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Seismic(effect on) time history analysis for cable-stayed suspension hybrid bridge considering different geometrical configuration for far field earthquakes

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Abstract

To increase the maximum span of cable-stayed bridges, Uwe Starossek has developed a modified statical system. The basic idea of this new concept is the use of pairs of inclined pylon legs that spread out longitudinally from the foundation base or from the girder level. Spread-pylon cable-stayed bridge has distinct advantage like reduction of sag of cables and oscillation of cable during earthquake over traditional cable-stayed bridges. Spread-pylon also improves seismic performance of deck during strong ground motion. Here in this paper dynamic behaviour of cable stayed suspension Hybrid bridge with different structural configuration with seismic loading was studied.

The primary aim , here, is to present response to Seismic effect on Cable stayed Bridges with different cable system taking under consideration SSI.It is evidently clear that Soil Foundation Structure Interaction relies greatly on various factors such as soil and its properties, manner and type of structure and/or its foundation.. In this paper , the emphasis is on the simplified model and foundation on piles. For the modelling author has used SAP2000 software. The study includes the response of the bridge modelled towards variation in the cable system under consideration of SSI. A bridge similar to that of Bridge at Ling Ding Strait China is taken as a reference and 6 models are created with variation in cable system (ranging from original cable stayed bridge to suspension type, composite bridge and cable stayed suspension hybrid bridge). Soil modeling is done using the spring and dashpots (Kelvin element) for simulation of SSI effects.The results observed that effects of SSI has a substantial impact on selection of system of cables and the pylon leg inclination for any Cable- Stayed- Suspension Hybrid Bridge(CSSHB)

Keywords: Seismic performance, Cable-Stayed-Suspension Hybrid Bridge(CSSHB) , Modal-Time-History-Analysis (MTHA) , Soil-Structure-Interaction (SSI) , SAP2000

1. Introduction

Bridges have maintained to be among the top in the list of Transportation which certainly is a lifeline service in todays current socio-economic horizon. Bridges are among the top in the list critical lifeline services. This has necessitated demand of bridges of more and more longer span with booming infrastructural development. With passage of time , thus , dream and wish to have bridges of long to very long to superlong spans got accumulated purely on account and because of geometrical rise in population across the globe, furthermore leading to increase importance of material(s) with high to ultra high strength infused with innovated structural system to ascertain optimal cost/utility ratio in the current competitive globe .

A number of fascinating, mesmerizing bridges have been erected and constructed over the most recent decades. The systems of cable supported bridges for the most part used to accomplishand ascertain longer lengths/spans can be easily be figured as Cable Stayed type Of Bridges (CSB's), Suspension type of Bridges (SB's), Composite Bridges (CB's), Cable stayed Suspension Hybrid Bridges (CSSHB's).

As a general attempt, CSB's and SB's are evidently preferred to achieve longer spans , However, it can be seen , that CSSHB should inherently be preferred over Suspension type and/ or Cable stayed type as it adopts merits of both the syatems namely the CSB's and SB's

Bridge, have thus become spine for transportation and communication , therefore its failures may/can lead to great and higher level of damage and loss to life and material , may be at par to that of catastrophic failures. This infuses in the need of prevention of such failures possibly by acquiring conceptual knowlwdge about the possible reason(s) and remedial measures possible thereon.

1.1 Causes for failures of Bridges

The list of causes for failures leading to their collapse can be categorized as ::

- Failures observed during construction
- Failure observed while bridge in service (in absence of any external action)
- Collapse observed in event of impact (may be due to collision)
- Failure as a result of onset of natural tragical acts such as earthquakes , explosions ,fire , tsunami,

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floods , hurricane, flooding, ice or other-floating objects;; falsework; inadequate or faulty design etc

- Combination of more than one of above

To summarize, causes or reasons of failure of bridges can be attributed to inadequacies/incompetency with regard to planning, designs, and/or upkeep/maintenance, sudden unexpected/unintended load and/or burden and their after effects.

"Remedial Prevention is the best cure" suits herein too. For this conceptualisation of expecting the causes of failures and keeping allowance for failures to to happen and plan for them. This needs to be adopted in order to secure safety and protection thereon from expected injuries and damage to public life and property.This can be achieved by enhancing and infusing keen interest towards procedural and design methodology to be adopted for contiunuos improvement for updating /upgrading bridge design, execution of works, quality control tools, and various constructional practices adopted

1.2 Soil Structure Interaction (SSI)

Evidently, majority of the structure(s) in the world of Civil Engineering does have a structural element which comes in direct contact of ground/earth/soil beneath. When external forces namely Earthquake occurand act on these , a process comes in picture ,wherein response of the soil influences the response of the Structural system and vice versa.This process is termed as Soil Structure Interaction (SSI, hereafter). So, SSI,happens to be an pivotal parameter and must not be overlooked in the seismic design of important structures including bridges

SSI [2] can be further sub classified into as Static SSI & Kinematic or Dynamic SSI. Moreover, SSI [3],[4] can be broadly divided into two phenomena: Kinematic interaction and Inertial interaction.SSI is a complex phenomenon, investigations for which has pointed two possible approaches/ methods, Wolf (1985) namely : Direct method & Sub-structure method respectively

2. Literture Survey

The literature reviewed is presented is tabulated for the **work** under two tables separately for SSI and CSB's.

