The Effect of Wing Wall Configurations on Seismic Response of Girder Bridges

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***Abstract* — Many studies systematically have investigated seismic lateral load distribution using comparisons of experimental test data and analytical models to formulate improved design recommendations. Moreover the lateral loads that are acting on the girder to be studied for suggesting a better design model. The present study aims to investigate the seismic response taking into account the effects of different types of wing walls on the behaviour of concrete girder bridges. The effect of gap between adjacent girders and between girder and abutment are of great importance. The parametric study includes three types of cantilever wing walls; inline, flared and U-shaped wing walls. The effects of wing wall configurations are assessed in terms of deformation and stresses. The numerical results showed that the parameters such as frequency, displacement and stress were affected by different wing wall model. Seismic evaluation was done using Ansys software.**

Keywords—Concrete girder bridge, gap, wing wall

I. INTRODUCTION

A girder bridge, in general, is a bridge that uses girders as the means of supporting the deck. A bridge consists of three parts: the foundation, the substructure (abutment and piers) and the superstructure (girder, deck, etc). A girder bridge is the most commonly built and utilized bridge in the world. In the most simplified form, its basic design can be compared to a long ranging from one side to the other across a river or stream. In modern girder bridges, a good number are box-girders. The term girder is often used interchangeably with beam in reference to bridge design.

Before Kobe earthquake (1995), the consideration of a gap of 10cm has been used in the real bridge in Japan. Nevertheless, several damages on bridges occur, such as collision between contiguous decks and between deck and abutment. Consequently, collision becomes one of the key aspects to be evaluated in the seismic performance of the bridge. It has been determined that essential gap between the ends of two adjacent girders shall be taken in the design of the superstructure for preventing any loss of the bridge caused by the collision between two contiguous superstructures, a superstructure and an abutment, or a superstructure and the truncated portion of a pier head, when a bridge is subjected to earthquake Ground Motion. Wing wall is a necessary component of bridges to retain the fill that supports the roadway. Wing wall orientation have impact on the forces that are induced in and for the distribution of forces throughout the structure.

The present study aims to inspect the seismic response taking into account the effects of different types of wing walls on the behaviour of girder bridges and the effect of spacing between adjacent girders and between girder and abutment are also included. The parametric study include three types of cantilever wing walls; inline, flared and U-shaped wing walls. The gap between girders and between girder and abutment is chosen as 20cm. The effects of wing wall configurations are assessed in terms of deformation and stress.

II. LITERATURE REVIEWS

Desy Setyowulan, Tomohisa Hamamoto (2014) studied the elasto-plastic behavior of 3-diamensional reinforced concrete abutments with wing wall as a parameter. They concluded, Installing wing wall had a capability of reducing longitudinal displacement and cracking.

Desy Setyowulan Tomohisa Hamamoto (2015) done the dynamic analysis of concrete girder bridge taking into account the effect of collision on parapet wall. In addition, adopting of seismic isolation rubber on pier structure and wing wall on parapet were analyzed. It was found that, installation of wing wall had a capability of resisting horizontal displacement. The isolation rubber and wing wall structure had effect in reducing the response stress.

Desy Setyowulan Toshitaka Yamao (2016), seismic response behavior of two span concrete girder bridge taking into account the effect of displacement restriction and different wing wall types was investigated. The numerical results showed that the parameters such as stress, strain, displacement and cracking were affected by displacement restriction and different wing wall model.

Andreas Paraschos & Amde M. Made (2016) found that Use of cantilever wingwalls with integral abutments has a modest impact on the behavior of integral abutment bridges. Cantilever inline wingwalls have the most impact on the behavior of integral abutment bridges.

S.A. Mitoulis & M.D. Titirla (2014). In this, A new earthquake resistant abutment with high capacity wing walls was designed and its efficiency in enhancing bridge’s earthquake resistance was analytically investigated and assessed. A real with an expensive isolation scheme consisting of lead rubber bearings and dampers was utilized as benchmark for the study. Two alternative bridge design

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scenarios DS1 and DS2 werere-designed and compared to the benchmark on the basis of seismic demand and cost-effectiveness.

