Improvements in Track Fasteners to Cope With Heavy Axle Loads

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ABSTRACT

Increasing axle loads and heavy traffic on North American railroads have placed additional stresses on the fasteners used in track. This paper describes many of the changes that have occurred over the last several years to the fasteners used in track as well as the change in how the railroad industry looks at fasteners. There has been a trend toward higher strength materials and larger fasteners across all applications. Some innovations and modifications to fastener design have been employed to improve fastener performance and life. The increasing demands have led to a better understanding that fasteners are part of a system which must be examined as a whole if they are to survive.

Screw spikes have increased in size and strength and have seen increased usage in curves and special trackwork. The Evergrip™ screw spike, which is installed with standard track spike equipment, has shown great promise in performance and ease of installation. Special trackwork bolts have increased in size and have been increasingly supplied as grade 8. Self-centering bolting systems are being used in several applications. In order to realize the benefits from upgraded fasteners, many changes have been required to equipment, installation and maintenance practices.

INTRODUCTION

The increasing stresses of heavy axle load traffic have placed greater demands on the fasteners used in track components. Just as all other components have needed to adjust to the higher stress environment, there has been a movement to upgrade standards for spikes, bolts and screws that were in place for many years to more robust designs. In addition to the proliferation of 286,000 lb cars and the potential for 315,000 lb, higher
speeds, more traffic, and the use of continuously welded rail have also put increased demands on the fastening systems. The increased lateral loads from higher speeds and modern equipment place demands on special trackwork and curves, leading to new systems to resist the loads and fight rail rollover. The widespread use of continuously welded rail has placed thermal loads on components in some locations.

The need to resist greater loads has led to a general trend to make the fasteners larger and make them out of higher-strength and better-controlled materials. Many fasteners traditionally used in limited applications have found more widespread use as more places began to see the vulnerabilities of the legacy fastening systems.

Maintenance-of-way practices have changed to accommodate and make better use of the new fasteners and applications. In some cases, maintenance practices have needed to change significantly to properly install and take advantage of higher strength fasteners. In other cases, wider usage of parts has forced a look at installation methods to keep work crews productive.

**TRACK SPIKES**

The track spike has seen modest changes. It has been replaced by screw spikes in some special trackwork and curves on some roads, but the track spike is still the norm in the vast majority of track. In 2005, AREMA Committee 5 updated the track spike specification, which had been unchanged since 1968. The old version (1) had “Soft-Steel” and “High Carbon” versions. The 2005 revision (2) specifies a single version that is similar in properties to the “High Carbon” version, but with significantly different chemistry. (Table 1)
The 2005 specification applied upper limits on the Carbon and more control over other elements in the steel. Limits were applied to Manganese, Silicon, Phosphorus, and Sulfur, while Vanadium was added to the chemistry. The optional minimum Copper content for corrosion resistance was made mandatory. The minimum yield strength was effectively increased and an on-request impact property test was added. The dimensions remained unchanged.

Overall, the 2005 version of the standards eliminated a lot of potential variability that was allowed under the 1968 version and resulted in more consistent performance.

While the track spike has seen only modest changes and has been replaced in a few areas, it can be expected to remain a staple of track construction. It is by far the least expensive and easiest to install fastener used in track. As long as the conditions don’t exceed its capabilities, it remains a proven performer.

**SCREW SPIKES**

Probably no fastener has seen more changes in usage and design than the screw spike (aka. lag screw or coach screw). The higher lateral loads of special trackwork and curves frequently exceed the ability of a track spike to maintain gauge and hold the rail in place. Screw spikes are typically used to affix plates when elastic fasteners are used. Under static conditions a track spike can be pulled out with about 7,000 lbs. A 15/16” screw spike typically will take 15,000 lbs or more. Moving the spikes farther from the rail base, as on a typical elastic fastener plate, also gives them more leverage to prevent rail rollover. How well the spikes stay in place under dynamic loads is probably more important. However, very little work has been done to quantify such conditions.
The only standard currently addressing screw spikes is ASTM A66 (3). It specifies minimum 60,000 psi tensile and gives some guidance on testing and tolerances. It does not give any specifics on configuration, dimensions, or chemistry.