Sr	Researcher	Year	Reseach work
1	Spyrakos	1990, 1992	Influence of SSI on seismic reaction of ridges
2.	Ciampoli and Pinto	1995	Explored parametric examination on traditionally structured bridges established on shallow establishments. and reasoned that SSI impacts reliably diminished the pliability requests of the piers when contrasted with the system without SSI impacts
3.	Mylonakis and Gazetas	2000	Utilized an improved model for the bridge and its foundation, and presumed that the period protracting and expanded damping due to SSI impacts can detrimentally affect the forced seismic demand, by taking a lot of real acceleration time histories recorded on delicate soil,
4.	Jeremic et al	2004	effect of SSI to the response towards the structure as a whole can prove either advantageous or detrimental , wherein the characteristics of the ground motion considered plays a pivotal role
5.	Zhang	2004	Investigated the response of 9/15 Overcrossing in Los Angles for the study of the effect of SSI to submit that SSI should not be ignored to properly estimate seismic forces
6.	Tongaonka-r & Jangid	2004	Assessed 3 span cont.'ous type deck bridges, by performing MTHA , with elastomeric bearings ,towards the effects of SSI to summarise that analysis with SSI consideration will lead to an increased safety and thereby reduced design costs
Sr	Researcher	Year	Reseach work
7.	Siddharth Shah *et al*	2011	Studied the impact of pylon's shape on the CSB against seismic reaction and revealed that the pylon's shape provides an extraordinary impact on the seismic reaction of CSB.. SSI impacts are transcendent for delicate soil conditions for all shapes of the pylon

Similarly, The brief of some of the research work reviewed towards CSSHB has been shown in table below

Sr	Researcher	Year	Reseach cocntents
1	Zhang ,Sun	2005	Aerodynamic stability of cable-stayed-suspension hybrid bridges
2	Zhang, Stern[267]	2008	Wind-resistant design of cable-stayed-suspension hybrid bridges
3	EGON KIVI	2009	Structural Behaviour of CSSB : Thesis ; *ISSN 1406-4766*
4	Bruno, Greco, Lonetti	2009	A Parametric Study on the Dynamic Behavior of Combined Cable-Stayed and Suspension Bridges under Moving Loads
5	T.G.Konstantakopou-los, *et al*	2010	A mathematical model for a combined cable system of bridges
6	Jing Qiu *et al*	2011	Analysis of Structural Parameters of Cable-Stayed Suspension Bridges
8	Ghanshya--m Sevalia	2016	Effect of Geometrical Aspects on Static & Dynamic Behaviour of CSSHB
9	Kartik Patel *et al*	2017	"Effect of Pylon shape on response of Cable Stayed Suspension Hybrid Bridge

2.1 Software : SAP2000 : An Introduction

In the current study for research, the software utilized is SAP2000 v 20.2.1. It is a result of CSI, Berkely, USA, and is recognized and preferred by international community around the globe.It adopts FEM based approach with powerful display and can be handful for modeling , altering, analysis and design of simplest structures to complicated ones like retaining walls, stadia, bridges, space structures etc. as variety of elements (1D to 3D such as frame,cable,plate,shell, solid etc), boundary conditions and a vast variety of loads(fixed to variable to moving and their combinations can be incorporated.On Analysis front static to Dynamic, linear to non linear,Pushover analysis,P-δ analysis , TMHA , seismic analysis can be ascertained

Chronology of steps to be performed for modeling in SAP2000 has been summarized as :

- Define material, sections- shape and type(category) to be used..
- Draw the geometry of the structural element defined, manually,by either inserting coordinates or by graphical interface
- Draw the required support / end condition as per requirement (e.g fixed for no SSI, springs (predefined) for SSI case etc)
- Define and assign the Load, load cases and their combinations considered to be applied on the structures.
- Define the Analysis ought to be performed (e.g Modal Time history) for the analysis and include it in the analysis case
- Perform Analysis and study the output generated in variety of formats
- Design and check the design

3 Problem Studied

In the present study, the cable stayed bridge considered is similar to Bridge of East channel of Lingding Strait in China is considered as illustrated in Fig.1

The example, earth-anchored cable-stayed-suspension hybrid bridge consists of a main span of 1400 m and two side spans of 319 m as shown in Fig. 1, which was proposed in the east channel of Lingding Strait in China (Xiao 2000). The central span consists of the cable-stayed portion of 788 m and the suspension portion of 612 m. The lateral spacing of two main cables is 34 m, the cable sag to span ratio is 1/10, and the interval of hangers is 18 m. The stay cables are anchored to the girder at 18 m intervals in the central span and 14 m in the side spans. The deck is a steel streamlined box steel girder of 36.8 m wide and 3.8 m high. The towers are door-shaped frames with three transverse beams, and their height above ground is about 259 m. The cross section and material properties of the bridge and its components are given in Table 1 below

