TTCI TECHNOLOGY DIGEST

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Performance of Under Tie Pads (UTPs) in a Curve at FAST

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Key Findings:

- Both UTPs appear to cause higher variation of ballast acceleration below the tie in the vertical directions compared to the ties without UTPs. This likely is due to the increased resiliency and deflection allowed by the UTPs.
- The zone with elastic rubber UTPs showed higher variation of lateral acceleration (about twice as much) than the polyurethane UTP zones and the control zone. This behavior may account for the increased ballast migration and degradation observed in this test zone.
- The elastoplastic UTP appears to allow for a much higher degree of ballast particle embedment and plastic deformation of the UTP. This behavior appears to reduce ballast migration in the test zone.
- UTP properties, including stiffness, damping, and elastic versus elastoplastic behavior need to be designed and carefully considered for their intended applications.

Transportation Technology Center, Inc. (TTCI) continues to study a variety of concrete tie and fastener system designs to improve track performance. One such design is the use of under tie pads (UTPs). Under tie pads have been used in various applications to reduce the impact loading on ballast and decrease track modulus; particularly in stiffer areas of track. This includes bridges and special track-work. It also is used to reduce degradation and settlement in track stiffness transitions. Concrete tie test zones with and without under tie pads have been installed in a test curve at the Facility for Accelerated Service Testing (FAST) in Pueblo, CO since 2009. Observations of increased ballast migration and increased ballast degradation in one of the under tie pad zones compared to the control ties without UTPs highlighted the need to further understand the effect of UTP properties on performance.

Researchers conducted tests on track with two different UTPs. Three concrete tie test zones were selected: a control zone without UTPs; a zone with elastic-rubber UTPs; and a zone with polyurethane UTPs. An innovative wireless device, known as SmartRock™, was utilized to measure dynamic ballast particle movement under train passages at FAST. SmartRocks were installed at the ballast-tie interface underneath the high side of tie, low side of tie, middle and in the ballast crib adjacent to a tie in each zone.

The objective of the testing presented in this *Technology Digest* was to further understand the behavior of the ballast at the interface with UTPs in a curved, open-track scenario. Recent testing has helped explain ballast migration observed since early in the test and increased ballast degradation in a UTP zone at FAST compared to a conventional non-UTP control zone. These observations have drawn attention to the differences in UTP performance and the importance of UTP properties.

Future research on UTPs will focus on the development of recommended design criteria and testing methods incorporated into the American Railway Engineering and Maintenance-of-Way Association (AREMA) *Manual for Railway Engineering*.

TEST BACKGROUND AND SETUP

In 2009, five zones of concrete ties were installed in a 5-degree curve (4 inches of superelevation) at FAST, including two zones of conventional concrete ties, each with a different UTP, as well as a conventional concrete tie control zone.[1] Even though the fastening systems on these ties are different in the zones, the differences are not considered to be a major factor in ballast performance. Figure 1 shows the layout of these zones at FAST. FAST operates a heavy axle load train consisting of approximately 100 cars weighing 315,000 pounds each. The train is operated at 40 mph, about 1.7 inches of overbalanced speed for this curve.

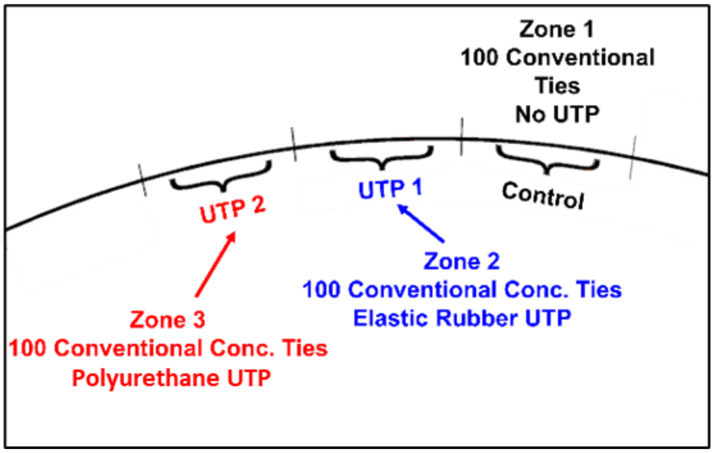


Figure 1. Layout of the two UTP zones and control zone at FAST

These test zones were part of a broader, long-term test focused on studying a variety of concrete tie and fastener system designs under the heavy axle load traffic at FAST. Recent work has focused on the performance of the UTP materials and better understanding the UTPs role in track quality. [2-7]

UTP 1 in Zone 2 is elastic rubber that was cast directly into the tie during manufacturing. UTP 2 in Zone 3 is elastoplastic that was epoxied to the tie in the field prior to installation in 2009. Figure 2 shows the condition of these pads during an inspection after 900 MGT of tonnage accumulation.