III. NUMERICAL PROCEDURES

A. General description of analytical method

The numerical model of bridge was conducted by Finite element tool ANSYS Workbench. In this research, parametric study of bridges taking into account the effect of different wing walls and gap was varied from 10, 20 and 30cm. Two types of loads were applied in the bridge; self weight as gravity load of 9.8 m/s^2 and external load as seismic ground acceleration applied at footing of pier.

B. Analytical model of bridge

A four span concrete bridge with a clear span of 30m with a width of roadway 7.5m was adopted. Thickness of deck slab adopted is 0.25m. Abutment and parapet walls are located at both ends. The bridge is having three piers of 8m height with a dimension of 8m x 0.8m. Abutment is having a height of 3m with a dimension of 5.8m x 0.9m. Parapet wall dimension is taken as 5.8 x 2.5 x 0.5m.

Fig. 1 shows the cross section of the superstructure.

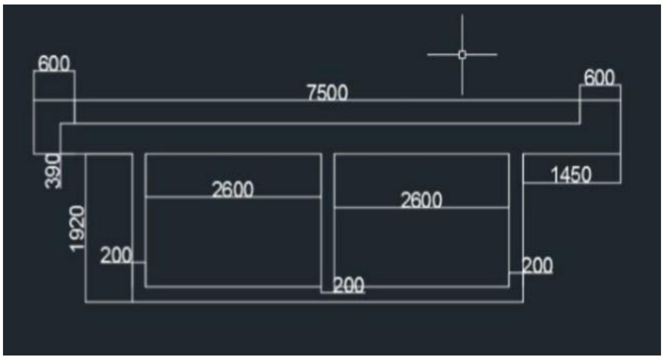


Fig 1: cross section of superstructure

The study include three types of cantilever wing walls; inline, flared and U-shaped wing wall. Dimension adopted for In-line wing wall is 3x 0.5m, for Flared wing wall dimension adopted is 3x 0.5m, at an angle of 45° to the abutment and U-wing wall dimension is 3 x 0.5m. Fig 2(a), 2(b) and 2(c) shows the figure of In-line, Flared and U-wing wall respectively.

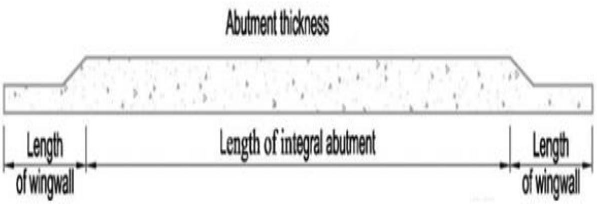


Fig 2(a): In-line wing wall

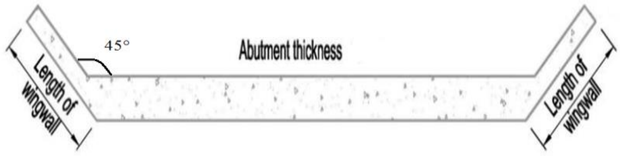


Fig 2(b): Flared wing wall

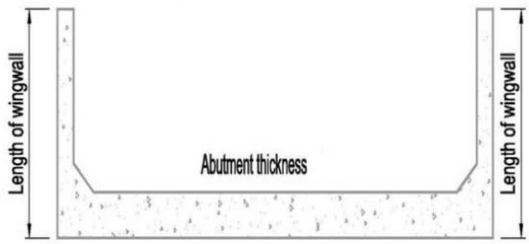


Fig 2(c): U-wing wall

The boundary condition of abutments and pier were fixed at the bottom. Bearing supports were movable at pier and abutments. Elastomeric bearing of dimension 500 x 250 x 39mm were provided.

The 3-dimensional Finite element models of bridge is shown in fig 3(a), 3(b) and 3(c).

