A Review on types of Vibration Control Techniques used in Cable Stayed Bridge

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ABSTRACT

Cable stayed bridge is one of the rapidly growing bridge in the field of construction with having many advantages over suspension bridge including aesthetical looks which increases the desirability of these kind of bridges. As these bridges becoming popular some of the limitations restricts the construction of these kind of bridges, and one of the major hurdle is the vibration caused in the cable stays due to wind, rain, etc. which causes the loss of strength due to fatigue and ultimately bridge collapses. A review is presented in this paper about different types of vibration control devices or techniques used for damping vibrations.

Keywords- Cable Stayed Bridge, Piezoceramic Damper, RM Fluid, Smart Damper, Vibration Damper.

I. INTRODUCTION

Cable Stayed was first introduced in the early 20th century but actual construction and research of these bridges were started from 1970s. In the beginning the length of the cable stayed bridge was restricted to 900 m but with the evolution of new technologies the length of the cable stayed bridge was increased to 1200 m and still the research is going on to increase the length by overcoming the restricting forces. The increase of span of the cable stayed bridges was restricted because of many reasons but the predominant reason was the vibration induced in the cable stays which holds the deck and transfers the load to the pylon and then to the ground surface. The Problem of vibration further increases if the natural frequency of structure is in the range of vibrating frequency since it will lead to resonance and we know that resonance magnifies the amplitude of vibration [1].

So this was the reason because of which many damping techniques were introduced which includes Mechanical Rubber Damper, Oil Dampers, Adjustable Fluid Damper, MR Fluid Damper, Smart Damper and Piezo-ceramic Damper. Even though these dampers were developed but the research continues to overcome the limitations of these dampers by the introduction of new materials and optimization of the previously know damping techniques.

In the subsequent section we will discuss about the above mentioned damping techniques, their advantages as well as their limitations.

II. DAMPERS

2.1 Mechanical Rubber Damper

The mechanical damper is used to damp the vibration with the help of high damping rubber attached at the lower part of the suspended cable as shown in Fig. 1. The high damping rubber can also be installed axially.

This is one of the most simple but very effective type of damper having many advantages

1. Temperature has ideally no affect on the damping characteristic of rubber.
2. Vibration mode does not change the optimum damping coefficient.
3. Compact mechanism which is economical and easy to maintain with no aesthetical problems

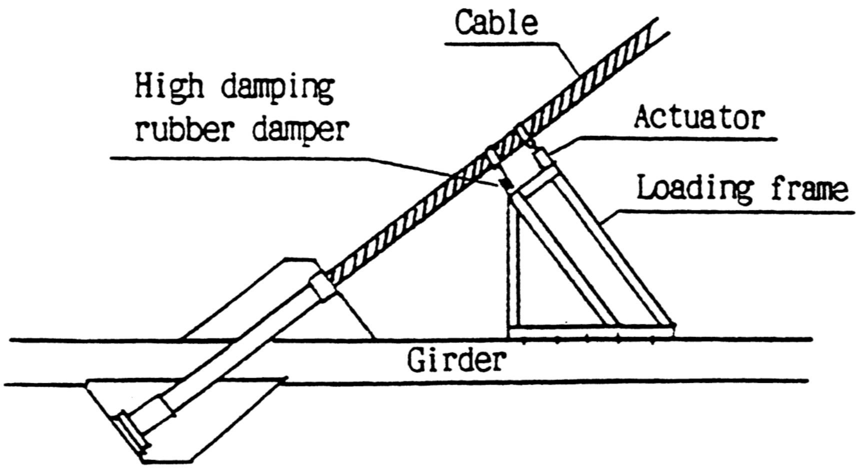

Fig. 1

The limitations of mechanical rubber damper is that the damping effect is restricted to 0.05 order of logarithmic decrement for mono cable, which can effectively resist the vibration due to rain but when the cables are arranged in parallel then the logarithmic decrement decreases or damping effect decreases. Maximum logarithmic decrement reported for parallel cables is reported to 0.01 and it is also observed that the damping effect varies with change of the size of cables & location of damper, so this damper technique requires further research to increase the damping properties of this damper [2].

2.2 Oil Damper

Oil damper type of damping technique uses oil for damping the vibrations in the cable stays as shown in Fig. 2. The damper works as follows, a piston plate arrangement is connected to the lower part of the cable and the piston plate arrangement is dipped in the silicone oil damper which restricts the vibrations in the cable stay.