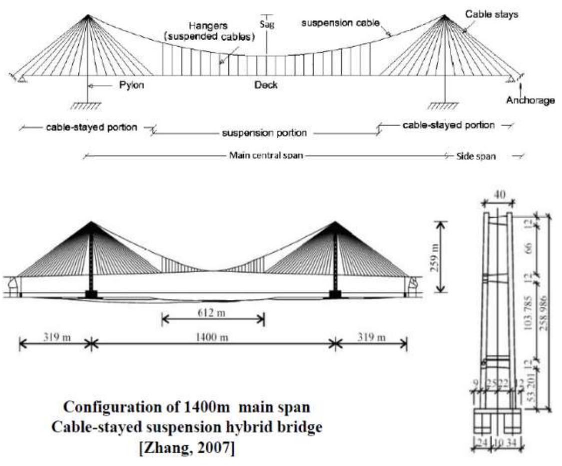


Fig. 1. Lingding Strait Bridge (China) Bridge

Cross-sectional properties of different elements in Cable-stayed suspension hybrid bridge (CSSHB) (Zhang, 2007)

Members	E (Mpa)	A (m²)	J_d (m⁴)	I_y (m⁴)	I_z (m⁴)	M (Kg/m)	J_m (Kg.m²/m)
Girder	2.1×10^5	1.2481	5.034	1.9842	137.754	18386.5	1.852×10^6
Stay cable	2.0×10^5	0.008	0.0	0.0	0.0	62.5	0.0
Hanger Cable	2.0×10^5	0.0065	0.0	0.0	0.0	30.19	0.0
Main Cable in center span	2.0×10^5	0.3167	0.0	0.0	0.0	2445.80	0.0
Main Cable in Side span	2.0×10^5	0.3547	0.0	0.0	0.0	2979.5	0.0
Pylon C	3.3×10^4	30	350	320	220	78000	5.7×10^5
Pylon TB	3.3×10^4	10	150	70	70	26000	4.7×10^5

E - Modulus of Elasticity; A - Cross section area;
J_d - torsional constat; I_y-Lateral bending moment of inertia; I_z -Vertical bending M O Inertia;
M - Mass per unit length; J_m – mass moment of inertia per unit length.

Property	**Material**	
	Steel (Fe345)	**Concrete (M45)**
Modulus of Elasticity (E)	2.0×10^8 kN/m²	3.354×10^7 kN/m²
Unit Weight	76.973 kN/m³	24.993 kN/m³
Poisson's ratio (μ)	0.3	0.20
Shear Modulus (G)	1.115×10^6 kN/m²	1.397×10^7 kN/m²
Coeff. Of Thermal Expansion (α)	1.17×10^{-5}	0.55×10^{-5}

Table. 1. Material & C/s Properties Bridge

Cable No.	**Diameter (m)**	**Area (m²)**	**Cable wt. (kN/m)**
Hanger	0.0903	6.4×10^{-3}	0.493
Main Cable (SS)	0.635	0.367	28.238
Main Cable(CS)	0.672	0.3547	27.302
Stay Cable(1)	0.1009	8.00×10^{-3}	0.616
Stay Cable(2)	0.1059	8.00×10^{-3}	0.678
Stay Cable(3)	0.1106	9.61×10^{-3}	0.740
Stay Cable(4)	0.1156	10.41×10^{-3}	0.802
Stay Cable(5)	0.1194	11.20×10^{-3}	0.863
Stay Cable(6)	0.1277	12.81×10^{-3}	0.987
Stay Cable(7)	0.1316	13.61×10^{-3}	1.048
Stay Cable(8)	0.1354	14.41×10^{-3}	1.109

Using above properties, assignment of various bridge elements was completed in SAP2000…

Girder was modelled as frame element , using steel, as a steel streamlined c/s

Pylon Tower (H type) modelled ,as frame element using concrete with 6m x 5.0m c/s , 258.786m high, with 3 transverse beams (along its height.

Cables modelled as cable element.

Supports and Links are modelled in accordance

Load assignments considered are

Type of Load	Element assigned	Value
D.L.	Deck	97.98 kN/m
SIDL	Deck	50 kN/m
LL	Deck	34.65 kN/m

3.1 Bridge super Structure

3.1.1 Cable Configuration

The study is focused to the effect of the cable pattern as described below for the Bridge with main central span of 1400m and side spans of 319 m, H type Pylon 259m high, and all elemental properties keeping same as in above .The modifications were carried out to study effect of cable pattern and bridges modeled as scheduled in tasks below, namely

1) Bridge Type I (CSB).
2) Bridge Type II (SB).
3) Bridge Type III (Composite CSSB 1)
4) Bridge Type IV (Composite CSSB 2)
5) Bridge Type V (Combined CSSB)
6) Bridge Type VI (CSSHB)
7) Bridge Type VII (CSSHB, overlap 1_3)
8) Bridge Type VIII (CSSHB, overlap 1_2)
9) Bridge Type IX (CSSHB, overlap 2_3)

