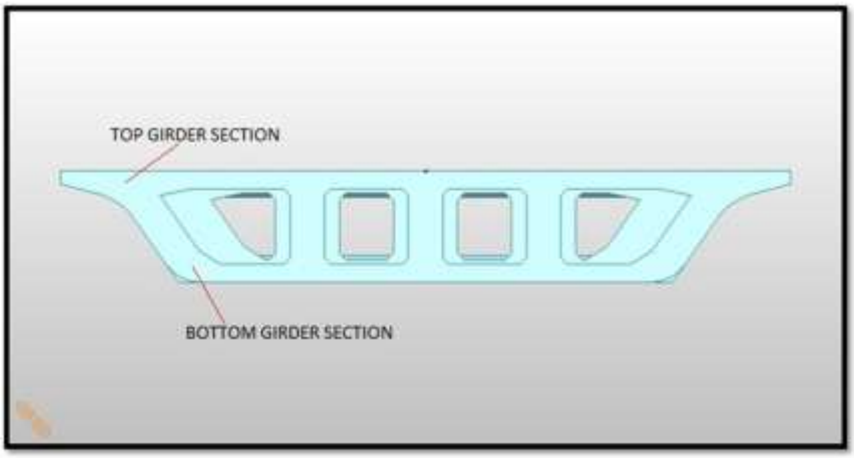


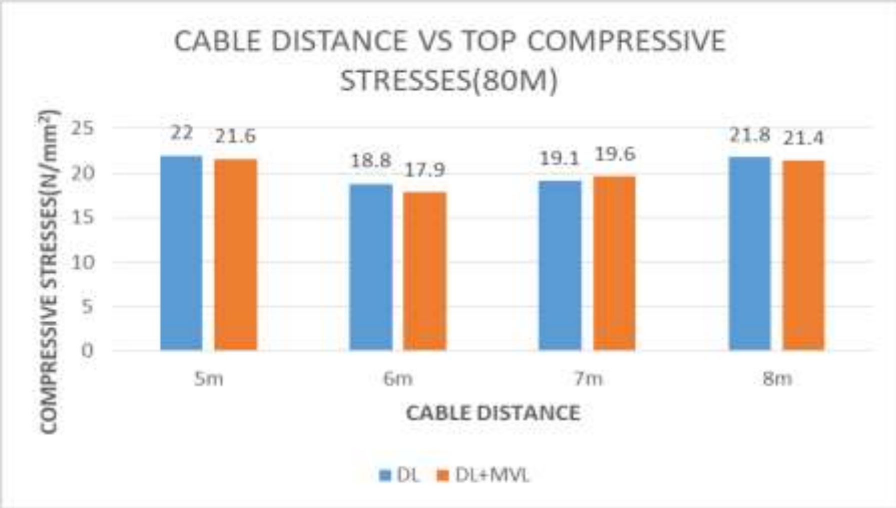
Fig-4: Girder cross-section of the model

