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BRIDGE VIBRATION CONTROL USING VISCOUS DAMPERS

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Abstract: The effectiveness of multiple viscous dampers in reducing response of the bridge subjected to earthquake and wind load is investigated. A bridge of span 32 m with an intermediate bent at centre and abutment at the ends, subjected to various loads is analysed in software. The resonant response of the bridge is studied for different loads like wind, earthquakes, and other external forces. In this study, dampers are installed in strategic locations throughout the bridge, and their damping coefficients are adjusted to control the level of vibration. Response of the bridge is also studied for different arrangements of FVDs. Additionally, the location and number of dampers can be optimized based on the specific characteristics of the bridge, such as its size and geometry, to achieve the best performance.

Keywords: FVD – Fluid Viscous Damper, Resonant response.

I. INTRODUCTION

Transportation infrastructure is one of the significant factor which reflects the development of a nation's economy. Due to the deficiency of land and increased traffic in urban areas, the bridges have become inevitable part of the transportation facilities, such as highways and railways. At the same course of time, day by day, the bridges are becoming more slender and lighter and hence more prone to vibrations due to heavy vehicles. Nowadays, energy dissipation devices have become the focus for vibration mitigation in different types of structures including bridges. Vibrations induced by moving vehicles become excessive when the vehicle velocities reach resonant or critical values. Therefore vibration control using control devices is very efficient way to suppress response of bridge. Passive energy dissipation devices or supplemental damping devices have been successfully implemented into structures for controlling the excessive vibrations under moving load, wind and seismic excitation. Literature review shows that the dynamic behaviour of the bridges has been significantly impacted due to moving loads. Bridge models of different spans prepared in CSI Bridge V_23. Load case is generated in such a way that two moving 70R vehicles crosses the bridge. The spacing between two vehicles is kept 30m according to code IRC: 6, & the velocity of the vehicle is taken as maximum permissible velocity according to IRC: 99. The deflection of mid span of the bridge without damper and with damper is measured. After changing the properties of fluid viscous damper deflection vs. time graph is plotted.

This results in reduced structural response and increased damping, which can significantly improve the overall performance of the bridge.

The specific objectives of this study is summarized as.

(1) To measure vibration induced in bridges due to moving vehicles.
(2) To measure vibration after providing viscous dampers.
(3) To use Multiple Dampers at strategic locations in order to achieve maximum control over deflection.
(4) To measure vibration after changing properties of the viscous damper.

To use Multiple Dampers at strategic locations in order to control seismic and moving load excitations.

Modelling of Bridge, load case and FVD:

A bridge of length 32m and width 8.7m modelled in CSI Bridge V_23. The depth of longitudinal beams kept as 1.2m and thickness is taken as 0.3m. Thickness of deck slab is taken as 0.2m. After providing FVDs at the location shown in fig.2 the reduction in deflection is measured and the graph of deflection vs. span is plotted. Then in software moving combination is applied. Deflection of bridge without providing damper is measured.

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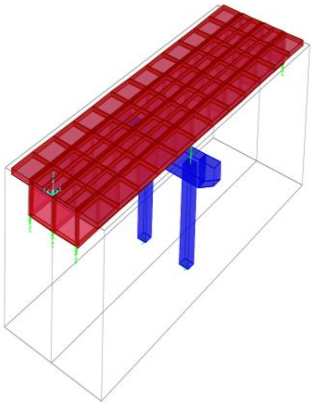

Fig.1 Continuous Bridge

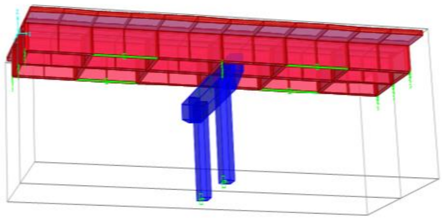

Fig.2 Continuous Bridge with Damper

Deflection of bridge is measured without damper and with damper. It is shown in fig. 3 and fig 4. Comparative graph is shown in fig. below.