The bridge(s) modeled is shown in Fig.2, subsequently

Bridge Type I (CSB).: This is a bridge with modified cable system, hence called Bridge Type I (CSB) hereafter This is a pure cable stayed bridge with no suspension cable and or hangers in the bridge. Sag to central span ratio is taken as same i.e 1/10..The side spans are same as original CSSHB.The suspension portion , in Bridge Type VI, is replaced by cable stays Cab8 as shown in Fig 2(a) , wherein cable stays are placed/connected to deck at same respective location(s) where hangers were connected to the deck in the originally designed CSSHB

Bridge Type II (SB).: This is a bridge modified into a suspension bridge system, hence called Bridge Type II (SB) hereafter This is a pure suspension bridge with no stay cables in the bridge. Sag to central span ratio is taken as same i.e 1/10. The material for hangers as well as suspension cable is same as that of original CSSHB. Herein, hangers are placed at the same points where cable stays were attached to girder in the case of original CSSHB. , in Bridge Type VI.This type of bridge is as shown in Fig 2(b).

Bridge Type III (Composite CSSB 1): This is again a bridge with a modified cable system, hence called Bridge Type III (Composite Bridge CSSB1) hereafter. In this the central span is converted to SB whereas the side spans are CB type as shown in Fig 2(c) . Sag to central span ratio is taken as same i.e 1/10. The material for hangers as well as suspension cable is same as that of original CSSHB. Herein, hangers are placed at the same points where cable stays were attached to girder in the case of original CSSHB.

Bridge Type IV (Composite CSSB 2): This is again a bridge with a modified cable system, hence called Bridge Type IV (Composite Bridge CSSB1) hereafter. In this the central span is converted to CB whereas the side spans are SB type as shown in Fig 2(d) . Sag to central span ratio is taken as same i.e 1/10. The material for hangers as well as suspension cable is same as that of original CSSHB. Herein, hangers are placed at the same points where cable stays were attached to girder in the case of original CSSHB.

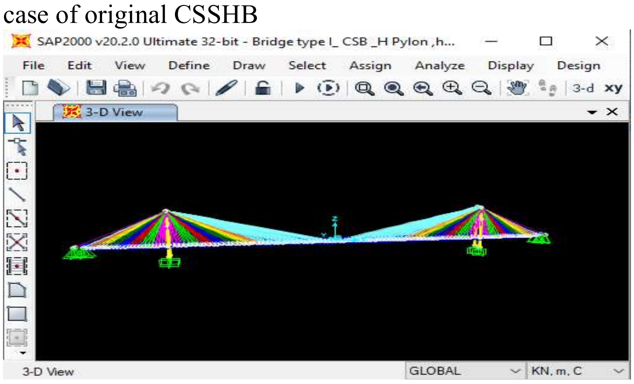
Bridge Type V (Combine CSSB): This is again a bridge with a modified cable system, hence called Bridge Type V (Combine Bridge CSSB) hereafter. In this the central span is combination of CB and SB whereas the side spans are CB type as shown in Fig 2(e) . Sag to central span ratio is taken as same i.e 1/10. The material for hangers as well as suspension cable is same as that of original CSSHB. Herein, hangers are placed at the same points where cable stays were attached to girder in the case of original CSSHB

Bridge Type VI (CSSHB) : This is the benchmark model which has been validated and the same is described 5.2.1 above. It is hereafter termed as Bridge Type VI (CSSHB).The modeled bridge view is as shown in Fig.2(f)

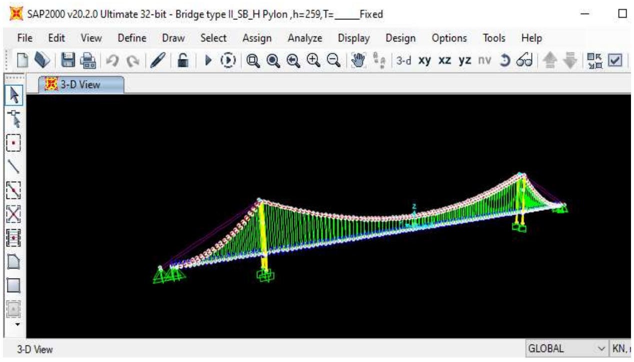
Bridge Type VII (CSSHB, overlap 1:3): This is again a bridge with a modified cable system, hence called Bridge Type VII (CSSHB, overlap 1_3) as shown in Fig 2(g) wherein cable stays are also provided upto 1/3 of suspension portion in the central part.Thus there is an overlap of CSB and SB pattern . Sag to central span ratio is taken as same i.e 1/10. The material for hangers as well as suspension cable is same as that of original CSSHB. Herein, hangers are placed at the same points where cable stays were attached to girder in the case of original CSSHB

