LOCK-PIN AND COLLAR FASTENING SYSTEM

Final Report

Experimental Features
Project No. OR 93-02

Marquam Bridge Interchange
Morrison Street Ramp

By

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16. Abstract

In 1993, a steel girder I-beam deck was extended to cross a new on-ramp at the Marquam Bridge Interchange in Portland ,Oregon. The steel members of this new structure were fastened together using the lock-pin and collar fastening system.

These fasteners are quicker and easier to install than the standard threaded ASM 325 bolts. While the lock-pins are about the same length and strength as the standard bolts, the collars are not threaded but rather are swaged onto the lock-pin by a special hydraulic installation tool. Once the collar is swaged on, no additional tightening with a torque wrench is required. A simple sound test by pinging it with a hammer verifies the tightness of fit. While reports of nuts working loose on standard bolts are common, the lock-pin collar fasteners remained tight after three years of service.

Costs can be reduced with less labor by using this system. Since the lock-pins do not need to be torqued, the second and third tightness checks are eliminated. Material costs are about the same when torque indicator washers are used with standard bolts.

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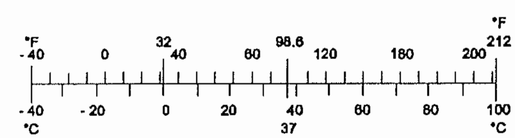
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

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DISCLAIMER

LOCK-PIN AND COLLAR FASTENING SYSTEM

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1.0 INTRODUCTION

In 1993, the Morrison Street Ramp of the Marquam Bridge in Portland, Oregon was extended to cross a new grade level connection to the Banfield Freeway. The new extension was built with welded steel plate girders to span the longer distance. The diaphragm cross members of this deck girder structure were fastened with the lock-pin and collar (LPC) fastening system.

This report compares the LPC fastening system with conventional threaded nuts and bolts. Installation time, material costs, ease of inspection and three years of this system's performance are discussed.

Figure 1.1 Morrison street ramp.

2.0 BACKGROUND

High strength steel LPC fastening systems have been used for more than fifty years in many heavy-duty applications such as rail car and truck, truck and trailer construction, and military aircraft. Engineers are increasingly using LPC fastening systems for a variety of highway applications including new construction and repairs. They are used as an alternate for high strength steel nuts and bolts where increased resistance to traffic vibration is desirable to prevent the nuts from coming loose.

LPC fasteners consist of a pin and locking collar. The pin has a head, a series of annular lock grooves, a breakneck groove and pull grooves. The collar is cylindrical in shape and is swaged onto the lock annular grooves by a hydraulically operated installation tool, which engages the pull grooves on the pin and applies the tensioning and swaging forces to the fastener system. After the collar is fully swaged into the locking grooves, the pin breaks at the breakneck groove. This imparts a bolt tension comparable to the tension specified for conventional nut and bolt fastening systems. Load-indicating washers and torque checks used with conventional fasteners are not necessary.

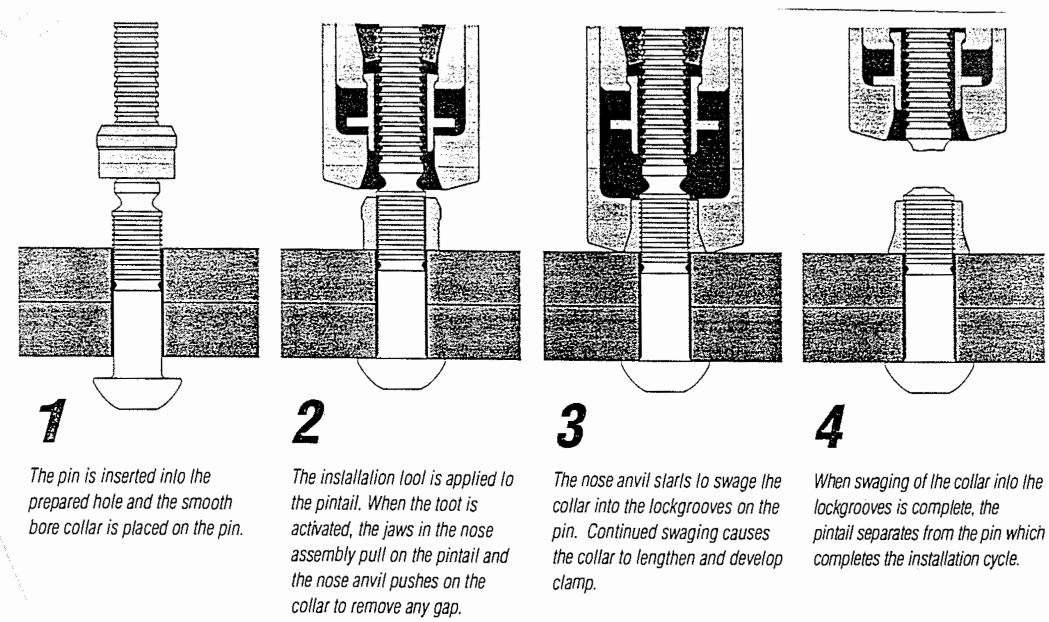

Figure 2.1 Operation of lock-pin and collar system. Courtesy of Huck manufacturing company. The LCP Fasteners used on this project were manufactured by the Huck Manufacturing Company.

