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Evaluations of Track Damping Pads and Track Designs for Reducing Impacts at Special Trackwork

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Summary

Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), has developed track design parameters and has evaluated available materials and components for reducing impacts at special track work frogs to facilitate easier track support transition.

Crossing diamonds and turnout frogs are special cases of track support transitions. Based on the effects at crossing diamonds, as well as dynamic modeling of vehicle-track interactions, it is desirable to add and enhance damping of crossing diamond foundations. This will protect more components from the effect of high frequency transient vibrations due to the wheel impact loads. The main objective, therefore, was to investigate those design options for crossing diamond foundations that will effectively attenuate both the high frequency impact load on the flangeway gap corner as well as those loads associated with partial wheel unloading following the impact.

One of the options being investigated is to use available noise and vibration pads currently used to provide the additional damping to conventional ballasted frog foundations. Since these pads are not marketed for impact attenuation, it was necessary to evaluate the pads and classify them in relation to impact attenuation. These pads were evaluated via laboratory tests and in-track testing. The results are reported in this *Technology Digest*.

Rail seat pads are an easy way to add damping without having to make major changes to existing track structure. Findings from the laboratory tests conducted on the rail seat and under tie plate pads include:

- There is no available product literature for impact attenuation properties.
- A database of pad characteristics has been developed.
- A range of stiffness and damping properties are available.
- Durometer readings are not a good indicator of damping characteristics. These readings may indicate the durability of the pads. For example, a soft rubber pad with a low durometer reading will not withstand the harsh environment of the railroad.

Laboratory data alone is not enough to determine which type of pad is best for impact attenuation. The data will have to be correlated with the results from the in-track testing being conducted at the Facility for Accelerated Service Testing (FAST) at the Federal Railroad Administration's (FRA) Transportation Technology Center (TTC), Pueblo, Colorado.

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INTRODUCTION AND CONCLUSIONS

Transportation Technology Center, Inc. has developed track design parameters and evaluated available materials and components for reducing impacts at special track work frogs,

One of the most significant maintenance problems in mainline track today is associated with impact loads at special track work, bridge approaches, and road crossings. Impacts result from sharp changes in loaded running surface profiles and elevation changes that occur at track stiffness transitions. These impact loads can be as high as 3 to 5 times the static wheel load. Of the special track work, the crossing diamonds are likely to be the higher impact locations compared to those of switches and frogs. The high magnitude and frequency of impact loads on crossing diamonds result in shortened component lives and increased deterioration of ballast layer and the subgrade. Due to the short lives of conventional components, a premium track structure may be economical for these locations. This premium track must provide good load transmission and work as an efficient mechanical filter against high frequency wheel/rail loads.

Crossing diamonds and turnout frogs are special cases of track support transitions. Based on the effects seen at the crossing diamonds, as well as dynamic modeling of vehicle-track interactions, it is desirable to add and enhance damping of crossing diamond foundations. This will protect more components from the effect of high frequency transient vibrations due to the wheel impact loads. TTCI's main objective, therefore, was to investigate those design options for crossing diamond foundations that will effectively attenuate both the high frequency impact load on the flangeway gap corner as well as those loads associated with partial wheel unloading following the impact.

Through recent AAR and FRA sponsored projects, TTCI estimated the effects of track stiffness and damping.[1,2,3] These efforts developed the tools needed to model track in sufficient detail to predict vehicle track interaction at frogs and to measure track damping in the field. The results of these studies were:

- The effect of crossing diamond foundation stiffness on maximum vertical wheel impact loading were negligible due to an increase in track modulus up to 30,000 lbs/in/in.
- An optimal track damping value of about 300 lbs/in/sec/tie/rail was determined to minimize dynamic vertical loads for typical freight cars.[1] See Figure 1.
- Conventional ballasted track was found to have a damping value of about 56 lbs/in/sec/tie/rail.[2] See Figure 2.
- Vehicle dynamics modeling suggests that diamonds with optimal damping will reduce maximum forces by 20 percent.

