

Research Report
KTC-89-55

LOAD INDICATING WASHERS

by

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in cooperation with
Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
US Department of Transportation

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COMMONWEALTH OF KENTUCKY
TRANSPORTATION CABINET
FRANKFORT, KENTUCKY 40622

MILO D. BRYANT
SECRETARY
AND
COMMISSIONER OF HIGHWAYS

WALLACE G. WILKINSON
GOVERNOR

April 12, 1990

Mr. Paul E. Toussaint
Division Administrator
Federal Highway Administration
330 West Broadway
Frankfort, Kentucky 40602-0536

Dear Mr. Toussaint:

Subject: IMPLEMENTATION STATEMENT
Research Study KYHPR 85-107
Long-Term Monitoring of Experimental Features,
Subtask 10, "Direct Tension Indicators"

The Kentucky Transportation Cabinet's "Standard Specifications for Road and Bridge Construction" provides for the use of direct tension indicating washers as an alternate method to torquing for achieving the proper tension in bolted field splices. Information gained during this study has validated that provision. It is possible that other bridges will be constructed incorporating that feature.

As a result of this study, the Division of Construction will consider the experimental use of mechanically galvanized direct tension indicators on several new bridges.

Sincerely,

A handwritten signature in cursive script, appearing to read "O. G. Newman".

O. G. Newman, P. E.
State Highway Engineer

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16. Abstract <p>Kentucky Transportation Center (KTC) personnel monitored the installation of load indicating washers (LIWs) on the US 60 bridge at Catlettsburg, KY during construction. On completion of the bridge, KTC personnel performed torque measurements on a number of LIW installations. LIWs previously installed on the Thirteenth Street Bridge over the Ohio River at Ashland, KY were also inspected.</p> <p>The KTC construction inspections revealed no significant problems in installing LIWs. Workers were able to use them to determine proper bolt assembly installation. They also permitted inspectors to rapidly check for proper bolt tension. As with other bolt tensioning methods, LIWs had to be tested prior to installation.</p> <p>The follow-up field torque tests indicated that the LIWs provided consistent bolt tension values.</p> <p>The only potential service problem with LIWs, as discerned on the Thirteenth Street bridge, is related to corrosion. Uncoated LIWs must be hand painted to prevent rusting.</p>					
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EXECUTIVE SUMMARY

Load indicating washers (LIWs) are used on bolted friction splices (field connections) of steel bridge members to ensure proper bolt tension. That feature has been used on two Kentucky bridges, the Thirteenth Street Bridge over the Ohio River at Ashland and the US 60 bridge over the Big Sandy River at Catlettsburg.

Kentucky Transportation Center (KTC) personnel monitored the installation of LIWs on the US 60 bridge during construction. On completion of the bridge, KTC personnel performed torque measurements on a number of LIW installations.

The KTC construction inspections revealed no significant problems in installing LIWs. Workers were able to use them to determine proper bolt assembly installation. They also permitted inspectors to rapidly check for proper bolt tension. As with other bolt tensioning methods, LIWs had to be tested prior to installation.

The follow-up field torque tests indicated that the LIWs provided consistent bolt tension values.

The only potential service problem with LIWs, as discerned on the Thirteenth Street bridge, is related to corrosion. On the US 60 bridge, corrosion was prevented by hand painting the LIWs. The use of mechanically galvanized LIWs may be a better solution to potential corrosion problems.

INTRODUCTION

Friction splices employed for field connections of steel bridge members require proper bolt tension to achieve the necessary joint strength. To do this, workmen must use installation procedures that reliably tension bolts. Also, inspectors must perform quality assurance tests to confirm proper bolt tension.

There are two common methods to achieve proper bolt tension: 1) torquing and 2) turn-of-nut. In the first method, workers tighten a bolt assembly with a torque-wrench to a specific torque value. In the second method, workers tighten the bolt assemblies to snug the joint. Then, they turn each nut through a specific rotation to properly tension the bolts.

Most contractors use power wrenches for tightening bolt assemblies. Usually, those tools have stall or cut-off adjustments that are preset to a desired torque. However, presetting wrench torque does not assure proper tensile loading of fasteners. Therefore, inspectors need to check tightened bolt assemblies to insure proper bolt tension.

Inspectors normally use torque wrenches to confirm bolt tension. An inspector tightens a previously installed bolt assembly with the torque wrench. The torque at which the assembly will turn (breakaway) approximates the installation torque. That value should be close to the specified or calibrated torque value for that type of fastener.

The Kentucky Transportation Cabinet specifies the use of a bolt tension (load) calibration device to relate torque values to bolt loads. It provides reasonable assurance that torque settings of bolt installation tools achieve proper bolt tension. Some variation in bolt loads will occur for specific torque values. That is due to differences in thread tolerances and finish. Also, torque wrenches used for field inspections require frequent recalibration.