Bridge Type VIII (CSSHB, overlap 1:2): This is again a bridge with a modified cable system, hence called Bridge Type VIII (CSSHB, overlap 1_2) as shown in Fig 2(h) wherein cable stays are also provided upto ½ of suspension portion in the central part.Thus there is an overlap of CSB and SB pattern . Sag to central span ratio is taken as same i.e 1/10. The material for hangers as well as suspension cable is same as that of original CSSHB. Herein, hangers are placed at the same points where cable stays were attached to girder in the case of original CSSHB

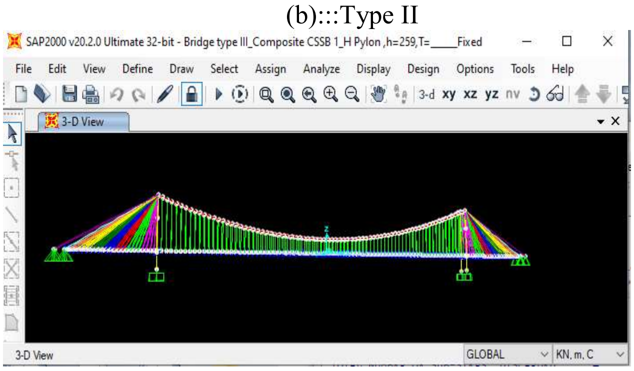
Bridge Type IX (CSSHB, overlap 2:3): This is again a brid ge with a modified cable system, hence called Bridge Type IX (CSSHB, overlap 2_3) as shown in Fig 2(i) wherein cable stays are also provided upto 2/3 of suspension portion in the central part.Thus there is an overlap of CSB and SB pattern . Sag to central span ratio is taken as same i.e 1/10. The material for hangers as well as suspension cable is same as that of original CSSHB. Herein, hangers are placed at the same points where cable stays were attached to girder in the case of original CSSHB