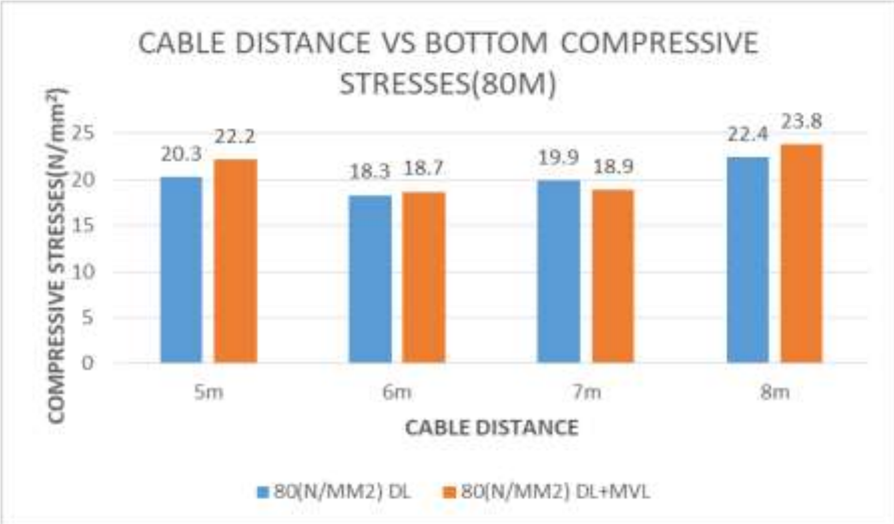
5. Results and Discussion

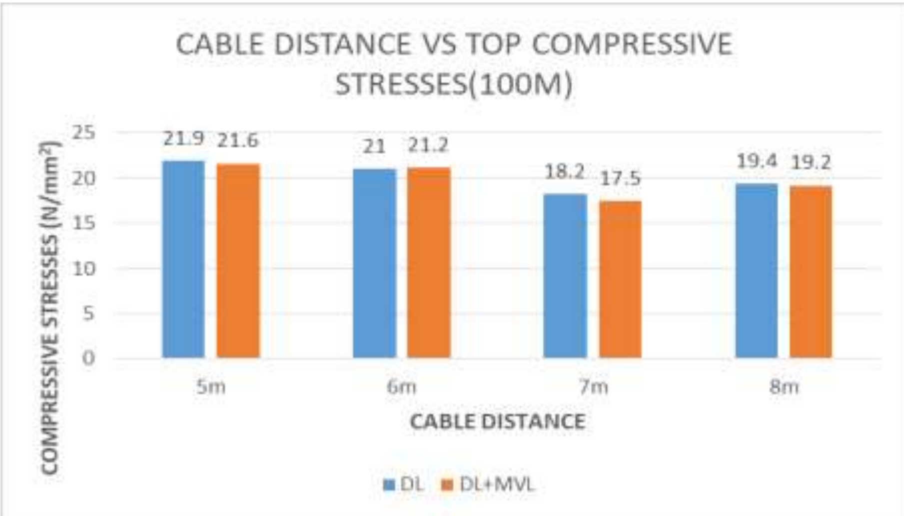
The results obtained from above models are presented.

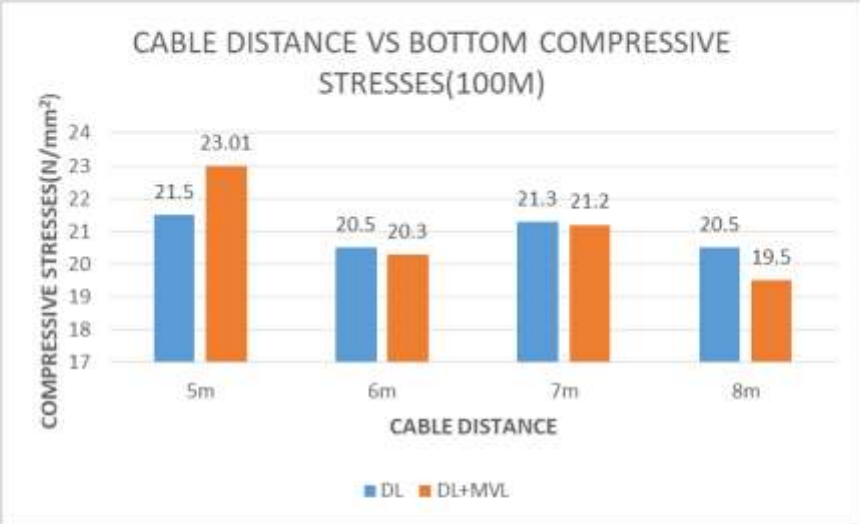
Table-3: Comparative stress results for different spans for varying cable distance and constant pylon ht/span ratio