Commercially available noise and vibration attenuation pads can be used at various layers in the track structure to increase track damping to near optimal levels.[3]

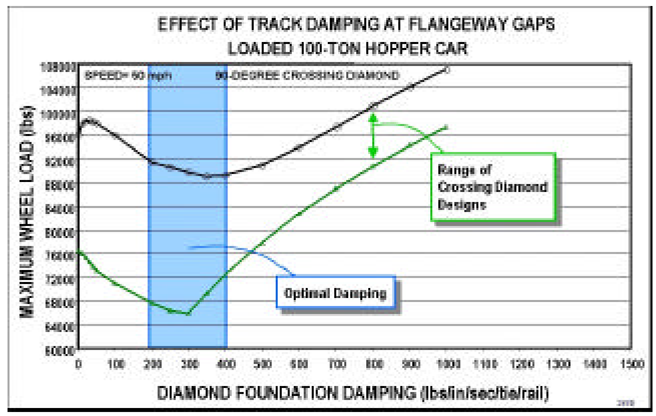

Figure 1. Predicted Maximum Vertical Loads versus Track Damping

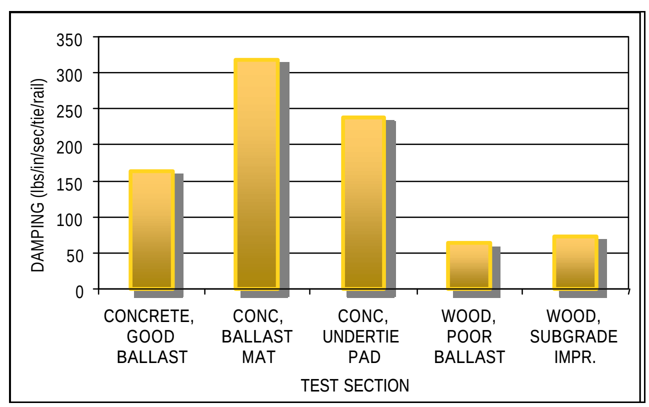

Figure 2. Measured Track Damping for Various Track Structures

TEST RESULTS

TTCI conducted laboratory tests of commercially available noise and vibration attenuation pads for track. Since increasing damping is not the explicit goal of these products, it is difficult to obtain published data on the relevant properties. Tests were conducted to develop mechanical properties data that can be used to evaluate track pads for damping.

Rail seat pad and tie plate pads were tested. The following properties were determined from the laboratory tests:

- Stiffness was determined by looking at the force and the deflection relationship of each pad.
- Equivalent viscous damping can be determined by calculating the total energy dissipated. The stress-strain curve for a vibratory system is referred to as the "hysteresis loop." The area enclosed by the hysteresis curve is proportional to the stress amplitude and represents the energy dissipated per cycle of vibration. The frequency of interest is at 200 Hz. This is the frequency at which the rail and tie vibrate in phase. This is when the damping pad is being engaged by the system.
- Permanent Set was determined from a creep test. Deformation is an important factor in determining each pad's durability.
- A durometer reading was done to compare with product literature.

Table 1 lists the results of the laboratory tests.

Figure 3 shows the various types of pads available. Installation of rail seat pads and tie plate pads are the easiest modifications that can be made to existing track structure. More components are protected from the additional impact attenuation occurring higher in the track structure. However, these pads require a higher performance and durability. They are subjected to both a harsh loading environment and varying atmospheric elements (e.g., heat, cold, and moisture). Rail seat pads and tie plate pads may be squeezed out from under the rail or tie-plate and will require more maintenance.

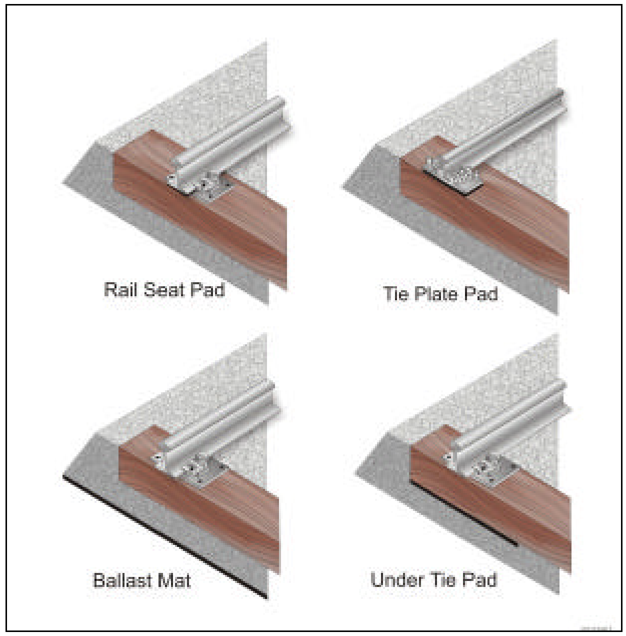

Figure 3: Various Types of Damping Pads

Major modifications must be made to an existing track structure when ballast mats and under tie pads are installed. These pads can provide damping to the overall track structure, but will not protect track components from the impact loading. Although the pads will not be exposed to the elements, they will not be easy to maintain. Thus, a long service life is required.