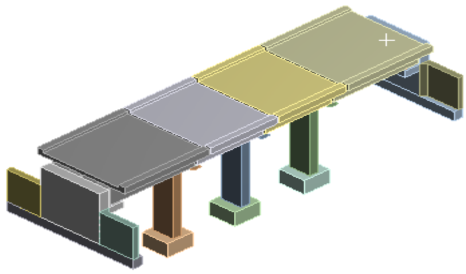


Fig 3(a): Reinforced concrete girder bridge with cantilever inline wing wall

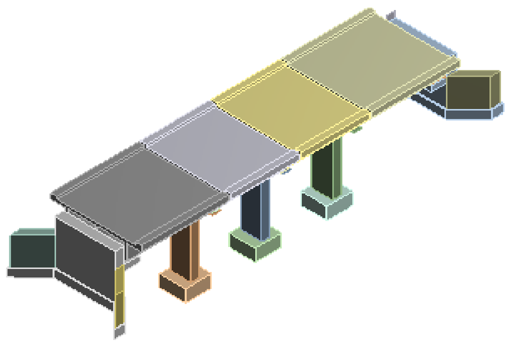


Fig 3(b): Reinforced concrete girder bridge with cantilever flared wing wall

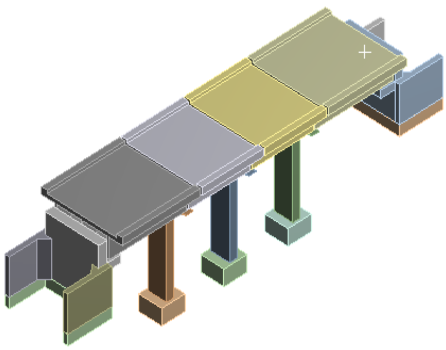
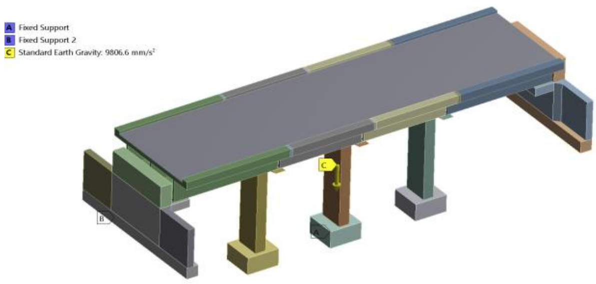


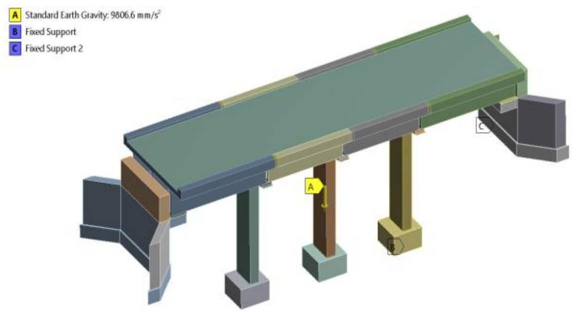
Fig 3(c): Reinforced concrete girder bridge with cantilever U – wing wall

C. Support Conditions

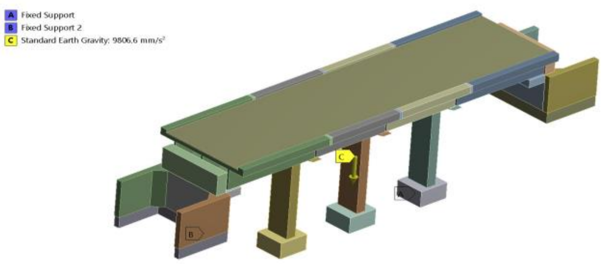
Support conditions adopted are fixed at bottom of pier and bottom of abutment. Self weight of the bridge is provided as gravity load.



(a)



(b)



(c)

Fig 4: Support conditions

D. Input seismic waves and material properties

Input acceleration data of Hyogo-ken Nanu Earthquake 1995 is adopted.

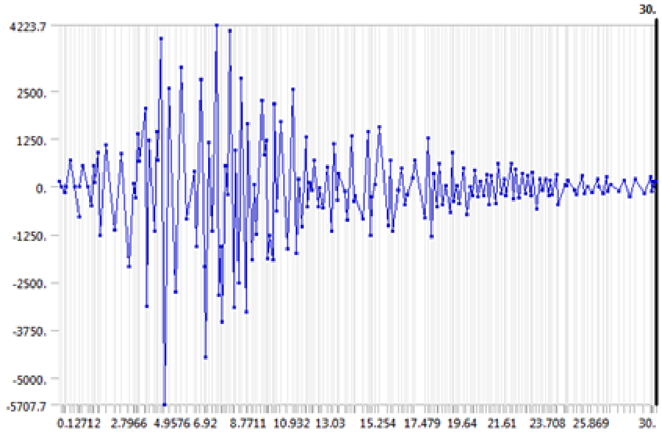


Fig 5: Input seismic waves of Hyogo-kun Nanu Earthquake

Material properties of the bridge are shown in table 1.