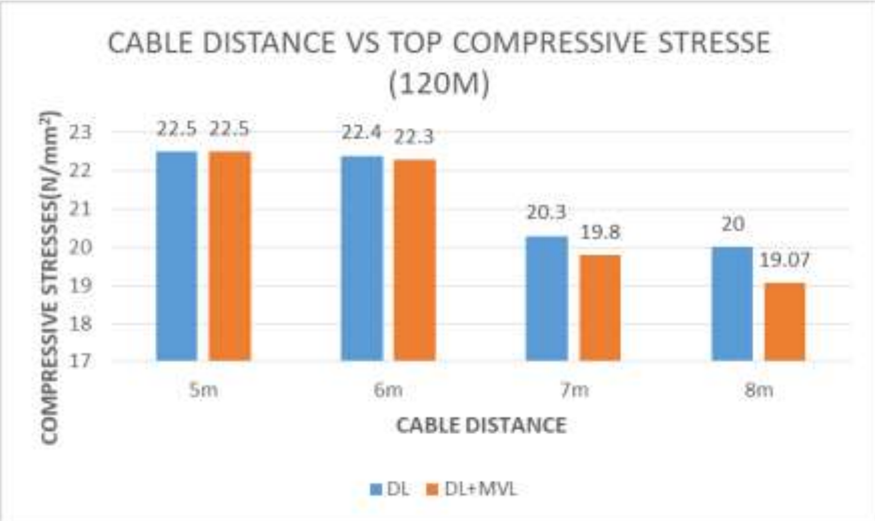
Pylon height/ span=1/10					
Span	**Cable distance(C.D.)**	**Compressive Stresses at Girder Sections for DL (N/mm^2)**		**Compressive Stresses at Girder Sections for DL+MVL (N/mm^2)**	
		Top	**Bottom**	**Top**	**Bottom**
80m	5m	21.9	20.3	21.6	22.2
	6m	18.8	18.3	17.9	18.7
	7m	19.1	19.9	19.6	18.9
	8m	21.8	22.4	21.4	23.8
100m	5m	21.9	21.5	21.6	23.01
	6m	21	20.5	21.2	20.3
	7m	18.2	21.3	17.5	21.2
	8m	19.4	20.5	19.2	19.5
120m	5m	22.5	22.8	22.5	21.8
	6m	22.4	21.7	22.3	21.9
	7m	20.3	19.4	19.8	19.6
	8m	20	19.2	19.07	21.6
140m	5m	21.8	22.7	20.9	23.2
	6m	16.7	10.8	16.7	10.7
	7m	15.6	8.5	14.9	8.6
	8m	15.1	7	14.2	6.5

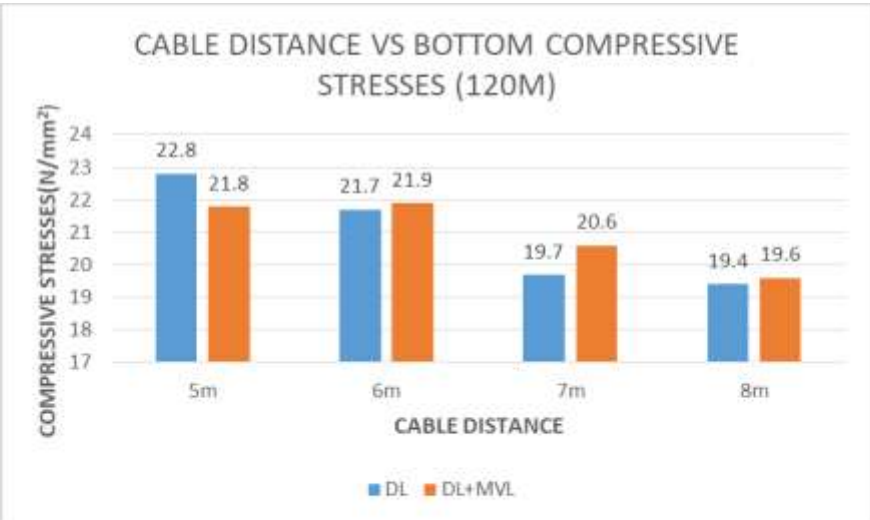

CABLE DISTANCE VS TOP COMPRESSIVE STRESSES(80M)
COMPRESSIVE STRESSES(N/mm²)
25
20
15
10
5
0
22
21.6
18.8
17.9
19.1
19.6
21.8
21.4
5m
6m
7m
8m
CABLE DISTANCE
DL
DL+MVL

