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Alternative Material Ties for Open Deck Bridges

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This Technology Digest (TD) describes the development of guidelines for alternative material ties for open deck bridges. It compliments a second TD, TD 11-036 which describes testing conducted in support of these guidelines.

Summary

In 2009, Transportation Technology Center, Inc. (TTCI) began investigating alternatives to timber ties for open deck bridges as part of the Association of American Railroads' Strategic Research Initiatives on bridges. Alternative material ties for open deck bridges are urgently being sought by some railroads. Heavy axle load traffic and reduced durability and availability of sawn timber deck ties has driven this need. Conventional plastic composite ties are currently being used on some bridges where they act in bearing only, but lack the bending strength, shear strength, and other properties required for many open deck bridges, particularly steel girder bridges, which make up a significant portion of the bridge population.

Many qualities affect the performance of a bridge tie, and TTCI has worked to develop recommended guidelines for many of these. Specific recommended guidelines include the following:

- Demonstrated ability to carry a design live load of 53,000 pounds per rail seat
- Maximum deflection of 0.33 inch to 0.43 inch under design live load before factor of safety, depending on intended girder spacing
- Minimum deflection of 0.10 inch to 0.12 inch under design live load before factor of safety, depending on intended girder spacing. The minimum deflection is intended to provide some of the beneficial properties of timber, such as the ability to distribute loads and attenuate impacts.
- The alternative material should be at least as fire resistant as timber bridge ties.
- Deterioration and weathering performance should be, at a minimum, comparable to that of a timber bridge tie.
- There is a further recommendation that the manufacturer institute a rigorous system of quality control.

The load and deflection recommendations for structural performance are based on the ability of a tie to meet test requirements. TTCI has demonstrated that these tests can be satisfactorily conducted in a laboratory.

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INTRODUCTION

In 2009, TTCI began investigating alternatives to timber ties for open deck bridges as part of the Association of American Railroads' Strategic Research Initiatives. Alternative ties for open deck bridges are urgently being sought by some railroads. Heavy axle load traffic, reduced durability, and reduced availability of solid-sawn timber deck ties have resulted in more frequent replacements and higher costs. Issues include declining tie life and performance from some of the new (rapid-growth) timber, as well as the spread of Formosan termites in recent years. Concrete ties are not considered a workable alternative due to poor resilience, lack of impact resistance/attenuation and heavy weight compared to timber.

The bridge ties on a given bridge, acting together, must meet FRA track tie requirements including ability to hold track gage, surface, and alignment. In addition, on most open deck steel bridges, bridge ties must act as a structural beam to carry the load between girders. Conventional plastic composite track ties may lack the bending strength, shear strength, and other properties required for a structural beam.

TTCI has worked with the American Railway Engineering and Maintenance of Way Association (AREMA) Structural and Tie committees to develop performance-based guidelines for alternative material ties for open deck bridges. This is an important first step to encourage suppliers to invest in bridge tie development.

A test rig has been developed at TTCI to conduct deflection and design load testing. The tests have been demonstrated on various timber bridge ties. Results of these demonstration tests were used as benchmarks in the development of tie load and deflection requirements. Further benchmarking of timber tie deflections was conducted on a vintage steel open deck span installed at the Facility for Accelerated Service Testing (FAST).[1,2]

GUIDELINES FOR OPEN DECK BRIDGE TIES

Guidelines have been proposed as an addition to Chapter 30 of the *AREMA Manual for Railway Engineering* (AREMA 30), which currently provides guidelines for track ties.[3]

In 2005, AREMA structures group leaders provided a list of criteria for preliminary evaluation. A key recommendation was that any open deck bridge tie should meet the recommended practices of AREMA 30 as a track tie, as well as function as a bending member. They recommended that any wood tie derivatives (i.e., glued-laminated (glulam), Parallam, etc.) would continue to be covered by Committee 7 – Timber Structures and that pure steel bridge ties would fall under Committee 15 – Steel Structures.

A performance-based approach was used, because the guidelines need to apply to a variety of materials. In developing guidelines, TTCI referred to existing provisions for track ties whenever possible, including ability to hold track gage, surface, and alignment. These include, but are not limited to, parameters such as rail seat abrasion, tie plate cutting, fastener retention, dimensional stability, electrical impedance, durability, and fire resistance. The notable exception is that ties for open deck bridges need not meet single tie push test recommendations, which are intended for lateral stability in ballasted track.

New recommendations include structural matters, design validation tests, and recommendations for production quality control. In addition, a number of material-related and general requirements are included.