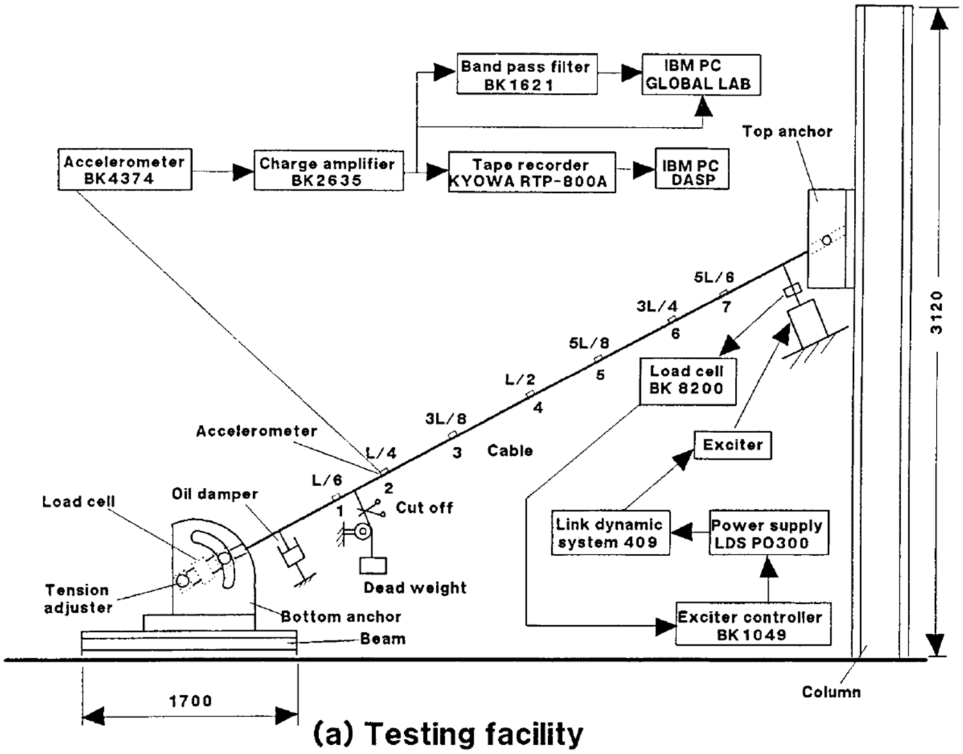

Fig. 2

Oil Dampers are succeeded in damping off the vibration by more than 50 % of the displacement amplitude as compared to the without damping vibrations. But the main problem related with the oil dampers was that they were unable to effectively damp the 4th frequency resonance because of the frequency avoidance. Some other problem related to oil dampers is the oil damper characteristics were affected by the environmental conditions [3].

2.3 Adjustable Fluid Damper

Adjustable Fluid Damper uses Shape Memory Alloy (SMA) actuator for damping the vibrations in the cable stays as shown in Fig. 3. The vibrations are controlled by this device by controlling the orifice opening inside the piston adjustment which allows the fluid to pass through the orifice to damp the vibrations.

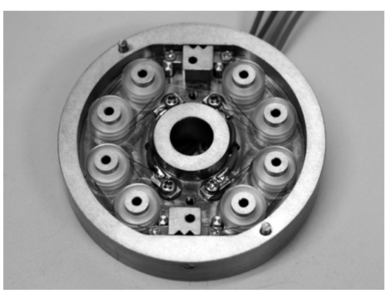

Fig. 3

This device is very effective in damping cable vibrations as it has modal logarithmic decrement greater than 4% in all stay cables for first two modes of vibrations when the damper located close to cable anchor of taut cable. But the major problem associated with this damping technique is that optimum viscous coefficient of damper depends upon many factors such as properties of cable, vibration mode of cable, location of damper and these properties are different for different cables. So this means that we have to design and locate the appropriate location of damper for every single cable for optimum efficiency. Hence this will make this damper difficult to implement since manufacturing, installation and maintenance are very difficult in this damping technique [4].