Table 1: Material properties of the structure

Material	Density	Modulus Of Elasticity	Poisson's ratio
Reinfrced concrete	2500	50000	0.15

IV. RESULTS AND DISCUSSIONS

The bridges were analyzed in ANSYS Workbench. Dynamic analysis is carried out in three steps. First Static Structural Analysis, is followed by Modal Analysis and finally Response Spectrum Analysis.

4.1 Modal Analysis

Table 2, 3 and 4 shows the natural frequencies and cumulative effective mass ratios of each mode of bridge with inline wing wall configuration, flared and U-wing wall confiuration.

Table 2 Eigen value results for In-line wing wall configuration

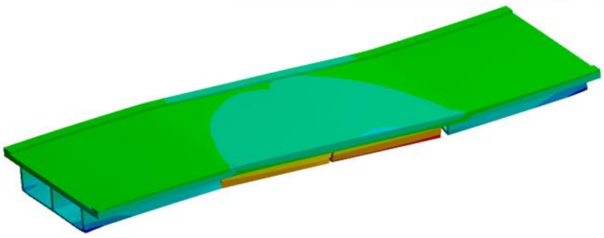
Mode	Frequency [Hz]	X Direction	Y Direction	Z Direction
1	3.3453	5.3547e-005	2.0524e-006	0.81926
2	3.4612	0.89741	3.2481e-006	0.81931
3	5.0736	0.89759	3.2888e-006	0.81933
4	9.3334	0.89764	0.90997	0.81933
5	10.068	0.91501	0.91135	0.81933
6	10.991	0.91501	0.91137	0.82502
7	11.419	0.91501	0.91145	0.82579
8	12.08	0.91501	0.91758	0.83005
9	12.4	0.91501	0.91947	0.84377
10	15.173	0.91501	0.99593	0.84377
11	15.378	0.91503	0.99616	0.8438
12	16.666	0.91503	0.99617	0.99992
13	17.736	0.91503	0.99999	1.
14	18.237	0.92391	0.99999	1.
15	18.98	1.	1.	1.

Table 3 Eigen value results for Flared wing wall configuration

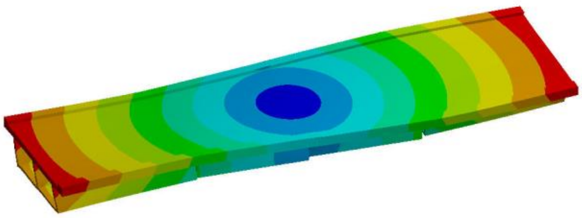
Mode	Frequency [Hz]	X Direction	Y Direction	Z Direction
1	3.6705	0.87028	1.3014e-005	4.3804e-004
2	3.7152	0.87063	2.7435e-005	0.971
3	5.4598	0.88939	2.8207e-005	0.97111
4	9.2218	0.88959	0.85818	0.97113
5	10.502	0.91386	0.86029	0.97114
6	11.351	0.91387	0.91996	0.9712
7	12.049	0.91387	0.92625	0.97795
8	12.735	0.91387	0.93023	0.98512
9	13.147	0.91387	0.93043	0.99981
10	15.847	0.91405	0.93097	0.99982
11	16.417	0.91406	0.99975	0.99987
12	18.76	0.93331	0.99978	0.99987
13	19.197	0.97033	0.99978	0.99987
14	19.47	0.99458	0.99992	0.99987
15	22.854	1.	1.	1.