Screw spikes are typically available in many head and thread configurations and diameters from ¾” to 1” (Figure 1). Three common combinations account for most of the market. There are three typical ranges in which material properties are generally specified, ranging from 60,000 to 120,000 psi tensile strength.

One common sticking point on screw spike specifications is a bend test. A66 requires a 90° bend test around a pin three times the spike diameter with no cracks. There are frequently some differences of interpretation on what constitutes a crack. It is also possible to aggravate the test with the placement of the pin. As the specified strength of the material increases the likelihood of a screw passing this test decreases. Most specs for higher strength screw spikes modify the size of pin or the angle of bend to make the test more compatible with the material. The most recent revision to A66 has changed the requirements to perform the bend test. When a reduced tensile test is performed and the elongation exceeds 18%, the bend test is not now required.

AREMA Committee 5 is currently working on a new screw spike specification for Chapter 5 of the manual. Most railroads have specifications for screw spikes which were developed uniquely for each road. In 2001 a “North American Common Standard” screw spike drawing was released by three US Class I’s. (Figure 2) That part has seen some widespread use, but other parts and variations on the Common Standard part are still in widespread use, even among the railroads issuing the spec.

While the prospect of reaching a universal standard on screw spikes seems unlikely, there have been some trends. The use of smaller diameter screw spikes has
diminished in favor of 15/16”. Most class I standards now require higher strength materials with tensile strength requirements ranging from 74,000 to 120,000 psi.

Screw spikes have become very common throughout special trackwork, especially in heavy traffic areas. The biggest growth in screw spike usage has been in curves, with several Class I’s now using screw spikes in curves with various limits of curvature and traffic where they are specified. One railroad is using screws in curves as low as 2° in very heavy tonnage areas while two Class I roads have not adopted screw spikes in any curves. Other rail rollover protection is generally used in those cases.

The loading environment that screw spikes operate under is not well defined. They tend to work loose with dynamic loading and eventually break. Broken screw spikes are frequently found in groups. The consensus is that a few broken spikes tend to leave the surrounding spike more vulnerable and a chain reaction results. It is not usually clear whether broken screws are an issue with the screw, installation or other factors caused by the track conditions.

Inadequately restrained CWR has been known to break screw spikes as curves or special trackwork move under thermal loads. Excessive movement of track, because of ballast and subgrade conditions can also cause premature failure of screw spikes.

Broken screw spikes can present a real problem for track maintenance crews. They generally break at the top of the threads, well below the top of the tie. The remainder of the screw left in the tie is very difficult to remove.

The installation of a screw spike is considerably more complex and time consuming than track spike. A pre-drilled hole is required to prevent tie splitting. The screws must be turned into place with machinery that is only used in the relatively limited areas where screws are needed. It is not uncommon for the crews installing screws to be
working significantly behind the primary gangs they are attached to, resulting in maintenance delays.

**EVERGRIP DRIVE SPIKE**

The Evergrip spike developed by Lewis Bolt has seen some success in curves. The spike was developed to have similar performance to a conventional screw spike and be installed with a machine typically used for standard track spikes. The result is a 15/16” screw spike with steep quadruple lead threads and a set of four fins just above the threads. The angle of the threads cause the spike to turn as it is driven in. The fins are oriented to resist rotation that would back the screw out. (Figure 3)

The head is configured with a double washer arrangement to allow a set of jaws to pull it out. On top of the washers is a square drive to fit a 7/8” socket. The top of the head has a dome that protects the square drive from damage when driven. The material is low carbon steel with tensile strengths of 75,000 psi minimum.

The spike was developed with coordination from spike machinery manufacturers to make it compatible with the equipment. Both Harsco and Nordco have kits available to convert late-model spike drivers to accept the Evergrip. The conversion involves simple changes to the feed chutes, jaws and drive anvil. The spikes are fed and installed with the spiker just as track spikes would be. A pre-drilled hole is still required.

Removal is either by direct pullout or unscrewing. Nordco has specially adapted spike pullers to remove them. They are fitted with heavier hydraulics, reinforced structure and special jaws.