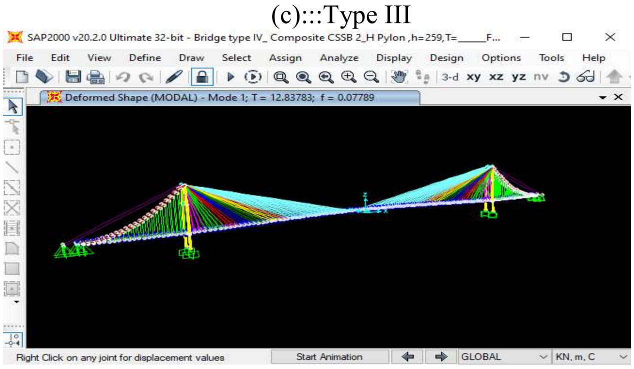
(a):::Type I



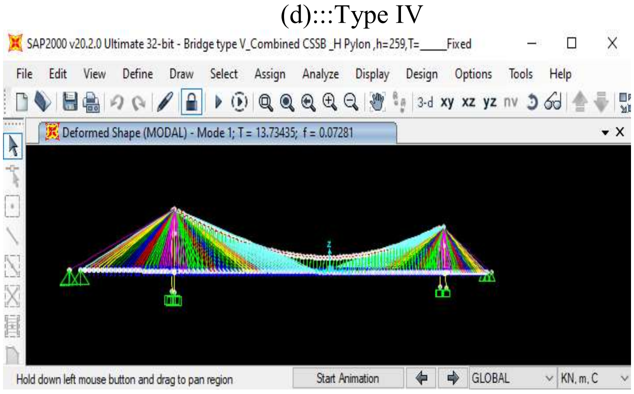
(b):::Type II



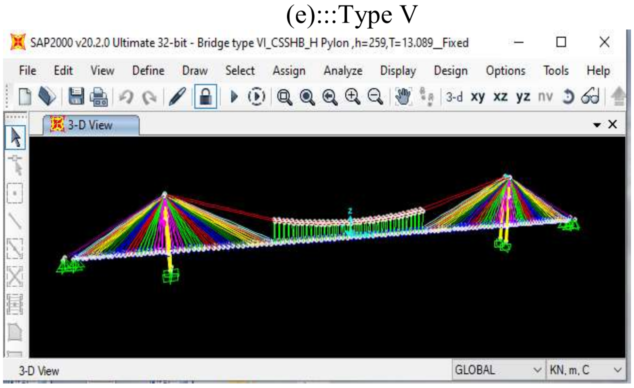
(c):::Type III



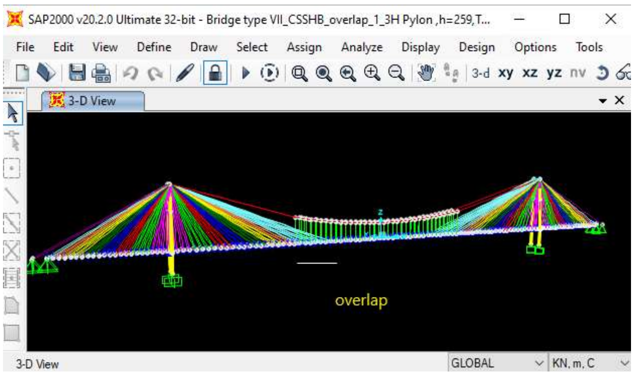
(d):::Type IV



(e):::Type V



(e):::Type VI



(g)-(i):::Type VII-IX

Fig. 2. Bridges with Different Cable Systems

3.1.2 Cable (Stay) Inclination

The study is, here,focused to illustrate effect of the <u>cable (stay) inclination n</u> as described below for the Bridge (Type VI illustrated before) with main central span of 1400m and side spans of 319 m, H type Pylon≡ 259m high, and all elemental properties keeping same as in above.It is evident that the lateral configuration of the Pylon tower governs the verticality of the plane of Stay Cables .Stay cable scan be arrznged /provided so that plane carrying them is *vertical or inclined. Over here,*we wish to study effect of cable configuration on dynamic stability of the Bridge type VI, by incorporating three cases/configurations by varying the planar inclination of cable stays with vertical axis passing through the joint at Pylon top where cable stays
meet Except the arrangement of cable planes other design parameters remain identical for all the three cases.

For this, considered cable configurations studied and considered, here, are depicted in Fig. 3 below , wherein –ve angle represents inward inclination and +ve angle represents outward inclination

3.2 Soil

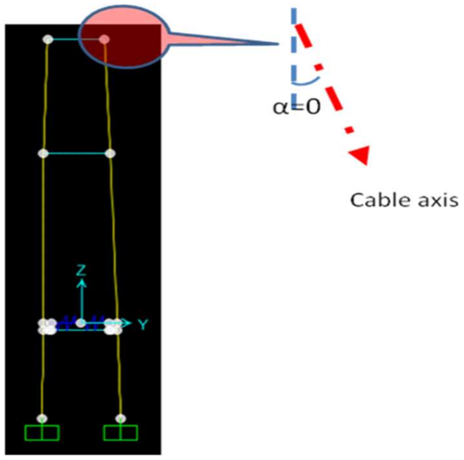
The interaction between the pier footing and the soil is modelled using transla-tional & Rotational springs**.**The spring coefficients have been computed by the method suggested in Specifica-tion for Highway Bridges issued by Japan Road Association. In the suggested meth-od, it should be mentioned that, when using equations (1) and (2), the units of B_e and E must be centimeters and kgf/cm^2 (1 kgf/cm 2 = 98 kPa), respectively. The horizon-tal and rotational spring coefficients for each part of foundation are obtained by mul-tiplying k by the area and the inertia moment of its surface perpendicular to the excitation direction, respectively. As for the bottom face of foundation, the soil

reaction coefficient per unit area in horizontal direction is taken as 1/3 of k.

$k_0 = 1.2E/30$……………………………………..(1)

$k = k_0^{-0.75}\sqrt{(B_e/30)}$…...………………………………(2)

Where,
k_0= reference soil reaction coefficient,
E=Young's modulus of elasticity for soil,
k =The soil reaction coefficient per unit area,
Be= the width of foundation perpendicular to the considered direction.



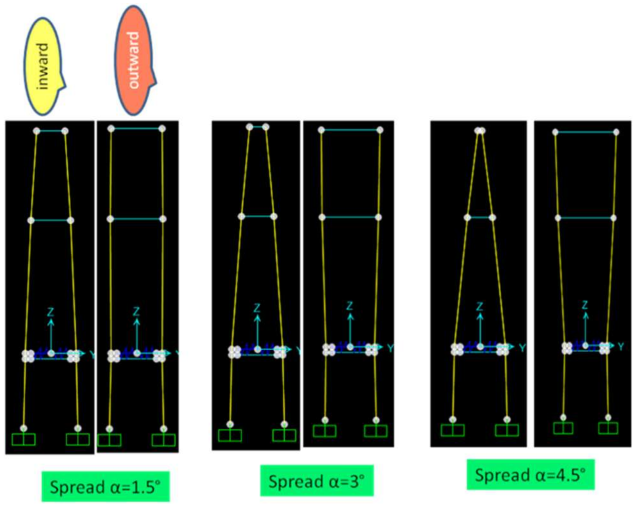


Fig. 3. Lateral spread of Pylon Tower Considered

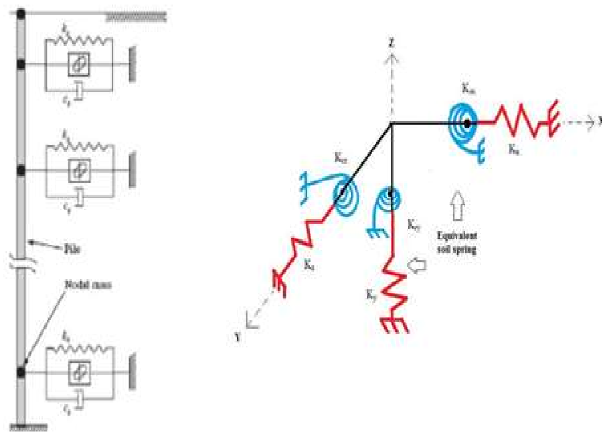


Fig. 4. Modeling of soil as spring & Dashpot (Kelvin Element) applied at nodes of pile[7] (Adopted from Soneji, B. B & Jangid 2009)

Three types of soils are in this study designated as soil type I,II,III in Table 2.