Structural Recommendations

Depending on the intended service conditions, bridge ties may be classified as structural or bearing ties. Structural ties are normally used on open deck bridges having steel girder spans where the girder spacing is wider than the rail spacing. Girder spacing of 7 feet to 10 feet is common. Under these conditions, the strength of the ties is governed by flexure or horizontal shear. Bearing ties are normally used for open decks of timber trestle spans, or on open decks of steel beam spans having four or more beams centered under the running rails. The strength of bearing ties is governed by bearing on the top of the stringer flange.

Structural performance recommendations for bearing ties are similar to those for track ties. Bearing ties for bridges must meet the recommended practices of AREMA 30 for rail seat bending and tie center bending. Additional performance guidelines have been developed for structural ties.

Design recommendations assume that alternative ties for open deck bridges will utilize tie dimensions and tie spacing similar to conventional timber bridge deck ties. Typical sizes and maximum clear spacing for bridge deck ties are tie widths of 8 to 12 inches, clear tie spacing not more than 6 inches, and tie depth determined to meet strength requirements. Tie depth for 8-foot girder spacing is often around 12 inches.

Note that these recommendations may yield different tie designs or depths for different girder spacing, track gages, or other changes in loading and support conditions. Wider girder spacing will typically require greater tie depth in order to meet the structural performance guidelines. For standard gage track, wider girder spacing leads to a greater bending moment for the tie to resist.

The recommendations for structural performance are based on: (1) the ability of a tie to meet test requirements and (2) a requirement that the manufacturer institute a rigorous system of quality control. Deflections rather than stresses are specified, because stresses are material specific and the recommendations must be applicable to various materials.

Design Live Load

TTCI recommends a design load case of the Cooper E-80 Live Load distributed evenly over three ties as recommended in AREMA Chapter 15.[3] An allowance for 100 percent impact load is included, as well as a factor of safety of 2.0. The resulting design load (after rounding) is 53,000 pounds per rail seat (Table 1).

Table 1. Derivation of Alternative Material Bridge Tie Design Load

E-80 Loading	Distributed Over 3 Ties	100% Impact	Factor of Safety of 2	Design Load (rounded)
40,000 pounds/rail	13,333 pounds/rail	13,333 pounds/rail	26,667 pounds/rail	53,000 pounds/rail

Deflection under Load

Both minimum and maximum deflections are recommended. The maximum deflection is to ensure that the tie can carry the required load and maintain proper gage. To provide some of the beneficial properties of timber ties, a minimum deflection is recommended. The minimum deflection requirement helps to distribute axle loads to adjacent ties. It also provides attenuation properties that should help ensure that impacts generated on supporting members do not significantly exceed impacts generated on a structure with standard wood ties.

Maximum recommended deflections are based on Chapter 7 of the AREMA *Manual for Railway Engineering* (AREMA 7) guidelines of span length divided by 250.[3] Minimum deflections are based on measurements of timber ties under load at FAST.[2]

Design Validation Tests

TTCI has recommended a series of design validation tests to be performed in the laboratory. Most critical are a bending deflection test and a design load test to demonstrate compliance with structural requirements. In addition, a series of general tests to verify compliance with material and other general requirements is recommended.

DeflectionTest. Table 2 shows minimum and maximum tie center deflections under loads of 27,000 pounds (live load before factor of safety) at each rail seat. The bending deflection test is to be carried out twice:

1. Slow load application rate. The load shall be increased in such a way that the time to reach the 27,000 pounds is at least 20 minutes.
2. Higher load application rate. The load shall be applied so that 27,000 pounds is reached in 2-3 minutes.

Table 2. Alternative Bridge Tie Test Deflection Requirements at 27,000 pounds per Rail Seat

Girder Spacing (foot)	Applied Load per Rail Seat (pounds)	Minimum Deflection (inch)	Maximum Deflection (inch)
7	27,000	0.10	0.33
8	27,000	0.11	0.38
9	27,000	0.12	0.43

Design Load Test. In addition, a design load test is recommended. The load should be 53,000 pounds per rail. As with the deflection test, the design load test is to be carried out twice, in such a way that the time to reach the 53,000 pounds is at least 20 minutes, and once in such a way that 53,000 pounds is reached in 2-3 minutes. Any loss of integrity or inability to sustain the specified load must be considered a failure. Failures may include, but are not limited to, cracking, crushing, buckling, delamination, permanent distortion, and excessive deflection. Because these recommendations apply to a wide variety of materials, design, and fabrication methods, failure modes will likely be different for various types of ties.

Members of AREMA Committee 7 – Timber Structures recommended the loading rates for these test to address static loading concerns.

Prior to the deflection and design load tests, it is recommended that several ties be chosen at random for laboratory testing. Each of the ties selected should be carefully measured and examined to determine their compliance with the material and general requirements. Procedures for the general tests will largely be based on the alternative material being proposed. Upon satisfactory completion of this examination, two of the ties should be subjected to the testing prescribed in AREMA 30 for track ties, with the exception of single tie lateral push testing.