While the original idea of the drive-in spike was ease of installation, the spike has also proven to be very effective. Since the ties in a typical curve cover the entire range of
age and condition, it is very difficult for a machine operator to know when a screw is properly seated and stop tightening it. It is not uncommon to see screws that are not completely seated on the plate or have been turned a significant amount after seating, which damages the wood and sharply reduces the holding ability of the screw. The drive-in spike is driven vertically into place and once it is tightly in place, there is no possibility of overdriving it and causing damage. They can still be installed with conventional screw spike methods. Especially in a controlled environment, with all new ties, screw installation works as well, or better than with conventional screw spikes.

The fins on the drive-in spike provide greater resistance to loosening than a typical screw spike. It takes around 200 ft-lbs of torque to break the spike free, compared to 80-100 for a conventional screw spike. The direct pullout resistance is similar to screw spikes, with the typical failure being the wood around the screw shearing out at 12,000 – 16,000 lbs.

Repeated cyclical testing conducted by Bodycote Materials Testing Canada, simulating severe curve loads, ran for 3 million cycles with no loosening. Early in the program there were many concerns that the fins would provide stress risers and lead to fatigue cracks in this area. Bending fatigue tests have actually shown the spikes to have superior fatigue resistance over normal screw spikes when subjected to bending loads in this area.

Evergrip first was adopted and saw widespread use with CSX in 2003 and several million have been installed since. Canadian Pacific switched to the part in 2007. The C.P. version is 1030 steel with tensile strength of 80,000 psi minimum. To date, no report has been received of an Evergrip being found loose or broken in the field.
SPECIAL TRACKWORK BOLTS

The increased loads and traffic have been especially demanding on special trackwork. In the last ten years more attention has been paid to the fasteners. As more bolts were broken or loosened in trackwork, the practice has been to increase the strength and size of the bolts. Other conditions within the trackwork that can cause bolt failure are more frequently considered.

Many bolts in special trackwork are now SAE J429 (4) Grade 8. AREMA included recommendations for grade 8 bolts in special trackwork in plan 100 of the trackwork plans in 1999. (5) The recommendations also include torque values and guidance to use lubrication. Older standards such as ASTM A183 for track bolts have seen their use diminish.

The use of grades 8 bolts in frogs has led to two changes in practice. Increased torque and thread lubrication have been recognized as critical to the reliability of special trackwork bolts, especially grade 8.

The torque required to properly install and see benefit from a grade 8 bolt is greater than can be produced with the equipment traditionally found in the field. New equipment has been fielded to apply the necessary torque.

For any rigid bolted joint, it is desirable to pre-load the bolt to between 70-100% of its yield strength. (6) For sizes over 1”, the yield strength of grade 8 is 60% higher than that for grade 5. For a 1-3/8” grade 8 bolt, that requires approximately 2200 ft-lbs of torque. Without achieving that level of tension in the bolt, the step up to a grade 8 bolt is mostly wasted. A bolt in service at a lower tension will leave it more vulnerable to fatigue and makes the joint more susceptible to loosening.
Most trackwork manufacturers have invested in specialized hydraulic machinery to torque the bolts to the specified levels. Many railroads, or their contractors, also employ this equipment for re-torqueing after installation or when bolts are replaced.

The second factor is proper lubrication of the threads. Experimental work has shown that a high pressure thread lubricant is essential to maintaining a consistent relationship between torque and bolt tension. The lubrication greatly reduces the scatter in the torque-tension relationship and makes it possible to achieve the high bolt pre-loads that are important. The lubrication also helps avoid thread damage at the high pressures involved when torquing a bolt to these levels.

The move to larger rail sizes in special trackwork has also driven the bolts to larger sizes. The majority of the body bolts in frogs are now supplied as 1-3/8” diameter. A ballot this year removed references in the AREMA Trackwork Portfolio to rail sizes under 115RE and their associated smaller bolt sizes. *(Ballot 05-06-01)*

Other changes have been made to bolt specifications to reduce the chances of premature failure of the bolts. A few roads are requiring stronger rolled threads and machined surfaces under the head of the bolt to improve surface finish and reduce stress risers.