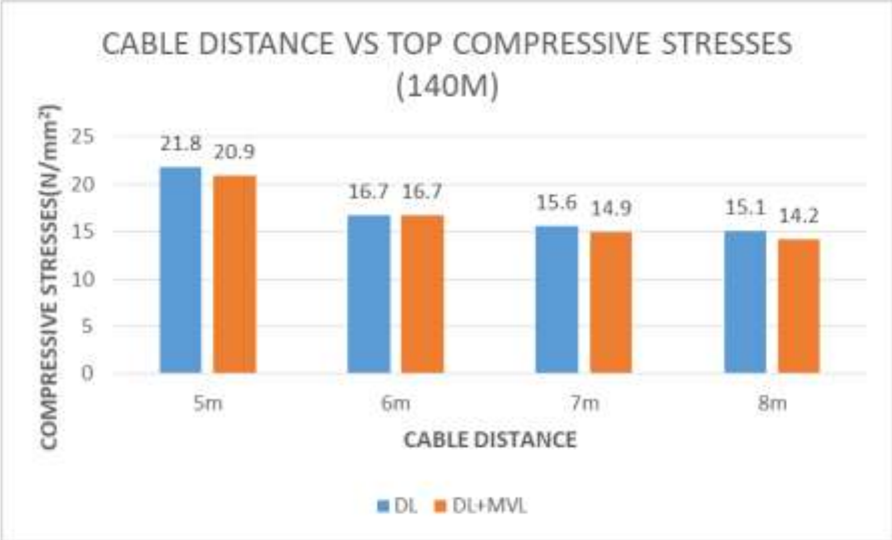

CABLE DISTANCE VS BOTTOM COMPRESSIVE STRESSES(80M)
COMPRESSIVE STRESSES(N/mm²)
25
20
15
10
5
0
20.3
22.2
18.3
18.7
19.9
18.9
22.4
23.8
5m
6m
7m
8m
CABLE DISTANCE
80(N/MM2) DL
80(N/MM2) DL+MVL


CABLE DISTANCE VS TOP COMPRESSIVE STRESSES(100M)
COMPRESSIVE STRESSES (N/mm²)
25
20
15
10
5
0
21.9
21.6
21
21.2
18.2
17.5
19.4
19.2
5m
6m
7m
8m
CABLE DISTANCE
DL
DL+MVL


CABLE DISTANCE VS BOTTOM COMPRESSIVE STRESSES(100M)
COMPRESSIVE STRESSES(N/mm²)
24
23
22
21
20
19
18
17
21.5
23.01
20.5
20.3
21.3
21.2
20.5
19.5
5m
6m
7m
8m
CABLE DISTANCE
DL
DL+MVL


CABLE DISTANCE VS TOP COMPRESSIVE STRESSE (120M)
COMPRESSIVE STRESSES(N/mm²)
23
22
21
20
19
18
17
22.5
22.5
22.4
22.3
20.3
19.8
20
19.07
5m
6m
7m
8m
CABLE DISTANCE
DL
DL+MVL


CABLE DISTANCE VS BOTTOM COMPRESSIVE STRESSES (120M)
COMPRESSIVE STRESSES(N/mm²)
24
23
22
21
20
19
18
17
22.8
21.8
21.7
21.9
19.7
20.6
19.4
19.6
5m
6m
7m
8m
CABLE DISTANCE
DL
DL+MVL