An alternate technique for assuring proper bolt tensioning employs load-indicating washers (LIWs). Those hardened washers have protrusions on one bearing face. The protrusions flatten during the tightening of a bolt assembly (Figure 1). At the desired tightening force (torque), the protrusions flatten by a predetermined amount. To confirm proper bolt tension, a worker or inspector can insert a calibrated feeler gage into a gap between the protrusions. If the space between the face of the washer and the bolt head is too small, the gage will not fit. That reveals the bolt has received the minimum specified tensile load. If the gage fits in the gap, the bolt assembly needs additional tightening.

Normally, workers install LIWs with the protrusions facing the stationary element of the bolt assembly (bolt head or nut) during tightening. Otherwise, they place a plain hardened washer between the turning element and the abutting LIW protrusions. That prevents the protrusions from wearing down during tightening. Workmen should not install LIWs with the protrusions facing a plate surface.

The Kentucky Transportation Cabinet first used LIWs on the 13th Street Bridge across the Ohio River at Ashland. The bridge was completed in 1985 before the start of work on this subtask. The US 60 Bridge over the Big Sandy River between Catlettsburg, KY and Kenova, WV was the second Kentucky bridge to incorporate LIWs. Erection of that bridge began in 1985.

At the time of construction of the 13th Street Bridge, the Kentucky Transportation Cabinet issued a special note for the use of LIWs. The special note provided for two types of LIWs -- one for use with ASTM A 325 and one for use with A 490 bolts. The LIWs were used on all high strength bolts from 1/2 to 1 1/4 inches in diameter. They were to be certified for accuracy to + 20 percent of the tensile load specified in Table IV, Section 607.08 of the 1983 Kentucky Transportation Cabinet Standard Specifications. The LIW manufacturer was to perform sample tests on each heat or lot of LIWs and furnish documentation of test results. The note also provided for field acceptance tests to confirm the manufacturer's tests.

The state inspector was to perform acceptance tests on at least three bolts and LIWs per lot by use of a bolt tension calibrator. Those tests were to assure proper LIW performance preceding field installation of the LIW/bolt assemblies.

After LIW installation on the bridge, the inspector was to check LIW compression with a feeler gage. The installation was acceptable if the gage did not fit in the

gap between the mating bolt head, nut, or washer. The special note stated that a zero gap was not desirable. However, a completely flattened LIW was not grounds for rejection. If the gaps varied, but the gage would not fit in at least half of the gaps, the installation was accepted. The special note required that the inspector check ten percent (two minimum) of the LIWs at each joint.

Kentucky Transportation Cabinet personnel who worked on the 13th Street Bridge stated that they experienced few problems with LIWs. A few bolts broke during installation (which might be related to the use of LIWs). Also, the structural paint did not seal the gaps between the protrusions on the LIWs. Eventually, many of the externally exposed washers rusted. On the US 60 bridge, the LIWs were hand coated with epoxy paint to seal the gaps and prevent corrosion.

KTC FIELD INSPECTIONS AND TESTS

Kentucky Transportation Center (KTC) personnel first inspected the US 60 bridge in June 1985. At that time, a portion of the steel superstructure was in place. The Cooper-Turner Co. Inc. of Bristol, PA supplied the Coronet LIWs used on the US 60 bridge. The LIWs were for ASTM A 325 bolts in the 5/8-, 7/8-, and 1-inch diameter sizes. The Kentucky Transportation Cabinet specified installation tensile loads of 19,200 psi, 39,500 psi, and 51,500 psi, respectively, for the three sizes of fasteners. The 5/8-inch LIWs were used on water lines and hanger brackets. The 7/8-inch LIWs were used on cross bracing. The 1-inch LIWs were used on web and flange splices.

The LIWs cost \$0.40 each and the case hardened washers cost \$0.25 each.

KTC investigators observed the state inspector performing acceptance tests on each lot of LIWs that had a different heat number.

The state inspector calibrated the LIWs against bolt tensile load on a Skidmore-Wilhelm Model "M" bolt tension calibrator. The Skidmore-Wilhelm Manufacturing Company of Cleveland, OH leased the device to the contractor. It was capable of calibrating various sizes of bolt assemblies. An inspector tightened a LIW/bolt assembly installed in the calibrator with a torque wrench. He read the tensile load applied to the bolt directly in pounds on a gage located on the side of the calibrator. The inspector tightened the LIW/bolt assembly to the correct load with a manual torque wrench. Then, he recorded the corresponding torque value for future field torque checks of the LIW/bolt installations.