Self centering systems are in use in some severe applications, particularly crossing diamonds. The intent of a self centering system is to provide a pair of mating spherical surfaces that can accommodate some angle in the assembly. This reduces the eccentric loading on the bolt, placing it closer to pure tension and reducing the bending stresses.

There are two typical implementations of the self centering system. *(Figure 4)* One patented system incorporates a convex spherical surface integral to the head of the
bolt and the nut. Washers are provided that are made at various angles with a concave bearing area to match the bolt and nut. D-bar washer are available that mate with 136RE rail web profiles as well as flat washers.

The other common system is a pair of washers that have matching concave and convex surfaces. This system is available from multiple vendors, and has the advantage of using standard bolts, nuts and other parts. The increased number of mating surfaces created by this system does pose some challenges in keeping the joints tight.

The tendency of bolted joints to loosen has also been the subject of changes. There are two mechanisms by which a bolted joint loosens. (6) The first is by the mechanical action of vibrations which causes a nut to loosen. The clearances in the threads, when subjected to movement, will tend to turn the bolt and nut small amounts in the direction that loosens the joint. Eventually, the nut can turn enough to loosen the joint.

The primary device used to combat loosening is the “lock”, or more appropriately, prevailing torque nut. This is a broad category of nuts that provide some resistance to rotation, usually through some interference in the threads. While many types are available, the most common type in trackwork use is a steel insert nut. A standard nut is modified with a cavity in the top. A hardened steel, threaded insert is placed in the cavity. The insert is deformed into an oval shape after it is threaded so that it provides a clamping force on the bolt threads. The amount of torque is relatively small compared to that required for preload, but is enough to give the loosening forces a little more to overcome and at least slow down the loosening process. The interference fit of the insert does have some risk of a build up of friction and seizing the nut onto the bolt.
The second mechanism of joint loosening is embedment. Embedment is caused by the wear of surfaces of the components that are fastened together. The uneven surfaces are worn by contact with each other and the slight motions caused with loads. As the stack of parts wears together it essentially shrinks and leaves the bolt loose. An embedment of .030” would completely remove the preload from a 12” long bolt. With the number of cast parts in a frog, significant loosening can occur from embedment.

To combat embedment, there have been some efforts to provide smoother mating surfaces on the frog components. Some have even coated the surfaces with epoxy.

Pin type fasteners have also found use in some areas of special trackwork, especially in switch points. They are also being used by Canadian Pacific for the body bolts in frogs. The “Pin” fastener is not a threaded bolt, but rather a fastener with concentric rings. It is installed with a special machine that pulls the fastener under tension and swages a soft steel collar onto the rings. A reduced diameter groove causes the tail of the pin to break off above the collar once the desired preload has been reached. Since the collar is swaged onto grooves, there is no way for it to loosen.

This type of fastener has the advantage of having a fairly well controlled pre-load and no possibility for loosening. This comes at the cost of being a permanent connection. Once installed, the fastener cannot be removed and reused or tightened. The embedment must be managed to have a successful joint using pin type fasteners.

CONCLUSIONS

The railroad engineering community has begun to recognize that other aspects of the track can cause fastener failures. Is has been common in the past for a broken bolt to be written off as “bad” and just discarded and replaced. When several bolts break in the
same location and not in other places, the likelihood of it being a “bad” bolt problem becomes remote. It is now more commonly recognized that ballast and subgrade issues, installation deficiencies, joint design, and maintenance practices can have fatal consequences for otherwise sound fasteners. Bolts are best used to clamp things together by tension. When they are loose and expected to hold trackwork together by resisting bending and shear, the result is usually a broken bolt.

The last several years have seen many changes in the fasteners used in track. The higher axle loads and increased traffic have forced railroads to move to different fastener systems, higher strength and larger parts. Different railroads have taken different strategies to address the issues, but nearly all have made some upgrades to fasteners and changes in installation and maintenance practices. There will, no doubt, continue to be changes in the fasteners and methods used in railroad track.

**ACKNOWLEDGEMENTS**

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All data on screw spike performance is from testing conducted by Lewis Bolt & Nut Co.
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