Table-1 Deflection without damper

	A	B	C	D	E	F
1	Layout Line Distance	ItemType	Sect Vert	Sect Tran	Sect Long	Sect RLong
2	mm		mm	mm	mm	Degrees
3	0	Max	-0.0148	0.18391	5.994358	5.67E-07
4	0	Min	-0.299437	-0.182987	0.309765	1.09E-07
5	2666.67	Max	-0.461282	0.201681	5.806747	4.34E-08
6	2666.67	Min	-11.167421	-0.201733	0.266513	4.31E-08
7	5333.33	Max	-0.15874	0.505589	5.300783	2.09E-07
8	5333.33	Min	-18.567311	-0.505148	0.189356	1.18E-07
9	8000	Max	0.859231	0.695216	4.708194	7.71E-08
10	8000	Min	-20.442601	-0.695224	0.13925	7.21E-08
11	10666.67	Max	2.025421	0.750694	4.240955	2.35E-07
12	10666.67	Min	-16.533815	-0.750384	0.17176	1.29E-07
13	13333.33	Max	2.171421	0.665049	4.088491	6.49E-08
14	13333.33	Min	-8.731493	-0.665155	0.336587	5.47E-08
15	16000	Max	-0.367708	0.495096	4.380566	2.25E-07
16	16000	Min	-0.900044	-0.494541	0.73823	5.83E-08

Table-2 Deflection with damper

	A	B	C	D	E	F
1	Layout Line Distance	ItemType	Sect Vert	Sect Tran	Sect Long	Sect RLong
2	mm		mm	mm	mm	Degrees
3	0	Max	-0.089632	0.158084	5.596514	4.09E-07
4	0	Min	-0.338751	-0.157121	1.625733	3.50E-08
5	2666.67	Max	-2.917076	0.193269	5.357732	7.89E-08
6	2666.67	Min	-10.40533	-0.193256	1.542473	3.32E-08
7	5333.33	Max	-3.980619	0.4571	4.63008	1.99E-07
8	5333.33	Min	-15.357408	-0.456743	1.300289	6.64E-08
9	8000	Max	-3.04312	0.609881	4.065641	-3.69E-08
10	8000	Min	-15.100752	-0.609942	1.120067	-1.12E-07
11	10666.67	Max	-1.603482	0.634188	3.633121	1.89E-07
12	10666.67	Min	-13.052897	-0.633956	1.030908	6.81E-08
13	13333.33	Max	-0.065811	0.53343	3.310916	1.11E-07
14	13333.33	Min	-7.661763	-0.533464	1.046856	2.50E-08
15	16000	Max	-0.578861	0.372481	3.650545	1.91E-07
16	16000	Min	-1.094185	-0.371666	1.449746	3.27E-08

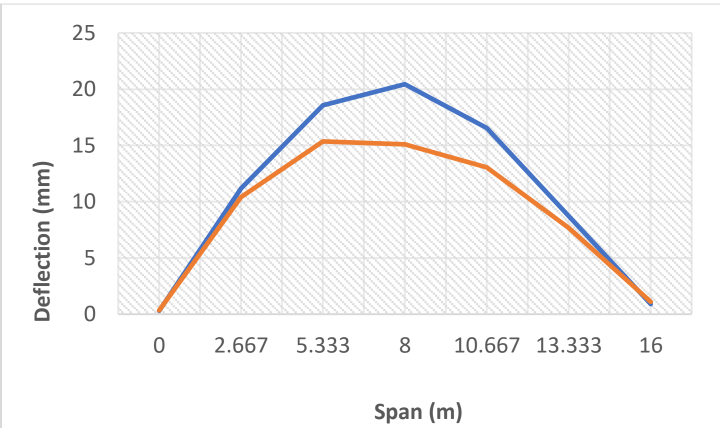

Fig. 3 Comparative study graph

Comparative study is carried out and Deflection vs. Time graph is plotted. Reduction in deflection for moving load combination is 24.875%.

Similarly the study carried out for earthquake load combination. Displacement of bridge span with and without damper is measured. FVDs provided in the bridge as shown in the figure 2. The properties of fluid viscous damper is taken from the manual of Taylor Devices. After providing viscous damper deflection of the bridge is measured for the EQ Basic load combination.