2.4 MR (magneto-rheological) Fluid Damper

It is one of the new introduced technologies which is specifically used to damp high vibrations caused to the structure due to earthquakes and strong winds. This damping technique uses MR fluid whose viscosity increases or decreases with the change of magnetic field. Fig. 4 shows the implementation method of MR fluid damper. Fig. 5 shows the mechanism of MR fluid damper.

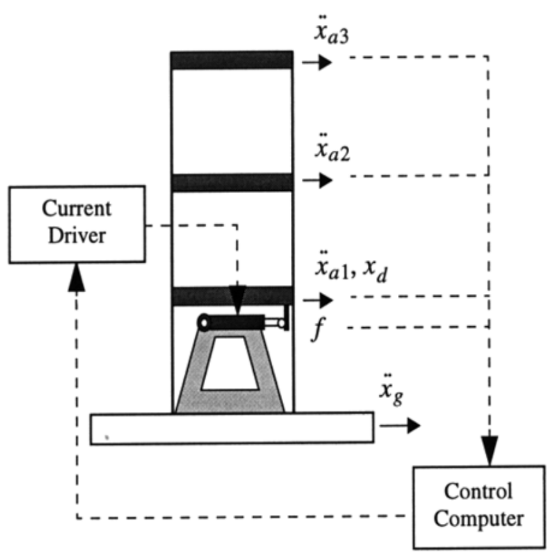

Fig. 4

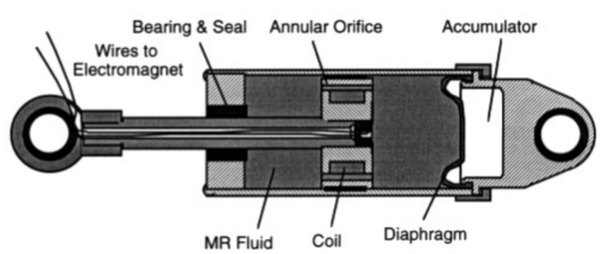

Fig.5

Semi-active MR fluid damper has achieved to reduce 74.5% of peak 3rd floor displacement and acceleration is also reduced by 47.6% as shown in Fig. 6. So this shows that it has very good vibration damping characteristics. This type of damper has many other advantages that it requires less amount of force as compared to active damper technique and hence consumes less energy. But the main drawback is that it requires constant power for operation. And if natural calamity occurs during power failures then this situation maybe will result in catastrophic disaster [5].

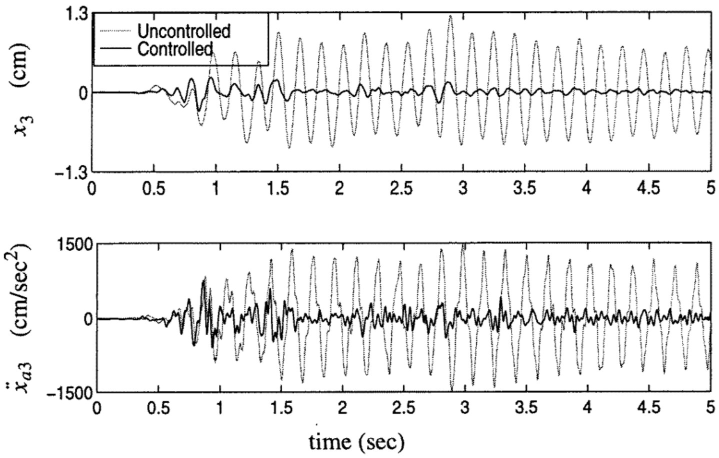

Fig. 6

2.5 Smart Damper

Fibre reinforced Polymer (FRP) cables are the newly introduced cables which have high strength to weight ratio as well as high resistance against corrosion because of which it is also one of the best materials for cable stays. FRP cables are light weight because of which they are susceptible to large vibrations to overcome this problem and also to design a self damping cable known as smart dampers are introduced. Smart dampers are integrated composite cable having core made of two separate portion of wires separated by visco-elastic material as shown in Fig. 7.

