Non Linear Analysis of Cable Stayed Bridge For Specified Ground Motion

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Abstract- *Cable Stayed type bridges have been around a lot longer than a lot of people think and can be traced back more than four centuries. Many early bridges using cable stays incorporated both cable stays and suspension cables. The objectives of study is to compare the axial cable forces & natural frequency.*

Keywords- Pylons, H frame, Response spectrum analysis

I. INTRODUCTION

Cable Stayed type bridges have been around a lot longer than a lot of people think and can be traced back more than four centuries. Many early bridges using cable stays incorporated both cable stays and suspension cables. One very famous example of this is the Brooklyn Bridge in New York City, which was completed in 1883. In recent years, starting around the 1970s, cable stay bridges have become increasingly popular, as improvements in materials and technology have resulted in cable stays bridges becoming a fast and economical way to cross medium to long spans (300 to over 3000 feet). Cable stays also have the advantage of being able to easily incorporate extra towers, creating multi-span bridges which can be several miles in length. The cable stay bridge system, which is a unique feature of the new Indian River Inlet Bridge, was a development of the posttension system invented by Mr. Eugene Freyssinet, in France, in the early 1900’s. The system has been continually developed and improved since that time. The History of Cable Stay Bridges The Science Behind Cable Tensioning Leon O’Neill (DelDOT) Brooklyn Bridge Page 2 Building for Tomorrow November 2010 If you are wondering what the cable stays look like up close, you can see a picture on the last page of this newsletter, but here’s a way to see how they work. Ask your parents to get a piece of thick rope and ask them to cut it so that the rope begins to unwind. The cables on the new Indian River Inlet Bridge operate under almost the same principle. Though the cables on the bridge are steel, they still wrap around a central core to create strength. The rope is also made up of many smaller strands that are all wrapped around the central core to create a stronger, better piece of rope. Apart, the strands are not very strong, but together they have a lot of strength.

The cable stay system being used on the new Indian River Inlet Bridge is a parallel strand system, where the stays are made up of several individually protected strands inside a protective plastic tubing, also known as an HDPE (High Density Polyethylene) sheath. This tubing, which is blue, offers additional protection from the ultraviolet rays from the sun, as well as giving an aerodynamic profile to help the cable withstand bad weather conditions, such as high winds and heavy rain. Each strand is made of seven steel wires, which are wound into a single strand, .62 inches diameter. The strand is then coated with a protective wax and placed in the plastic tubing. This strand is capable of withstanding over 25 tons of loads, providing exceptional resistance to the fatigue caused by the various changing loads on the bridge. It also has the multiple levels of corrosion protection needed in the harsh marine environment at the Indian River Inlet. The steel part of the strand is what carries all the load of the bridge deck and all the traffic that will drive across it. Each strand is individually anchored and is gripped tighter and tighter as more load is applied. The anchor blocks themselves are resting on steel bearing plates that are cast into the concrete deck and pylon. With the cable stay system, all the vertical loads from the deck are carried by the cables up into the pylon which then transfers the weight into the ground through the foundation piles. All the horizontal loads that occur as a result of the angle of the cable stay are passed through the deck itself, and balanced out as the main span and back span push against each other. It’s this balancing effect, which leaves only a vertical force in the foundation, which is one of the main reasons that cable stays bridges. Cable-stayed bridges have been known since the 16th century and used widely since the 19th. Early examples often combined features from both the cable-stayed and suspension designs, including the famous Brooklyn Bridge. The design fell from favor through the 20th century as larger gaps were bridged using pure suspension designs, and shorter ones using various systems built of reinforced concrete. It once again rose to prominence in the later 20th century when the combination of new materials, larger construction machinery, and the need to replace older bridges all lowered the relative price of these designs.

Fig :1 Ada Bridge at dusk in Belgrade (Serbia)

A. Objectives

1. To study the effect of linear static loading on cable stayed bridge with various cable arrangement.
2. To compare the axial cable forces and the deflection of girders under non-linear dynamic condition
3. To find out the most stable cable arrangement against the specified ground motion and compare acceleration, velocity and displacement for harp type and cable type.

II. METHODOLOGY

Buildings are subjected to ground motions. The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play predominant rule in studying the behavior of RC buildings under seismic loads. The structure stability depends on the structure slenderness, as well as the ground motion amplitude, frequency and duration. [23] Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories [38]:

1) High-frequency content PGA/PGV > 1.2
2) Intermediate-frequency content 0.8< PGA/PGV< 1.2
3) 3)Low-frequency content PGA/PGV < 0.8

The total design lateral force or design base shear along any principal direction shall be determined by this expression

$$V_b = A_{h*}W$$

Where,

Ah = design horizontal seismic coefficient for a structure
W= seismic weight of building

Z is the zone factor given in Table 2 of IS 1893:2002 (part 1) for the maximum considered earthquake (MCE) and service life of a structure in a zone. The factor 2 is to reduce the MCE to the factor for design base earthquake (DBE)