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Table -3 Deflection without damper

	A	B	C	D	E	F
1	Layout Line Distance	ItemType	Sect Vert	Sect Tran	Sect Long	Sect RLong
2	mm		mm	mm	mm	Degrees
3	0	Max	0.163284	0.197305	5.125327	2.19E-06
4	0	Min	-0.450862	-0.196522	0.126758	-1.82E-06
5	2666.67	Max	-0.10647	0.257	5.424846	8.11E-06
6	2666.67	Min	-9.620029	-0.257107	-0.724042	-8.05E-06
7	5333.33	Max	0.165741	0.537842	5.519561	5.57E-06
8	5333.33	Min	-15.758558	-0.537499	-1.955857	-5.38E-06
9	8000	Max	1.044786	0.724319	5.871937	6.04E-07
10	8000	Min	-17.372929	-0.724453	-3.171051	-4.96E-07
11	10666.67	Max	1.960388	0.788237	6.422853	3.74E-06
12	10666.67	Min	-14.051964	-0.788012	-4.332971	-3.54E-06
13	13333.33	Max	2.08469	0.723672	7.194755	5.11E-06
14	13333.33	Min	-7.598806	-0.72389	-5.39284	-5.05E-06
15	16000	Max	-0.098596	0.581733	8.302114	9.98E-06
16	16000	Min	-0.926213	-0.58131	-6.284596	-9.86E-06

Table – 4 Deflection with damper

	A	B	C	D	E	F
1	Layout Line Distance	ItemType	Sect Vert	Sect Tran	Sect Long	Sect RLong
2	mm		mm	mm	mm	Degrees
3	0	Max	0.090262	0.175477	5.183667	2.29E-06
4	0	Min	-0.463451	-0.174677	0.866008	-2.09E-06
5	2666.67	Max	-1.488486	0.250852	4.72321	8.47E-06
6	2666.67	Min	-9.678165	-0.250944	0.940719	-8.39E-06
7	5333.33	Max	-1.428982	0.495271	4.601639	9.08E-06
8	5333.33	Min	-14.719373	-0.495007	-0.362289	-8.94E-06
9	8000	Max	0.021018	0.649583	5.017975	6.11E-06
10	8000	Min	-15.131399	-0.649775	-1.745845	-6.22E-06
11	10666.67	Max	0.009748	0.686286	5.615872	1.20E-06
12	10666.67	Min	-12.501333	-0.686141	-3.047636	-1.09E-06
13	13333.33	Max	0.416793	0.608428	6.165885	6.02E-06
14	13333.33	Min	-7.001538	-0.608613	-4.10086	-5.94E-06
15	16000	Max	-0.268652	0.496834	7.249739	9.78E-06
16	16000	Min	-1.099	-0.496258	-4.879222	-9.72E-06

Figure shows graphical representation of span wise deflection of bridge with and without damper. Figure shows reduction in deflection is around 13%. The performance of FVDs in controlling the undesirable response of the bridge is investigated. The properties of fluid viscous damper is taken from the manual of Taylor Devices. When multiple fluid viscous dampers are provided at stretagic locations it become more effective in controlling vibration.

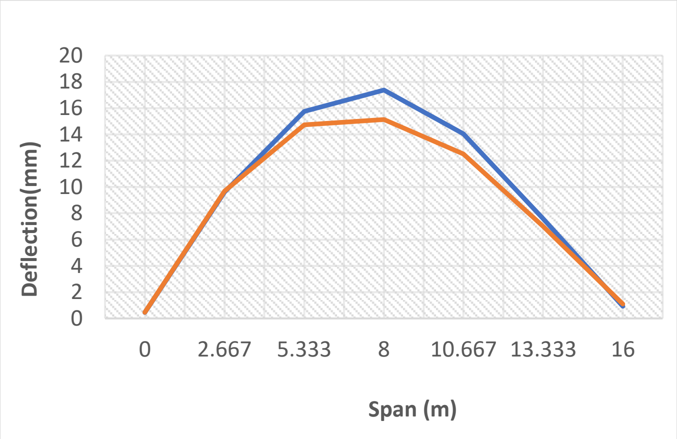

Fig.4 Comparative study

After changing position of FVDs and providing it on pier as shown in figure the deflection of bridge deck is measure for moving load combination. Span wise deflection is measured after providing FVDs properties for Taylor Device design manual.