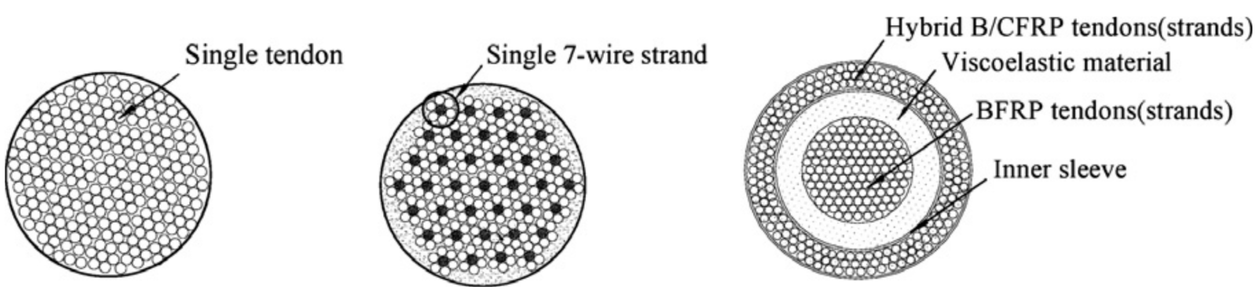

Fig. 7

Damping by this technique has found that the damping ratio for in-plane small amplitude vibrations (0.5-1m) is ranges from 0.13% to 0.26%, but for large amplitude vibrations (Greater than 2m) the ratio increases to 0.77%. For out-plane vibrations damping, this material is the best choice as it has damping ratio of 1.13% even for the small amplitude vibrations. The actual damping ratio for this type of material will be higher than the mentioned value because only damping due to smart damper is taken into account ignoring the damping due to internal friction, visco-elasticity of the cable material and air drag. Studies on damping has shown that damping ratio larger than 0.16% to 0.24% is sufficient for vortex induced vibrations and damping ratio larger than 0.32% to 0.48% is sufficient for the rain induced vibrations. So this type of damping technique is efficient and effective with no power required and minimum operational cost. But the only drawback is that it is very expensive [6].

2.6 Piezoceramic Damper

Piezoceramic material is one of the most efficient, light weight, low cost material having both sensing and actuation capacity. Piezoceramic material is a type of material which induces charges at the surface of the material when subjected to stress or vice-versa such as quartz crystal, etc. Piezoceramic material has long been used by scientists designing structures for spaces such as satellites, space stations, etc. Now this material has been proposed for the civil structures because of the great vibration damping quality. This material has achieved good damping capabilities in buildings, trusses and cable stayed bridges. It achieved a damping of 0.018 for the cable and 0.04-0.06 for the cable structure system. Fig. 8 shows use of Piezoceramic material in civil structure.

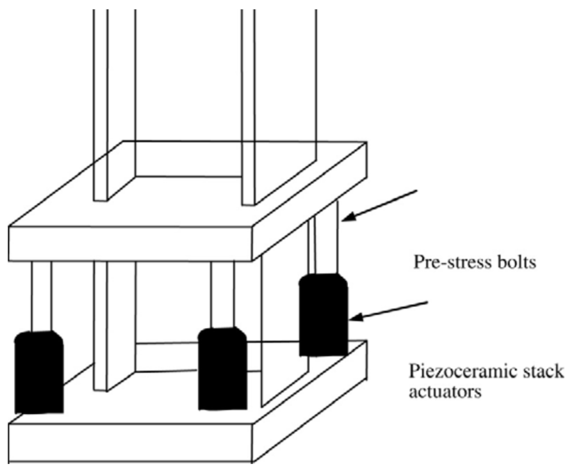

Fig. 8

But some of the main drawbacks of this damping material is that for construction work it should be introduced in the drawing at the time of the designing of structure and the structural design has to be changed accordingly. Second drawback is that it uses power so if the power fails then the whole system fails. Even though having some limitations but still the advantages it has overcomes the limitations [7].

III. Conclusion

We can observe from the above data that each and every damper has both advantages as well as limitations. So for reducing vibrations, an appropriate damper has to be selected so that it efficiently damps the vibrations with observing the overall economy of the project. Different location and environmental conditions requires different type of damper like for example a place which is mainly affected by temperature variation then a damper which is least affected by temperature should be used like Mechanical Rubber Damper But a place which is susceptible to earthquake requires damper which can easily withstand the high magnitude of force due to earthquake like MR fluid Damper.

New materials are also been introduced like smart damper and piezoceramic damper which has excellent damping properties.

We can also note that every damping technique mentioned above requires more research in discovering and altering their properties for optimum use of their properties in controlling vibrations.

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