Production Quality Control

After tie and rail fastening system have passed the above tests and have been approved by the appropriate engineer, further production of these items may proceed without further design testing. However, during production, quality-control tests are recommended to be performed to assure that at least 95 percent of the ties produced meet the design strength requirements. The quality-control tests must be acceptable to the railroad engineering department.

Material Requirements

In addition to the material guidelines in AREMA 30 for engineered composite ties, the following additional criteria are recommended for open deck bridge ties:

- Material should be at least as fire resistant in railway service as timber bridge ties with respect to flammability, toxicity or environmental hazard, heat generated during combustion, and duration of fire.
- At a minimum, deterioration and weathering performance should be comparable to that of a treated timber tie. A design service life of 40 years or longer should be considered. Bridge ties should be resistant to fuel spills and resistant to any specific service conditions or chemical environments expected to be encountered, as recommended by the railroad.
- Concrete ties are not recommended for open deck bridges because of their heavy weight. In addition, rapid tie degradation has been reported in a few cases where they have been used. Impact attenuation and dynamic resilience are key issues to be resolved.

General Recommendations

The following are general recommendations for bridge ties:

- Bridge ties shall not interfere with signals.
- Bridge ties shall be suitable for severe outdoor service under a wide range of weather conditions. This would include the ability to maintain structural integrity and dimensional stability for the temperature range of -50°F to 140°F or as otherwise specified by the railroad. In addition, structural integrity and dimensional stability for a humidity range of 5 to 100 percent must be maintained. Structural load testing might be required at a wide range of temperature and humidity conditions, depending on the tie's sensitivity to temperature and humidity.

- Bridge ties should have the ability to be handled with standard bridge and track machinery.
- Bridge ties should demonstrate acceptable performance under extreme impact load, i.e., derailment.
- Bridge ties should be able to mold around web projections and rivets or bolt heads with no adverse effects or otherwise allow for these projections without reducing the performance of the tie.
- Bridge ties should be suitable for drilling and framing to accommodate various installations.
- Bridge ties should have the ability to be used with standard track and bridge hardware (deck fasteners, tie plates, rail anchors, tie spacers, etc.). Alternatively, the supplier should provide special handling and framing details that have been approved by the railroad.
- Allowable bearing capacity on the side of a tie should be at least equal to that of a timber bridge tie in order to provide adequate rail anchor resistance.
- Bridge ties should have a life cycle equivalent to or greater than that of a treated timber bridge tie (estimated 40 years) under dapped or un-dapped conditions (both fatigue life and deterioration requirements).
- Bridge ties should result in a deck not more than 10 percent heavier than one made of Douglas Fir timber ties at conventional spacing, unless otherwise approved by the railroad.
- Bridge ties should not be subject to excessive creep or long-term deflection. This is particularly a concern for ties supporting walkways, as well as for other structural (bending) ties. Creep at any point on a tie shall be limited to L/250, where L is equal to the center-to-center girder spacing for structural ties, and L is equal to the center-to-center rail spacing for bearing ties.
- Bridge ties should provide a suitable walking surface.

Test Rig

TTCI recommends use of a test fixture based on a test rig designed by Madsen and Sweeney for timber bridge ties.[4] Figure 1 shows the recommended fixture.

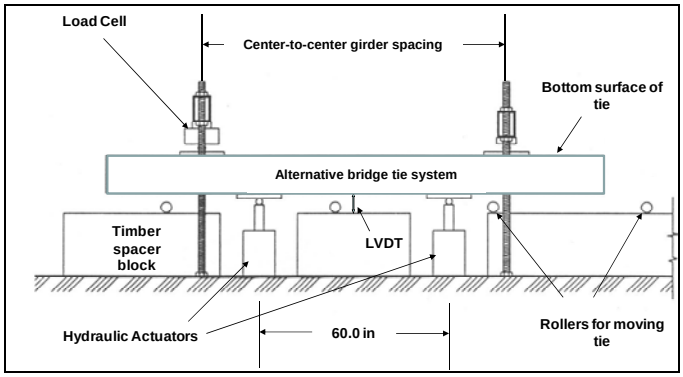

Figure 1. Tie Bending Test Apparatus

A key feature of the fixture is the ability to simulate different girder spacings. Spacing of the reaction points should be the same as the intended center-to-center girder spacing. Spacing of the load points should be 60.0 inches for standard gage track. Sizes of plates for load and reaction points should be 12.0 inches in the direction of the longitudinal axis of the tie, by the full width of the tie. Figure 2 shows a test rig fabricated at TTCI for demonstrating the recommended test procedures.

Figure 2. TTCI Demonstration Open Deck Bridge Tie Test Fixture

Acknowledgements

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