Table 4 Eigen value results for U-wing wall configuration

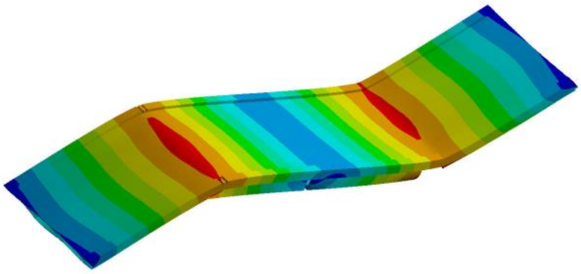
Mode	Frequency [Hz]	X Direction	Y Direction	Z Direction
1	3.2187	1.3907e-004	6.2515e-009	0.96567
2	3.2885	0.89276	1.1596e-006	0.96582
3	4.6389	0.89278	1.2432e-006	0.96582
4	9.3705	0.89282	0.91416	0.96582
5	10.018	0.90705	0.91575	0.96582
6	11.004	0.90705	0.91578	0.97108
7	11.512	0.90705	0.91597	0.97482
8	12.04	0.90705	0.92159	0.98324
9	12.386	0.90705	0.92369	0.99999
10	15.268	0.90707	0.92371	0.99999
11	16.114	0.90707	0.99996	1.
12	18.19	0.91442	0.99996	1.
13	18.925	0.9906	0.99997	1.
14	19.297	0.9959	0.99997	1.
15	22.013	1.	1.	1.



(a) 1st mode

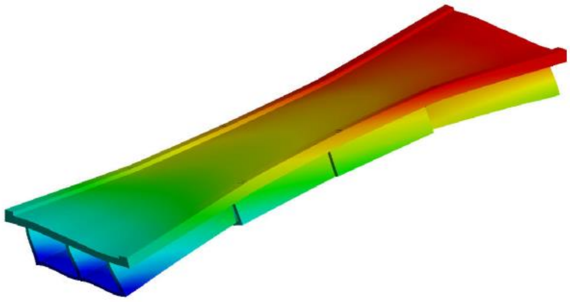


(b) 2nd mode

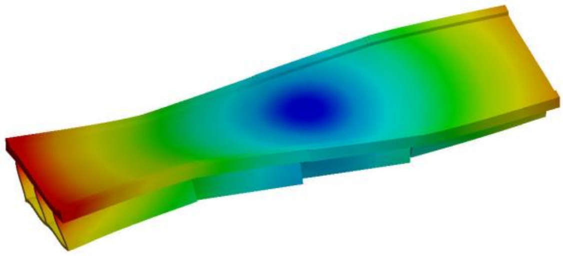


(c) 3rd mode

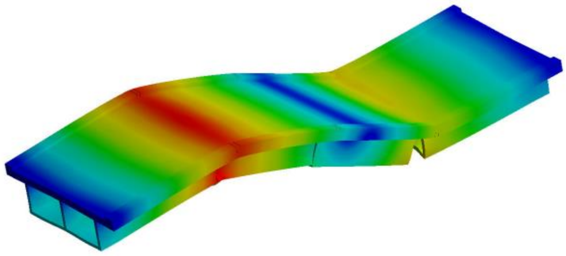
Fig 6: Predominant modes of bridge with inline wing wall configuration