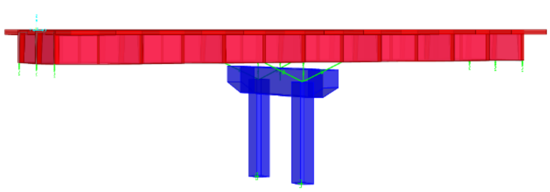

Fig. 4-FVDs at pier

For moving load combination span wise deflection with damper and without damper is shown in table below. Which shows reduction in peak mid span deflection.

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Table – 5 Deflection of bridge under moving load

Without Damper

	A	B	C	D	E	F
1	Layout Line Distance	ItemType	Sect Vert	Sect Tran	Sect Long	Sect RLong
2	mm		mm	mm	mm	Degrees
3	0	Max	0.163284	0.197305	5.125327	2.19E-06
4	0	Min	-0.450862	-0.196522	0.126758	-1.82E-06
5	2666.67	Max	-0.10647	0.257	5.424846	8.11E-06
6	2666.67	Min	-9.620029	-0.257107	-0.724042	-8.05E-06
7	5333.33	Max	0.165741	0.537842	5.519561	5.57E-06
8	5333.33	Min	-15.758558	-0.537499	-1.955857	-5.38E-06
9	8000	Max	1.044786	0.724319	5.871937	6.04E-07
10	8000	Min	-17.372929	-0.724453	-3.171051	-4.96E-07
11	10666.67	Max	1.960388	0.788237	6.422853	3.74E-06
12	10666.67	Min	-14.051964	-0.788012	-4.332971	-3.54E-06
13	13333.33	Max	2.08469	0.723672	7.194755	5.11E-06
14	13333.33	Min	-7.598806	-0.72389	-5.39284	-5.05E-06
15	16000	Max	-0.098596	0.581733	8.302114	9.98E-06
16	16000	Min	-0.926213	-0.58131	-6.284596	-9.86E-06

Table-6 Deflection of bridge with damper

With Damper

	A	B	C	D	E	F
1	Layout Line Distance	ItemType	Sect Vert	Sect Tran	Sect Long	Sect RLong
2	mm		mm	mm	mm	Degrees
3	0	Max	0.203073	0.173516	3.986364	2.21E-06
4	0	Min	-0.453652	-0.172471	-0.399985	-1.81E-06
5	2666.67	Max	0.867401	0.273907	4.067058	7.98E-06
6	2666.67	Min	-7.572063	-0.273882	-0.912325	-7.93E-06
7	5333.33	Max	1.985194	0.552595	4.230336	5.18E-06
8	5333.33	Min	-12.13256	-0.552102	-2.111213	-5.06E-06
9	8000	Max	3.483233	0.73333	4.729164	1.61E-07
10	8000	Min	-13.101032	-0.733261	-3.25441	-1.54E-07
11	10666.67	Max	4.360652	0.794214	5.34022	4.44E-06
12	10666.67	Min	-10.293256	-0.793849	-4.311027	-4.32E-06
13	13333.33	Max	2.928426	0.735638	6.177266	5.74E-06
14	13333.33	Min	-5.536204	-0.735608	-5.151303	-5.75E-06
15	16000	Max	-0.329618	0.603596	7.261842	9.95E-06
16	16000	Min	-1.154939	-0.603053	-6.112227	-9.90E-06

Comparative graph of displacement vs. span is plotted and the reduction in displacement is around 24.59%. It is important to note that the seismic analysis of bridges in India should be performed by qualified structural engineers who are familiar with the Indian code and its provisions.

The code provides detailed guidelines and procedures to ensure the safety and reliability of bridge structures under seismic conditions in the specific Indian context.

The effectiveness of viscous dampers depends on their design parameters, such as damping coefficient and installation location, which need to be carefully selected and calibrated to achieve the desired performance.

It is more effective to provide viscous damper at pier's location. Which reduced displacement in more effective way.