UTP 1 showed little embedment of ballast particles and minimal tearing/damage to the pad. UTP 2, however, showed signs of ballast particle embedment and plastic deformation of the UTP. Some areas where UTP 2 had been epoxied to the tie had delaminated. The tie pads were glued in the field for the ties, which may have contributed to the delamination. A more controlled environment for the gluing operation may potentially result in a more durable bond.

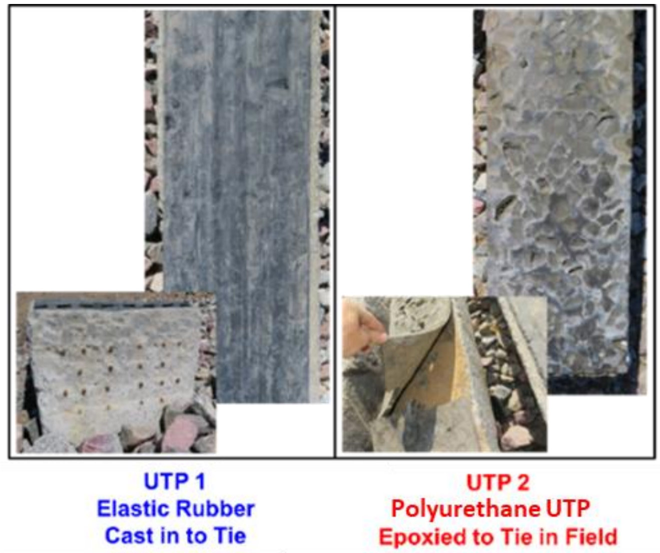


Figure 2. Condition of UTP 1 and UTP 2 during inspection at 900 MGT

Tonnage accumulation in this curve has shown more ballast migration (from high side to low side) and increased ballast degradation in Zone 2 (UTP 1) compared to Zone 3 (UTP 2) and the control zone without UTPs. Tutumluer et al. (2017) described the ballast degradation measured for these test zones as part of the development of a machine vision technique to measure ballast degradation.[8] Figure 3 shows the migrating ballast observed in the UTP 1 zone before routine ballast regulating was conducted. Regulating has been necessary approximately every 100 MGT in Zone 2.

Figure 3. Typical ballast migration observed in Zone 2 (UTP 1)

SMARTROCK™ TESTING

To better understand the dynamic interaction between UTPs and ballast particle movement, the three test zones were instrumented with SmartRocks wireless devices consisting of a tri-axial gyroscope (rotation), a tri-axial accelerometer (translation), and a tri-axial magnetometer (orientation), to monitor ballast particle movement under dynamic train loading at FAST.[9] SmartRocks were installed at three ties – one in each test zone. Four SmartRocks were installed at each tie – below the low, center, and high side of the tie and in the crib adjacent to the tie (Figure 4).

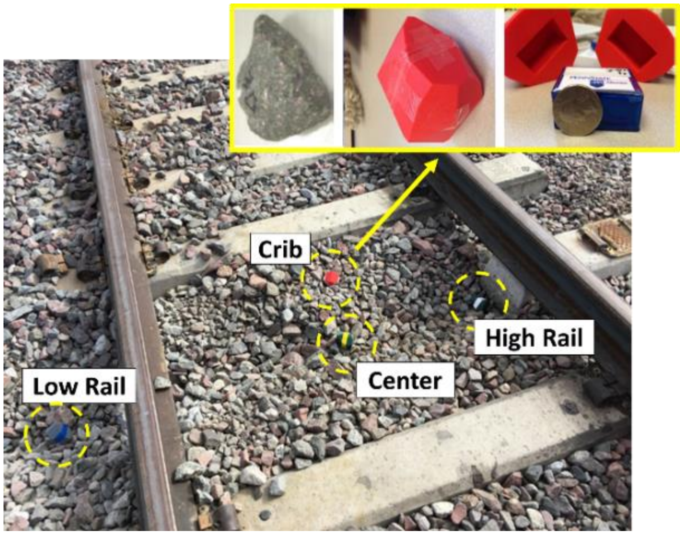


Figure 4. Instrumentation locations prior to tie being slid back in over the top of SmartRocks

The tie was carefully removed without disturbing the ballast bed, SmartRocks replaced ballast particles of similar size, and the tie was carefully placed in on top of the SmartRocks. Ten FAST train laps (about 0.1 MGT) were used to consolidate the contact of ties/ballast prior to data collection. Subsequently, data was collected for 15 laps of the train operations.

RESULTS

Figure 6 shows the distributions of SmartRock particle lateral and vertical accelerations for the three sensors installed underneath the tie at the high rail in each test zone. Results indicate that both UTPs led to a considerable increase in vertical acceleration variations likely due to the resiliency the UTPs added at the ballast-tie interface. Both UTPs showed increased lateral acceleration variance, however the mean lateral acceleration of the UTP 1 zone (Zone 2) was approximately 10 times greater than the other two zones. Additionally, the standard deviation of the UTP 1 zone was twice as much as in the other two zones. This suggests a lack of dynamic lateral stability at the ballast-tieinterface and appears to correlate with the increased occurrence of ballast migration in this zone.