The inspector checked gaps of LIWs tested on the calibrator with a 0.005-inch feeler gage if the LIW was installed under a nut, or a 0.015-inch feeler gage if it was installed under a bolt (Figure 2). If the LIW gap closed before reaching the prescribed tensile load, the LIW failed the test. The LIWs also failed if the feeler gage fit in the gap at the specified tensile load. If the gaps between the protrusions varied, the average gap spacing governed acceptance. Usually, the inspector tested four or five LIWs in each heat. If one LIW failed the test, he rejected the lot.

A three-man crew tightened the LIW/bolt assemblies. One man on the ground operated an air compressor. Two workers at the field splice installed and

tightened the LIW/bolt assemblies. One operated an air wrench used to turn down the nut or bolt (Figure 3). The other, located on the opposite side of the joint, secured the fixed end of the LIW/bolt assembly with a wrench. Normally, that worker installed LIWs on the stationary side of the bolt assembly. Therefore, he was also able to check the LIW/bolt installation with a feeler gage.

The state inspector visually checked all the LIW/bolt assemblies for protrusion flattening. He also gaged (Figure 4) at least 10 percent of the LIWs as required by the special note.

Several minor installation problems occurred early during construction. The contractor's workers had installed some of the LIWs facing the steel rather than the bolt heads or nuts. The state inspectors detected that problem and required the contractor to install new LIWs according to the special note. Inspectors noted that workers allowing the portion of the bolt assembly bearing on the LIWs to spin during the tightening process. Usually that occurred only briefly during the operation and probably did not affect the bolt tension. In several cases, the bolt or nut spun and wore down protrusions on the LIWs. The inspectors detected that problem and remedied the situation. Also, one lot of hardened washers had excessively large holes. That allowed them to shift during tightening and not bear properly on the LIW protrusions. Those washers were replaced.

During initial construction of the bridge, Kentucky Transportation Cabinet officials halted the project and replaced the contractor. That delayed work on the project. A second contractor completed the bridge in the late fall of 1987.

Before completion of the bridge, FHWA officials requested that KTC personnel test some of the installed LIW/bolt assemblies with a torque wrench. FHWA personnel wanted to determine tension values on some of the installed bolts.

A local contractor loaned KTC personnel a 1,000 ft-lb torque wrench. The contractor had not tested or calibrated the unit in some time. KTC investigators learned that the bridge contractor had returned the bolt tension calibrator to Skidmore-Wilhelm. That prevented the calibration of a torque wrench and the determination of bolt tension. Despite those limitations, KTC personnel decided to perform the tests to determine the consistency of bolt tensioning provided by LIWs.

In October 1987, Kentucky Transportation Cabinet officials provided a snoopers and personnel from District 9 to aid in the field tests. KTC personnel could only test 7/8- and 1-inch diameter LIW/bolt assemblies using sockets supplied with the torque wrench.

Tests were conducted at four different locations near midspan. Personnel on the snoopers platform fixed the torque wrench to a LIW/bolt assembly. They proceeded to tighten it until the LIW/bolt assembly turned (breakaway). KTC investigators recorded the maximum torque achieved when the LIW/bolt assembly turned. That is approximately the torque achieved during the original installation. In several tests, the capacity of the torque wrench was reached before breakaway. In some other tests, the crew could not fully torque the LIW/bolt assemblies.

Table 1. lists torque values for the LIW/bolt assemblies recorded during the tests.

They provide an approximate measure of consistency of tensile bolt loadings provided by LIWs. In performing construction field tests with a torque wrench, the state inspector reached the calibrated values on all test LIW/bolt assemblies without any breakaway. KTC field tests probably subjected the LIW/bolt assemblies to torques greater than specified values. KTC field readings were fairly consistent for torque measurement. Tests did not produce any unusually low readings. Those items suggest that the LIW/bolt assemblies were properly tensioned.

CONCLUSIONS

KTC field inspections and tests indicate that LIWs on the US 60 bridge performed satisfactorily. They provide rapid confirmation of proper bolt assembly installation in the field. The feeler gage test enables workmen to conduct 100 percent inspection of the bolt assemblies. It also eases follow-up quality assurance tests by state inspectors. KTC personnel found it very difficult to perform field tests with a torque wrench when working at extreme heights. Use of LIWs eliminates the need to perform such tests.

The corrosion of LIWs on the 13th Street bridge should be addressed in the future. When repainting the structure, those LIWs should be sealed. In the next few years, it might be desirable to remove a few LIWs and inspect them for corrosion of the protrusions. Corrosion may erode the protrusions and adversely affect bolt tension.