Table 1. Laboratory Test Results of Potential Track Damping Pads Laboratory Tests

Pad ID	Pad Type	Pad Description	Stiffness[1] (kip/in)	Damping[2] (lb/in/sec)	Permanent Set[3] (in)	Durometer Reading[4]
1-A	Rail Seat	Black rubber with micro-cells	556.76	15.81	0.031	A53
1-B	Rail Seat	Aqua polyurethane with abrasion plate	894.65	29.33	0.007	A94
1-C	Rail Seat	Black rubber	526.99	46.46	0.011	A86
1-D	Rail Seat	White polyurethane with dimples	287.18	8.11	0.012	A94
2-A	Tie Plate	Grey rubber	184.90	9.41	0.179	A55
2-B	Tie Plate	Black polyurethane with dimples	897.66	38.37	0.009	A97
2-C	Tie Plate	Black polyurethane with smooth finish	2360.23	57.50	0.002	A53

1) The pad was loaded with a 6-inch base rail. The deflection of the pad was measured from 0 to 50 kips. The stiffness was then calculated from the force deflection relationship.
2) Damping was measured at 200 hz — the characteristic rail on tie frequency.
3) Permanent set is the measured permanent deformation that occurred during a creep test. The pad was loaded from 0 to 50 kips in 5-kip increments. Each interval was held for duration of 30 minutes.
4) The hardness of each pad was measured with a Shore hardness test ASTM D2240 (also known as a durometer reading).

It is evident from the laboratory results that the available product literature is not helpful in determining impact attenuation characteristics for these pads. A durometer reading is not a good indicator of damping characteristics, however it may be an indicator of the pad's durability. Pads with low durometer readings are often associated with a soft rubber. This type of pad has been shown to provide a short service life in concrete tie applications.[4]

The type of environment where these pads will be used needs to be taken into account. Field experience indicates that pads with low durometer readings do not withstand the load environment of a concrete tie zone. Initially, they provide good damping to the track structure but fail early in comparison to the life of a concrete tie. The pads with a low durometer reading cannot be discounted from all uses. The typical life required in the area of special track work frogs may be 500 million gross tons.

The laboratory data alone does not give the complete picture of how each of these pads will affect the damping of the track structure. The second step in process is the in-track testing of these pads. A test panel, shown in Figure 4, was designed to simulate the foundation of a typical crossing diamond.

Figure 4. Damping Test Panel Installed at FAST

The panel is installed at FAST, and the laboratory test pads are being evaluated for contribution to the track damping properties and durability. The laboratory data will then be correlated with the field data. Once this is completed, the database of properties should give an indication of in-track performance of different types of pads.

FUTURE WORK

The laboratory test were a good first step in determining which pads would increase the impact attenuation of the track structure. The second step is in-track testing at FAST. During this phase of the test, the pads will be evaluated for durability and contribution to the damping properties of the track. In-track tests are proceeding.

References

1. Singh, S. and D. Davis, August 1998, "Reducing Impact Forces on High-Angle Crossing Diamonds Reducing Impact Forces on High-Angle Crossing Diamonds," *Technology Digest* TD98-021, Transportation Technology Center, Inc., Pueblo, Colorado.
2. Singh, S., D. Davis, D. Guillen, J. Robeda, and H. Wu, April 2001, "Damping Characteristics of Ballasted Track with Subgrade Improvement Layer," AAR Report R-946, Association of American Railroads, Washington, D.C.
3. Singh, S., D. Davis, D. Guillen, and D. Williams, 2003, "Reducing the Adverse Effects of Wheel Impacts on Special Trackwork Foundations," Report Number DTFR53-93-C-00001, Federal Railroad Administration, Washington, D.C.
4. Reilly, G., 2003, "Maintenance of a Heavy Haul Corridor," Proceedings AREMA Conference 2003, Chicago, Illinois.