(a) 1st mode

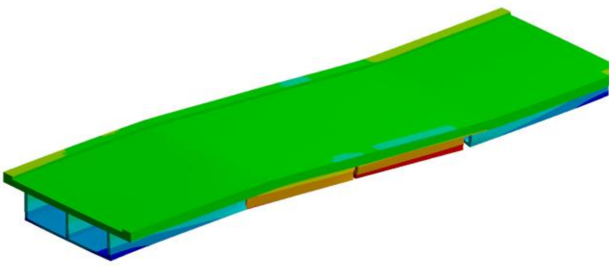


(b) 2nd mode

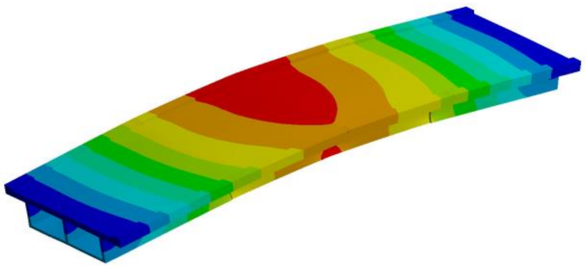


(c) 3rd mode

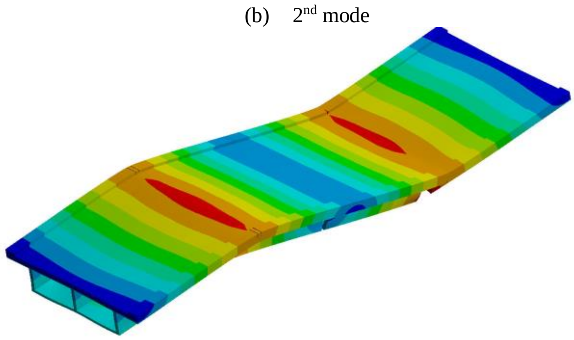
Fig 7: Predominant modes of bridge with flared wing wall configuration



(a) 1st mode



(b) 2nd mode



(c) 3rd mode

Fig 8: Predominant modes of bridge with U-wing wall configuration

The mode shapes deflecting in the longitudinal, traverse and vertical direction are shown in fig 6, fig 7 and fig 8.

4.2 Response spectrum analysis

4.2.1 Equivalent Stress

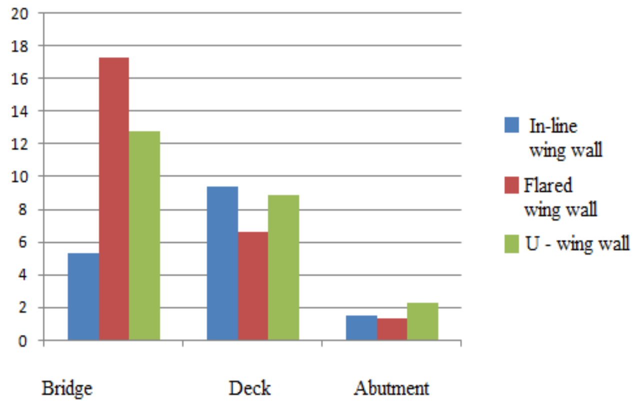


Fig 9: Equivalent stress on bridge, deck and parapet wall for different configurations

4.2.2 Total Deformtion

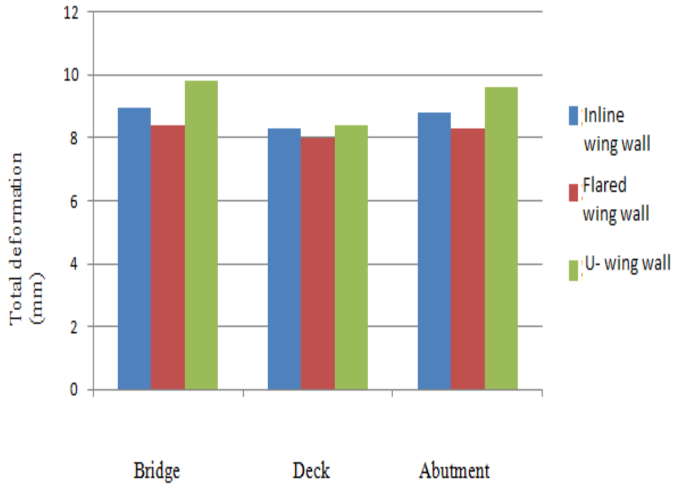


Fig 10: Total deformation of bridge, deck and parapet wall for different configurations

V. CONCLUSIONS

The dynamic behavior of concrete girder bridges subjected to earthquake ground motions considering the effect of different configurations of wing wall and varied spacing were investigated by seismic analysis. Analytical studies were carried out in bridges with the parameters of gap and wing wall. The conclusions of this study are summarized as following.

1. Abutment model with flared wing wall had a good capacity in resisting horizontal displacement of abutment due to earthquake.
2. Installing in-line wing wall in abutment increased the stress in deck and abutment of the bridge.
3. Installing Flared wing wall on abutment reduced the total deformation of bridge by 16.66%, deck deformation by 5%, abutment deformation by 15.67% .
4. Cantilever U-wing wall have most impact on the behavior of abutments due to earthquake.

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