LIWs used on new bridges should be hand-painted with epoxy paint to seal LIW/bolt assembly gaps as with the US 60 bridge. Kentucky Transportation Cabinet personnel should also consider using mechanically galvanized LIWs. Mechanical galvanizing of LIWs costs 35 percent more than the standard finish. That cost is probably less than hand painting and should provide a more durable finish.

High torsional forces might occur in fasteners if the mating threads were too snug or if the threads were rusted. Those forces might shear bolts during the tightening process. With torque measuring or applying devices, those defects might lead to acceptance of under-tensioned bolts. In those instances, LIWs would prove useful since they are directly affected by bolt tension and are not affected by thread fits or finishes.

Some bolts failed during construction of both bridges incorporating LIWs. Variations in the LIW performance could have caused those failures (though other causes are possible). If the hardness or protrusion size in some LIWs was too great, it is possible they would resist flattening. Workmen installing the LIW/bolt assemblies would continue to tighten them until the bolts failed. It is that proper acceptance testing of LIWs should prevent such occurrences.

During early construction of the US 60 bridge, workmen made several minor errors when installing LIWs. Inspectors detected and promptly remedied those errors. In the future, it would be desirable to familiarize workmen with installation procedures to prevent such events.

During the changeover between contractors, some of the LIWs became wet and corroded during storage. Upon resumption of work, the second contractor attempted to salvage them. The LIWs were tumbled in sand to remove the surface corrosion. However, they did not pass the field tests. A Cooper-Turner representative investigated the problem and determined that the LIWs softened during the tumbling operation. That event indicates that LIWs require careful handling to preserve their desired characteristics. Mechanical galvanizing might prevent potential storage problems posed by corrosion.

RECOMMENDATIONS

The following recommendations are presented for consideration for future use of LIWs.

1. LIWs may be used routinely to control bolt tension on friction splices of steel bridges.
2. Transportation Cabinet personnel could employ mechanically galvanized LIWs experimentally on at least one bridge. It would be preferable to employ those LIWs on a truss bridge since they would receive more environmental exposure than on girder bridges.
3. A question exists about the consistency of bolt tension provided by LIWs. Tests should be conducted on several lots of LIWs and standard fasteners using a torque wrench and bolt tension calibrator. It would be useful to determine the consistency of tension values provided by LIWs and the standard bolt tensioning methods (turn-of-nut and torquing), and the attendant effects of thread fit, finish and lubrication.
4. To reduce the chance of any problems related to LIWs, the Standard Specifications should require the contractor to: 1) provide sheltered storage for LIWs, 2) educate workmen on proper LIW installation, and 3) employ fasteners and hardened washers that are in good condition and that provide a proper fit.

TABLE 1. Torque Readings from Load-Indicating Washers on the US 60 Bridge at Catlettsburg, KY (October 20, 1987)

Test No.	7/8-inch Bolts (ft-lbs)	1-inch Bolts (ft-lbs)
1	900	1,000
2	900	950
3	*750	*900
4	850	*900
5	800	*800
6	900	*1,000
7	*750	1,000
8	900	*950
9	*550	1,000
10	950	*900
11	800	*950
12	850	1,000
13	750	1,000
14		850
15		900
16		1,000
17		1,000
18		1,000

* Denotes LIW/bolt assembly breakaway during torque test.

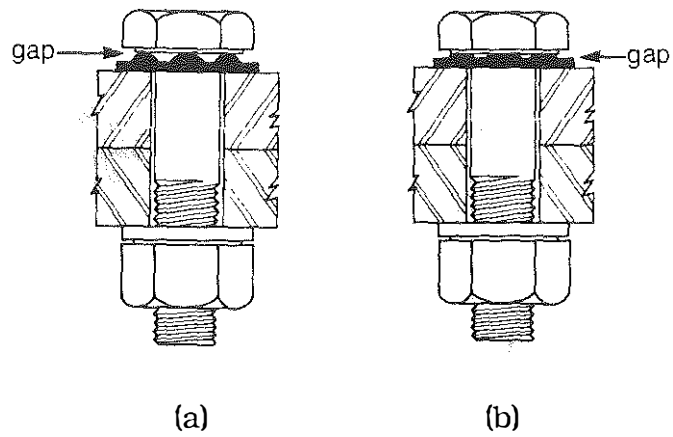


Figure 1. Schematic of a LIW (a) Before Tightening, (b) After Tightening.



Figure 2. A Feeler Gage Inserted into the Gap of a LIW Being Tested on a Skidmore-Whilhelm Bolt Tension Calibrator.



Figure 3. A Workman Installing a LIW/Bolt Assembly with an Air Wrench.



Figure 4. A State Inspector Checking the Gap of a LIW Used on a Flange Splice.



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April 12, 1990

Mr. Paul E. Toussaint
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330 West Broadway
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State Highway Engineer