3.3 Sub Structure(Pile Foundation)

For the sub structure , to study effect of SSI, Piles, of M45 grade concrete, 2m diameter , 20m deep, with a c/c spacing of 5m are provided with a pile cap(raft) 60m x 30m in plan and 2m thick , thereby incorporating 9 x 4 array of piles below each Pylon Tower.

The extruded view of the pile+cap is illustrated in figure 5.

Table. 2. Properties of Soil Considered [1]

Sr. No	Soil Properties	Soil-I Hard Clayey soil	Soil-II Soft Silty soil	Soil-III medium Sandy soil
1	Unit weight of soil-γ (kN/m^3)	20	18	19
2	Shear Strength-τs (kN/ m^2)	200	75	150
3	Poisson's Ratio-ν	0.3	0.4	0.35
4	Damping of soil-ξ	0.02	0.06	0.04
5	Shear wave velocity –Vs (m/ sec)	1050	83	309
6	Shear Modulus-Gs (kN/m^2)	269 x 10^4	12500	192 310
7	Young's modulus of Elasticity-E (kN/m^2)	700 x 10^4	35000	500 x 10^3
8.a	Soil stiffness K_x (kN/ m)	252 x 10^4	4.60 x 10^4	8.62 x 10^6
8.b	Soil stiffness K_y(kN/ m)	1050 x 10^4	5.52 x 10^4	10.3 x 10^4
8.c	Soil stiffness K_z (kN/ m)	1028 x 10^4	5.36 x 10^4	10.0 x 10^4
8.d	Soil stiffness $K_{\theta x}$ (kN m/rad)	8094 x 10^4	156 x 10^4	292 x 10^4
8.e	Soil stiffness $K_{\theta y}$(kN m/rad)	309 x 10^4	21.6 x 10^4	40.4 x 10^4
8.f	Soil stiffness $K_{\theta z}$ (kN m/rad)	9808 x 10^4	532 x 10^6	729 x 10^6

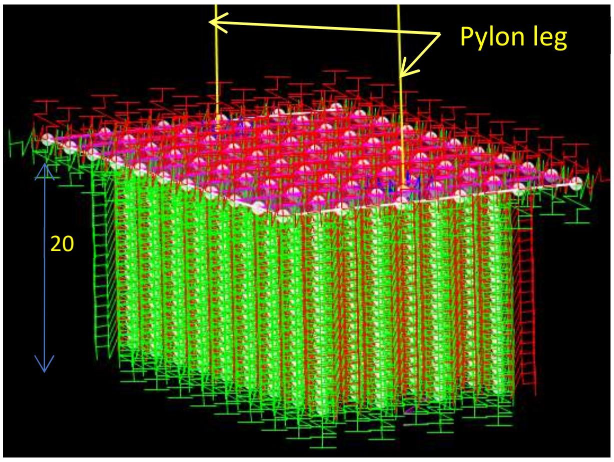
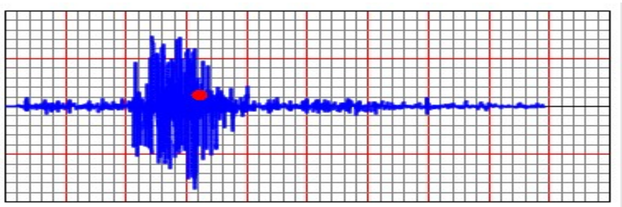


Fig. 5. Pile Cap +Piles with Springs

3.4 Details of acceleration Time History

- Name : Bhuj
- Magnitude : 7.7
- Duration : 133.53 seconds
- Peak Ground Acceln. : 1.0382 m/s²



Total 26706 number of Acceln. Records recorded

4 Analysis

Dynamic analyses were carried out to determine response of the structure for different cable pattern. The seismic response of cable stayed suspension Hybrid Bridge with far fault ground motion for different cable patterns and results of axial force in the main cable and pylon top displacements were noted with fixed base (no SSI).