Two fluid viscous dampers provided at each outer girder in order to reduce deflection.

Fig.5 Comparative study

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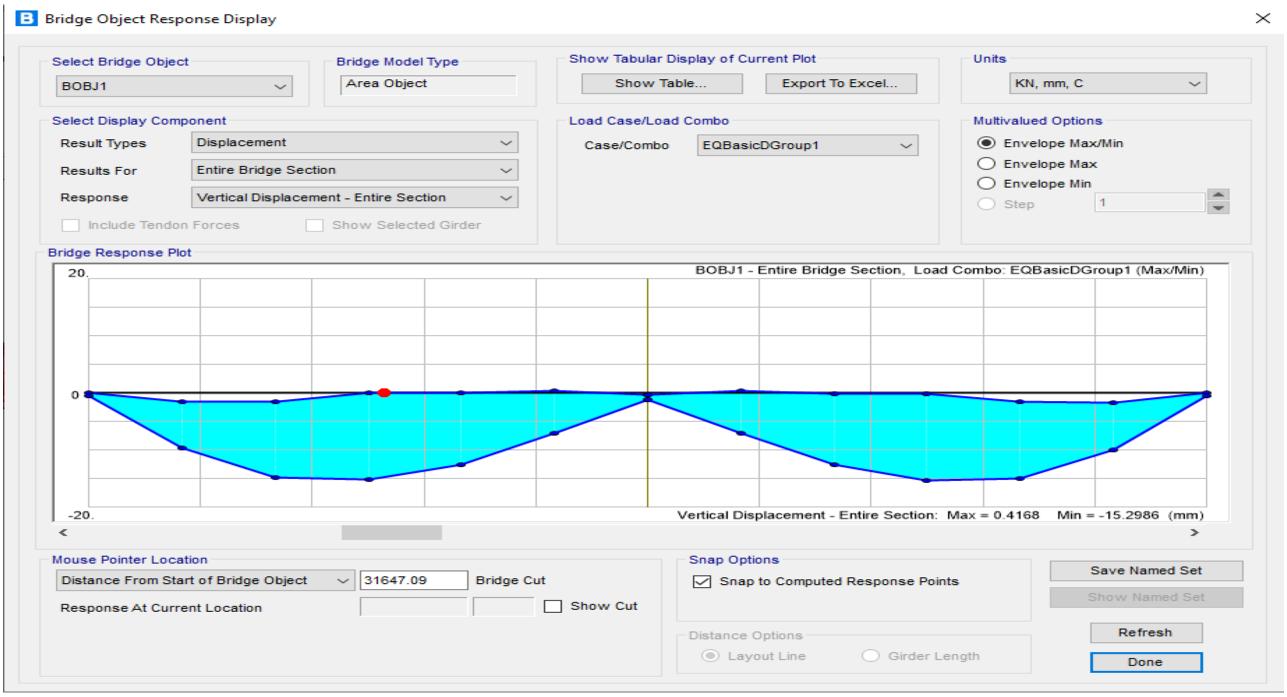

Fig.6 Min / Max envelope for deflection due to earthquake load combination

Similarly the study carried out for earthquake load combination. Displacement of bridge span with and without damper is measured. FVDs provided in the bridge as shown in the figure 2. The properties of fluid viscous damper is taken from the manual of Taylor Devices. After providing viscous damper deflection of the bridge is measured for the EQ Basic load combination.

Table 7 – Deflection without damper

Layout Line Distance	ItemType	Sect Vert	Sect Tran	Sect Long	Sect RLong
mm		mm	mm	mm	Degrees
0	Max	0.163284	0.197305	5.125327	2.19E-06
0	Min	-0.450862	-0.196522	0.126758	-1.82E-06
2666.67	Max	-0.10647	0.257	5.424846	8.11E-06
2666.67	Min	-9.620029	-0.257107	-0.724042	-8.05E-06
5333.33	Max	0.165741	0.537842	5.519561	5.57E-06
5333.33	Min	-15.758558	-0.537499	-1.955857	-5.38E-06
8000	Max	1.044786	0.724319	5.871937	6.04E-07
8000	Min	-17.372929	-0.724453	-3.171051	-4.96E-07
10666.67	Max	1.960388	0.788237	6.422853	3.74E-06
10666.67	Min	-14.051964	-0.788012	-4.332971	-3.54E-06
13333.33	Max	2.08469	0.723672	7.194755	5.11E-06
13333.33	Min	-7.598806	-0.72389	-5.39284	-5.05E-06
16000	Max	-0.098596	0.581733	8.302114	9.98E-06
16000	Min	-0.926213	-0.58131	-6.284596	-9.86E-06