I is the importance factor, depending upon the functional use of the structure, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical or economic importance. The minimum values of importance factor are given in table 6 of IS 1893:2002 R is the response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. The need for introducing R in base shear formula

Sa/g is the average response acceleration coefficient for rock and soil sites as given in IS 1893:2002 (part 1). The values are given for 5 % of damping of the structure.

a) Response Spectrum Method

Response spectrum analysis is a procedure for computing the statistical maximum response of a structure to a base excitation. Each of the vibration modes that are considered may be assumed to respond independently as a single-degree-of-freedom system. spectra which determine the base acceleration applied to each mode according to its period (the number of seconds required for a cycle of vibration).
Having determined the response of each vibration mode to the excitation, it is necessary to obtain the response of the structure by combining the effects of each vibration mode because the maximum response of each mode will not necessarily occur at the same instant, the statistical maximum response, where damping is zero, is taken as the square root of the sum of the squares (SRSS) of the individual responses.
Response spectrum analysis produces a set of results for each earthquake load case which is really in the nature of an envelope. It is apparent from the calculation, that all results will be absolute values - they are all positive. Each value represents the maximum absolute value of displacement, moment, shear, etc. that is likely to occur during the event which corresponds to the input response spectrum.

b) Materials properties:

Table shows the concrete and steel bar properties, which are used for modeling of the reinforced concrete buildings in STAAD Pro [1]. Concrete and steel bar properties as per IS 456 [30]

Concrete Properties		Steel Bar Properties	
Unit weight (γcc)	25 (kN/m3)	Unit weight (γss)	76.9729 (kN/m3)
Modulus of elasticity (*EEcc*)	22360.68 (MPa)	Modulus of elasticity (*EEss*)	2x105 (MPa)
Poisson ratio (νcc)	0.2	Poisson ratio (νss)	0.3
Thermal coefficient (*ααcc*)	5.5x10-6	Thermal coefficient (*ααss*)	1.170x10-6
Shear modulus (*GGcc*)	9316.95 (MPa)	Shear modulus (*GGss*)	76923.08 (MPa)
Damping ratio (Ϛcc)	5 (%)	Yield strength (*FFyy*)	415 (MPa)
Compressive strength (*FFcc*)	30 (MPa)	Tensile strength (*FFuu*)	485 (MPa)

III. PROBLEM STATEMENT

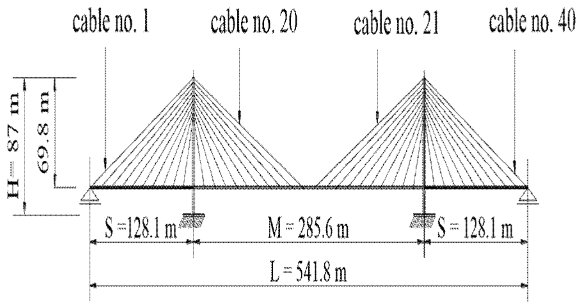


Fig 2 cable stayed bridge

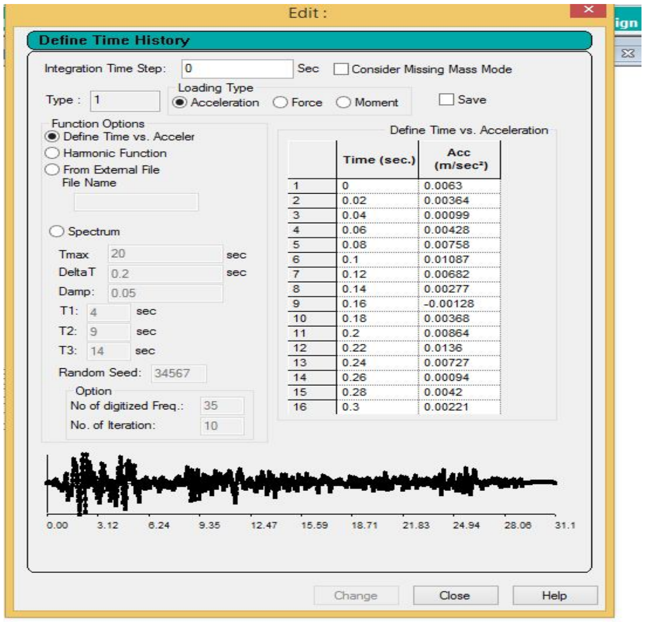
The geometry of the selected bridge for this study is similar to the Quincy Bayview Bridge, located in Illinois, USA. The length of the main span (M) is 285.6 m, with two side spans (S) of 128.1 m. Therefore, the total length of the bridge (L) is 541.8 m, as shown in Figure 2.

The deck superstructure is supported by double planes of stay cables in a semi-harp type arrangement, where forty cables are anchored into each transverse H frame-shaped pylon. As such, eighty stay cables support the entire bridge deck, with forty supporting the main span and twenty cables supporting each side span.