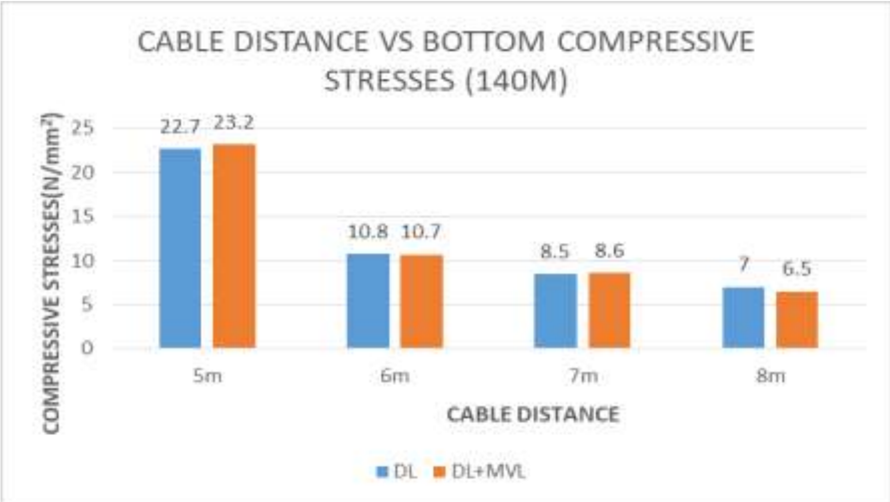
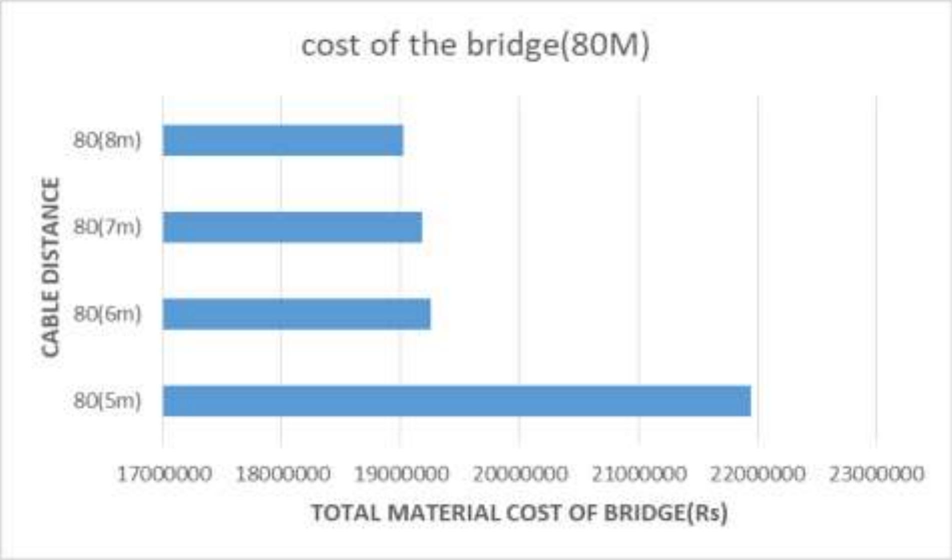
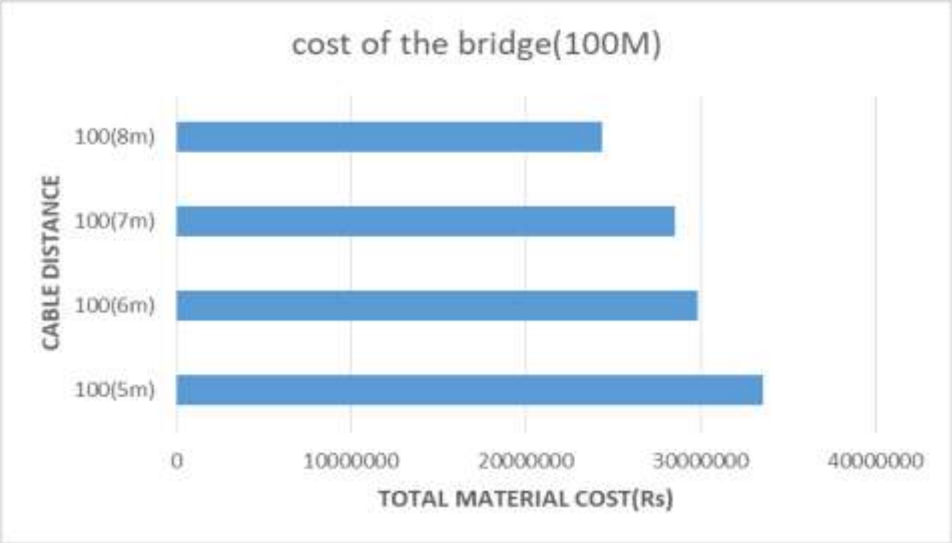
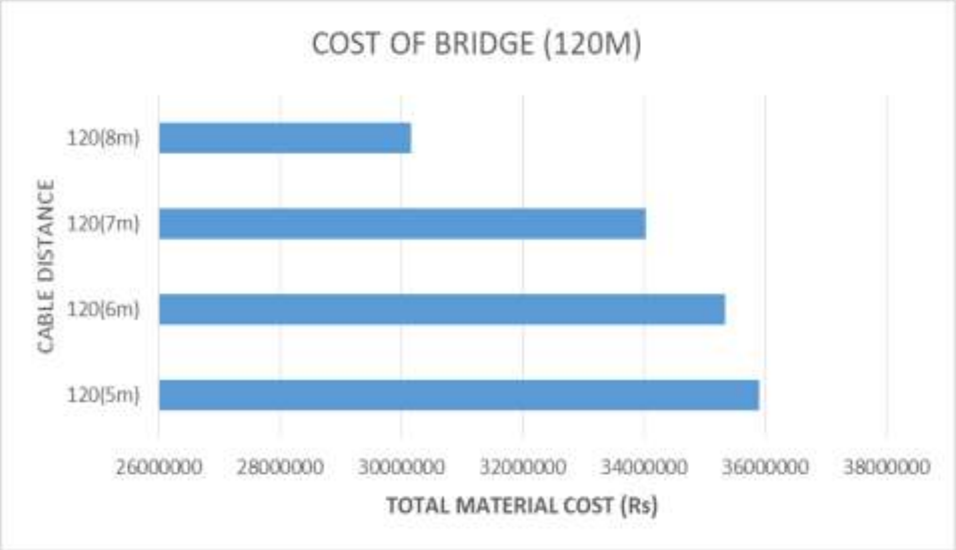