Table 8 – Deflection with damper

Layout Line Distance	ItemType	Sect Vert	Sect Tran	Sect Long	Sect RLong
mm		mm	mm	mm	Degrees
0	Max	0.203073	0.173516	3.986364	2.21E-06
0	Min	-0.453652	-0.172471	-0.399985	-1.81E-06
2666.67	Max	0.867401	0.273907	4.067058	7.98E-06
2666.67	Min	-7.572063	-0.273882	-0.912325	-7.93E-06
5333.33	Max	1.985194	0.552595	4.230336	5.18E-06
5333.33	Min	-12.13256	-0.552102	-2.111213	-5.06E-06
8000	Max	3.483233	0.73333	4.729164	1.61E-07
8000	Min	-13.101032	-0.733261	-3.25441	-1.54E-07
10666.67	Max	4.360652	0.794214	5.34022	4.44E-06
10666.67	Min	-10.293256	-0.793849	-4.311027	-4.32E-06
13333.33	Max	2.928426	0.735638	6.177266	5.74E-06
13333.33	Min	-5.536204	-0.735608	-5.151303	-5.75E-06
16000	Max	-0.329618	0.603596	7.261842	9.95E-06
16000	Min	-1.154939	-0.603053	-6.112227	-9.90E-06

After providing 4-FVDs at pier reduction in peak deflection is 25.36%. Following figure shows comparative graph of span wise deflection.

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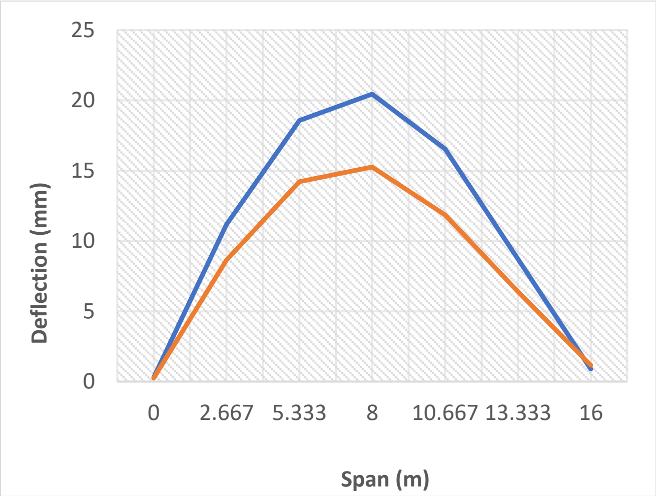

Fig.7 Comparative study

II. CONCLUSION

- The use of viscous dampers for vibration control in bridges has shown promising results.
- Viscous dampers can effectively reduce the amplitude of bridge vibrations induced by traffic and seismic excitations.
- FVDs reduces vibration in bridge around 45%. They work by dissipating energy through the relative motion of a piston and a viscous fluid, which converts the kinetic energy of the bridge vibration into heat.
- This results in reduced structural response and increased damping, which can significantly improve the overall performance of the bridge.
- Viscous dampers are relatively simple and easy to install and can be customized to suit specific bridge configurations and load conditions.
- They are also cost-effective compared to other vibration control methods such as active control systems.
- However, the effectiveness of viscous dampers depends on their design parameters, such as damping coefficient and installation location, which need to be carefully selected and calibrated to achieve the desired performance.
- It is important to note that the seismic analysis of bridges in India should be performed by qualified structural engineers who are familiar with the Indian code and its provisions. The code provides detailed guidelines and procedures to ensure the safety and reliability of bridge structures under seismic conditions.

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