Figure 7 shows the rotations of the SmartRock underneath the high side of tie in each zone during four train laps at FAST.

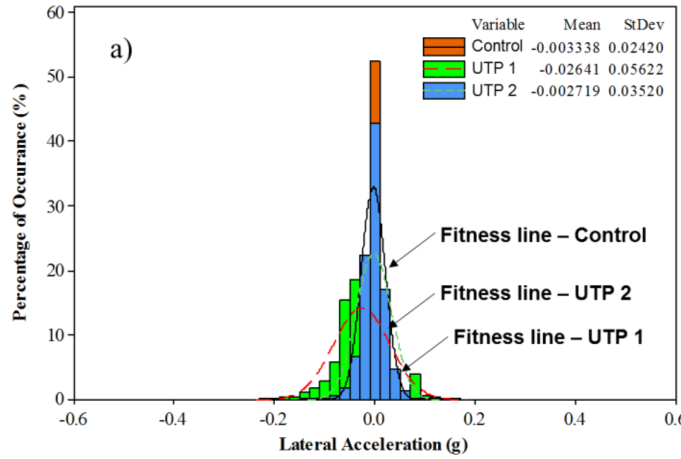
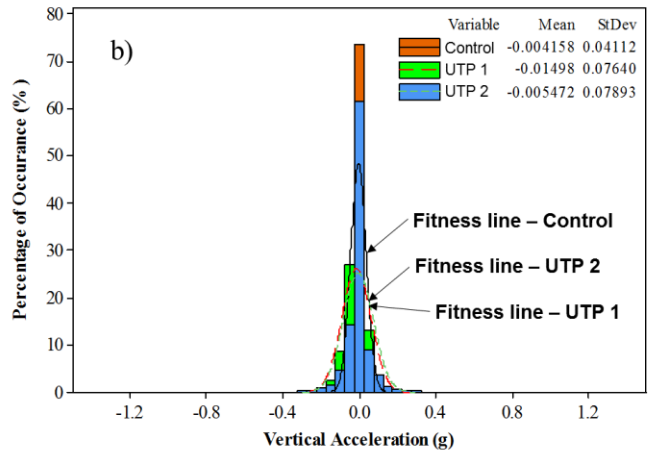


Figure 5. Particle acceleration distribution: (a) lateral; (b) vertical



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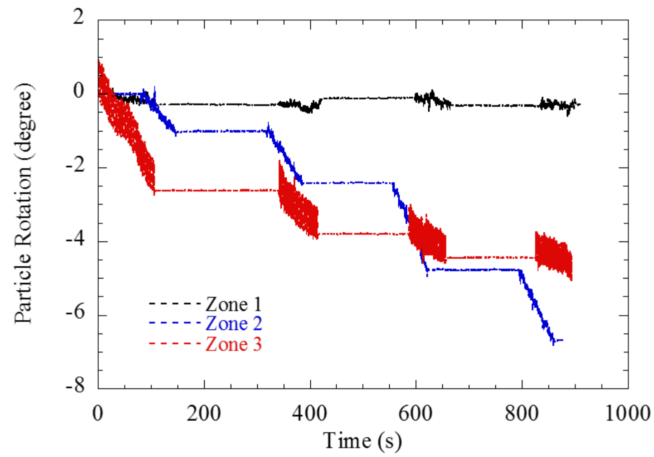

Figure 7. Particle rotation under four train passes

The rotations present a typical comparison among Zone 1, Zone 2 and Zone 3. The SmartRock rotated in a "shakedown" manner during each train passage and kept stationary until the next train pass. In general, SmartRock rotations were significantly increased by the inclusion of UTPs as compared to the control zone. In the control zone, the particle barely rotated. The accumulated particle rotation was negligible after these four laps of train passing. SmartRocks in Zone 2 appeared to continue to rotate under each train pass while the SmartRock rotation in Zone 3 showed a higher range of rotation at each passing car, but less overall rotation than Zone 2. This observation may be related to the elastoplastic nature of UTP 2 compared to the elastic property of UTP 1. By the end of the four laps of train passing. The control zone (Zone 1) had 0.5 degrees of total rotation, UTP 1 zone (Zone 2) 6.8 degrees, and UTP 2 zone (Zone 3) 5.3 degrees.

CONCLUSIONS AND FUTURE WORK

This work to date has mainly focused on the effect of UTP properties on ballast behaviour at FAST. The results thus far have indicated that the UTPs add resiliency to the track, therefore, decrease the track stiffness. However, the presence of UTPs increased ballast particle movement at the ballast-tie interface. The properties of the UTP (stiffness, damping, and elastic vs. elastoplastic behaviour) affects ballast particle movement. Research on UTPs to date has shown that they are successful in reducing track modulus and improving the consistency of load transfer into the ballast in particular applications. However, as this study suggests, the properties of UTPs need to be carefully considered and designed depending on the specific applications.

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