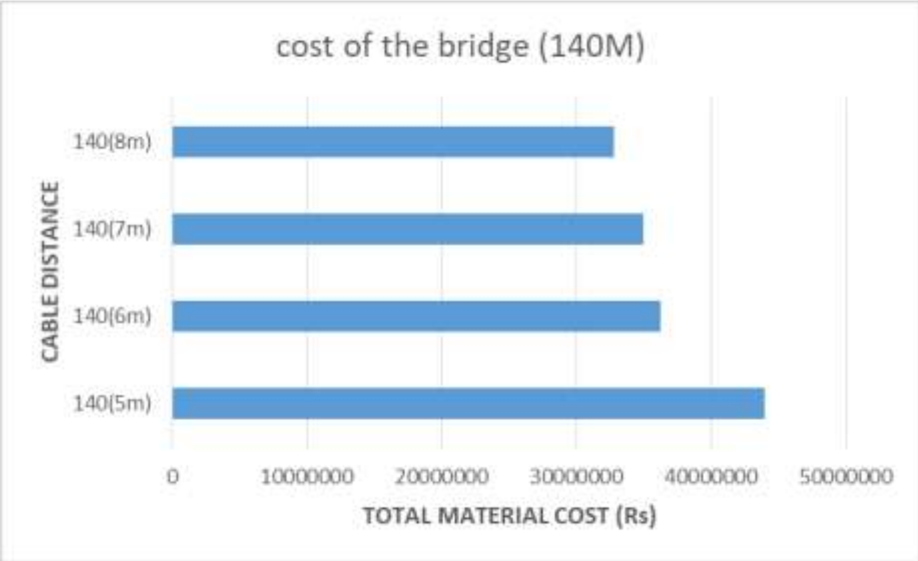
Table-4: Cost of the bridge for different spans for varying cable distance and constant pylon height/span ratio