2.1 PROJECT LOCATION

The project is located on the East side of the Willamette River in Portland, Oregon. The Morrison Street access ramp is one of many in the complex interchange structure. (See figure 2.2).

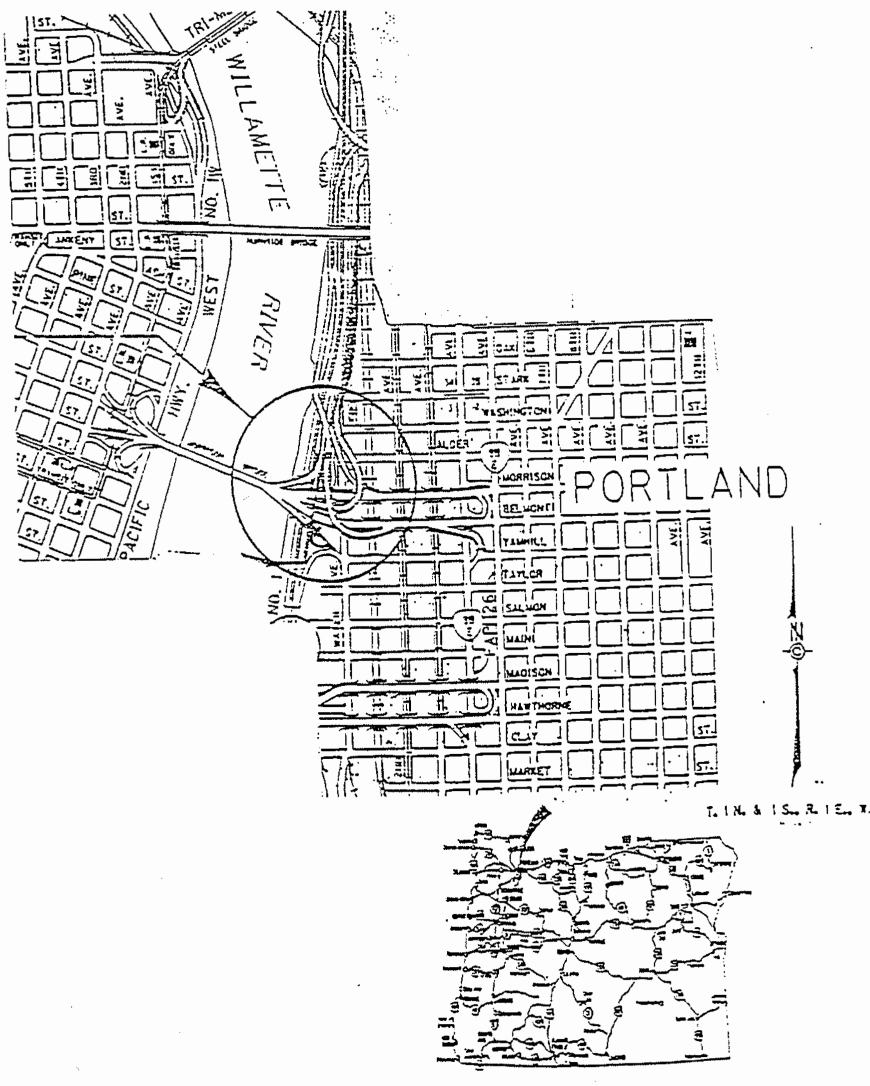

Figure 2.2 Project Location in Oregon

3.0 INSTALLATION

The steel plate girders were fabricated by LSI at their Portland plant. Top and bottom flanges were welded to the deep web plate to form the body of the girder. Stiffeners were welded to the web (see Figure 3.1), and holes were drilled through the stiffeners and the bottom flange for LPC fasteners. These bottom LPC fasteners were made by the Huck Company, and were installed at the fabrication shop. Although the lock-pin and collar system requires special equipment, the distributor (Dean Lewis and Company of Seattle Washington) rents the installation equipment to the contractor. Their field representatives also train the contractors people to operate the installation tools, and provide expert advice to the field engineers. The ODOT inspector observing the work stated that the installation was very fast and no problems were encountered.

After the girders were completed, they were transported to the job site. The girders and diaphragms were set up on the pier and abutment, temporarily braced into place, and the diaphragms were secured using the lock-pin system.

Workers report the lock pin system is easier to use than standard bolts. The reason was less physical stress on the operator using the LPC installation tool than that required for an impact wrench. The LPC installer only has to support the weight of the tool. Standard bolts usually take two men: one to hold the bolt head with a wrench while the other is tightening the nut to its final torque. After the initial tightening, only one man is needed for the final tightening of the lock-pin system.