The pylons consist of two concrete legs, interconnected with a pair of struts. The upper strut cross beam connects the upper legs and the lower strut cross beam supports the deck. The lower legs of the pylon are connected by a 1.22 m thick wall, which is placed as a web between the two legs.

IV. RESULTS & DISCUSSION

In this study comparative analysis of FAN type and HARP type is performed subjected to El-centro data. Linear static as well as dynamic analysis is done using staad-pro.Acceleration ,velocity and displacement is compared for time step 0.002 to 31.2 sec.



Integration Time Step: 0 Sec ☐ Consider Missing Mass Mode

Type : 1

Loading Type: ● Acceleration ○ Force ○ Moment ☐ Save

● Define Time vs. Acceler

Tmax 20 sec

DeltaT 0.2 sec

Damp: 0.05

T1: 4 sec

T2: 9 sec

T3: 14 sec

Random Seed: 34567

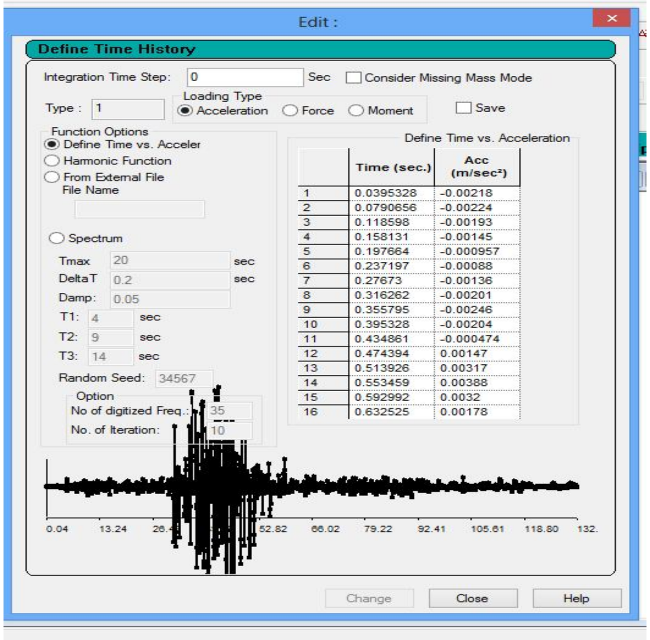
No of digitized Freq.: 35

No. of Iteration: 10

Define Time vs. Acceleration

	Time (sec.)	Acc (m/sec²)
1	0	0.0063
2	0.02	0.00364
3	0.04	0.00099
4	0.06	0.00428
5	0.08	0.00758
6	0.1	0.01087
7	0.12	0.00682
8	0.14	0.00277
9	0.16	-0.00128
10	0.18	0.00368
11	0.2	0.00864
12	0.22	0.0136
13	0.24	0.00727
14	0.26	0.00094
15	0.28	0.0042
16	0.3	0.00221

El-centro Data in staad Pro



Integration Time Step: 0 Sec ☐ Consider Missing Mass Mode

Type : 1

Loading Type: ● Acceleration ○ Force ○ Moment ☐ Save

● Define Time vs. Acceler

Tmax 20 sec

DeltaT 0.2 sec

Damp: 0.05

T1: 4 sec

T2: 9 sec

T3: 14 sec

Random Seed: 34567

No of digitized Freq.: 35

No. of Iteration: 10

Define Time vs. Acceleration

	Time (sec.)	Acc (m/sec²)
1	0.0395328	-0.00218
2	0.0790656	-0.00224
3	0.118598	-0.00193
4	0.158131	-0.00145
5	0.197664	-0.000957
6	0.237197	-0.00088
7	0.27673	-0.00136
8	0.316262	-0.00201
9	0.355795	-0.00246
10	0.395328	-0.00204
11	0.434861	-0.000474
12	0.474394	0.00147
13	0.513926	0.00317
14	0.553459	0.00388
15	0.592992	0.0032
16	0.632525	0.00178

Bhuj Data in staad Pro

L/C		Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	Loads	0	-1.81E+05	0	2.17E+06	0	-4.90E+07
2	Reactions	0	1.81E+05	0	-2.17E+06	0	4.90E+07
3	Difference	0	0	0	0	0	0.649

Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %	Type
1	0.09	11.16	0	4.878	0	Elastic
2	0.114	8.81	0	0	0	Elastic
3	0.14	7.139	0	0	0	Elastic
4	0.194	5.159	0	14.355	0	Elastic
5	0.195	5.141	0	0	0	Elastic
6	0.242	4.136	0	0.058	0	Elastic

V. CONCLUSION

Following observations are obtained

1. This paper has presented a method for modeling and analysis of cable-stayed bridges subjected to specified ground motion. Bridge damping, exact cable behavior, and nonlinear geometric effects have been considered when analyzing the linear dynamic response. The study has only focused on investigating the influence of ground motionon the bridge dynamic response.
2. Natural frequency obsrved more in FAN type which includes less time period during ground motion.
3. PGA is observed 25% more at HARP type as compared to FAN type.

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