Pylon height/ span=1/10		
Span	**Cable distance(C.D.)**	**Cost of the bridge In Rs**
80m	5m	21942160.94
	6m	19257576.11
	7m	19184219.82
	8m	19023263.53
100m	5m	33551656.39
	6m	29820907.85
	7m	28533783.61
	8m	24396329.56
120m	5m	35907792.46
	6m	35333133.33
	7m	34032974.31
	8m	30153167.42
140m	5m	44000069.32
	6m	36278695.7
	7m	35026860.71
	8m	32813121.88


cost of the bridge(80M)
CABLE DISTANCE
80(8m)
80(7m)
80(6m)
80(5m)
17000000
18000000
19000000
20000000
21000000
22000000
23000000
TOTAL MATERIAL COST OF BRIDGE(Rs)


cost of the bridge(100M)
CABLE DISTANCE
100(8m)
100(7m)
100(6m)
100(5m)
0
10000000
20000000
30000000
40000000
TOTAL MATERIAL COST(Rs)


COST OF BRIDGE (120M)
CABLE DISTANCE
120(8m)
120(7m)
120(6m)
120(5m)
26000000
28000000
30000000
32000000
34000000
36000000
38000000
TOTAL MATERIAL COST (Rs)



Discussion

A) For DL AND DL+MVL condition when pylon height to main span ratio is kept constant and cable distance(C.D.) is varying

1) For 80m span length the minimum stresses are observed for the cable distance 6m for top as well as bottom girder section.

2) In the IRC-112-2011 allowable compressive stresses in concrete is 21.6 N/mm2. This stress criteria is not satisfied by the models 80m (C.D. =5m) and 100m (C.D. =5m).

3) For 100m, 120m and 140m span length there is visible drop in compressive stress values as the cable distance is increasing. As the minimum stresses are observed for the cable distance 8m for top as well as bottom girder section (except the top girder section for the span 100m).

4) The stresses for models 120 (C.D. =5m), 120 (C.D. =6m), 140 (C.D. =5m) are exceeding the limiting value of compressive stress of 21.6 N/mm^2 as per IRC.

B) The cost of the bridge is decreasing when cable distance is increasing for constant pylon height.

6. CONCLUSIONS

By using various load combination the extradosed bridge is successfully analysed to reveal the behaviour of structure for various parameters. The models are studied and few conclusions are made on the basis of all the above results are listed below

1) The extradosed bridges are best suited for the spans more than 100m. As observed from above results the 120m and 140m spans stresses results are better as compared to 80m and 100m spans.

2) For 100m, 120m and 140m the optimum cable distance is 8m as the minimum compressive stresses are observed for this model as compared to others when the pylon height is kept constant to 10m, 12m and 14m respectively.

3) The optimum solution for 80m span is with 6m cable distance when the pylon height is kept constant to 8m as the minimum stresses are observed for this model when

4) It observed that there is significant reduction in stresses at bottom girder section as span are increasing and cable distances are increasing, as in above result table the stresses at 120m with cable distance 8m and 140m with cable distance 8m are lesser as compared to other results. Hence for extradosed bridges higher span with greater cable distance are better solutions.

5) The material cost of the bridge is inversely proportional to the cable distance when height of pylon is kept constant.

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