The figure 6 bellow shows a comparative graphical representation of the modal time periods for different configurations (Bridge Type)

Similarly, MTHA was conducted for H type Pylon with fixed base for different cases of lateral spread too

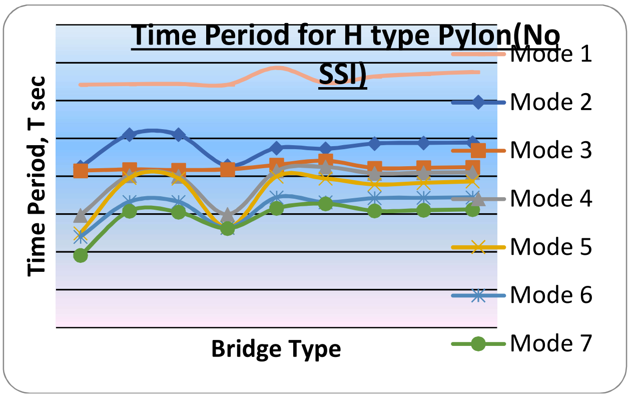


Fig. 6. Time Perod (1st Mode) for Diff. Cable Configurations w/o SSI

Similarly the subsequently figure 7 tabulates the first modal time period, axial foce(SS) and pylon top displacement for the 9 types of bridges modelled, with H type Pylon with and without SSI consideration

Sr No.	Bridge Type	1st Mode, T sec		Pylon Top, δ mm		Axial Force,SS kN		Case
			% change		% change		% change	
1	I	12.84		286		85606		No SSI
2		12.84	0.00	288	0.70	85621	0.02	Soil 1
3		12.91	0.55	303	5.94	80653	-5.79	Soil 2
4		12.89	0.39	298	4.20	85826	0.26	Soil 3
5	II	12.87		846		147188		No SSI
6		12.87	0.00	847	0.12	148666	1.00	Soil 1
7		12.96	0.70	892	5.44	149077	1.28	Soil 2
8		12.94	0.54	861	1.77	149421	1.52	Soil 3
9	III	12.88		837		146051		No SSI
10		12.88	0.00	869	3.82	146069	0.01	Soil 1
11		12.97	0.70	857	2.39	146491	0.30	Soil 2
12		12.94	0.47	851	1.67	146345	0.20	Soil 3
13	IV	12.84		344		90527		No SSI
14		12.84	0.00	345	0.29	90720	0.21	Soil 1
15		12.92	0.62	364	5.81	90894	0.41	Soil 2
16		12.9	0.47	357	3.78	90922	0.44	Soil 3
17	V	13.74		900		160173		No SSI
18		13.74	0	972	8.00	164192	2.51	Soil 1
19		13.82	0.58	992	20.00	164639	2.79	Soil 2
20		13.81	0.51	986	-6.00	164484	2.69	Soil 3
21	VI	13.09		794		140083		No SSI
22		13.09	0	796	0.25	140210	0.09	Soil 1
23		13.82	5.58	821	3.40	140736	0.47	Soil 2
24		13.17	0.61	813	2.39	140548	0.33	Soil 3
25	VII	13.27		824		143305		No SSI
26		13.28	0.08	827	0.36	144325	0.71	Soil 1
27		13.36	0.68	847	2.79	144773	1.02	Soil 2
28		13.34	0.53	841	2.06	144617	0.92	Soil 3
29	VIII	13.41		846		146991		No SSI
30		13.41	0.00	848	0.24	147000	0.01	Soil 1
31		13.49	0.60	868	2.60	147458	0.32	Soil 2
32		13.47	0.45	861	1.77	147298	0.21	Soil 3

Fig. 7. Comparison: Time Perod (1st Mode), Pylon Top Displacement & Cable Fore (SS) for Diff Cable Configurations with & w/o SSI

Effect ofLateral Spread α on Time Period , T (sec) for CSSHB.. for H Pylon f,pylon height 259m , Bridge span 319+1400+319		Spread
Lateral Spread α, °	T(sec)- 1st mode	
-4.5	12.658	Inward Spread
-3	12.7835	
-1.5	12.9314	
0	13.0895	α= 0
1.5	13.2623	Outward Spread
3	13.4429	
4.5	13.6421	

Again figure 8 tabulates the first modal time period, axial foce(SS) and pylon top displacement for bridg type VI with the H type Pylon with lateral sway (innternal , external), modelled, without SSI consideration

Effect ofLateral Spread α Pylon Top Displacement, δ(mm) for CSSHB.. for H Pylon ,pylon height 259m , Bridge span 319+1400+319		Spread
Lateral Spread α, °	δ (mm)- dead	
-4.5	528.88	Inward Spread
-3	676.38	
-1.5	764.64	
0	794.4	α= 0
1.5	765.02	Outward Spread
3	677.14	
4.5	531.49	

Fig. 8. Effect of Lateral Sway on Time Perod (1st Mode), Pylon Top Displacement for Bridge VI with lateralsway without SSI

5 Conclusions

The results of seismic time history analysis , as

1) Illustrated for 27cases (bridge and soil type). The table demonstrates the change in time period with change in stiffness of soil underneath.The trend observed in the deviation is almost same for all casesType V Bridge gives max modal time period(1st mode) thereby flexibility (up by approx 4.95% without SSI considerationand so is the case for Pylon top displacement
2) The MTHA on CSSHB with H type Pylon to study effect of lateral spread revealed that the Lateral spread results in increase of 4.2% in time Period when outward inclination is increased by 4.5% whereas it decreases by 3.30% when inward inclination is increased to 4.5%. In the same line, it can be concluded that the Pylon Top Displacement results a change in the range of 33% when lateral spread deviates by 4.5%

Disclosures

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