ODOT specs call for a special direct tension indicator (DTI) washer to be used with standard bolts. When the bolt has been tightened to the required tension, the washer has dimples which are flattened (see Figure 5.1). The special provisions for the Marquam Bridge called for a nil gap between the DTI and washer. Installers are required to check this on every bolt which consumes time. The LPC fastening system requires the pull grove section of the pin to be parted from the body of the pin at the breakneck groove, once this is done no further check is required by the workers.

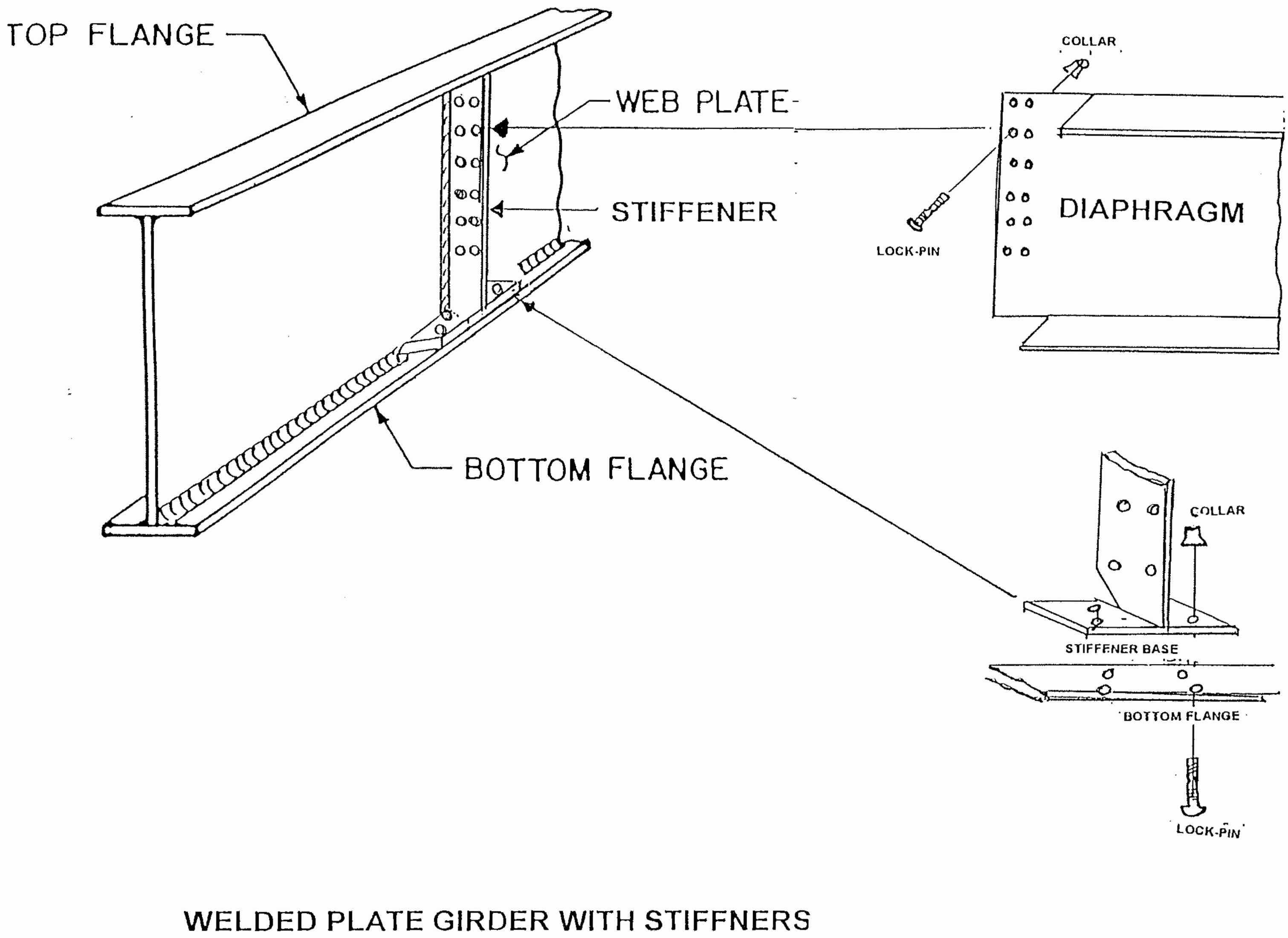

Figure 3.1 Girder Drawing

4.0 INSPECTION

ODOT specifications require all high strength bolts or fasteners to meet ASTM 325 requirements for chemical composition and mechanical properties. Chemical test results are provided by the fastener manufacture, and accepted by ODOT on their certification. Tension testing for breaking strength is performed at the job site.

Each shipment of LPC fasteners is sampled with five of each length, diameter and grade represented. They are tested with a Skidmore-Wilhelm bolt tension measuring apparatus (See Figure 4.1). Those not meeting the required breaking strength are rejected.

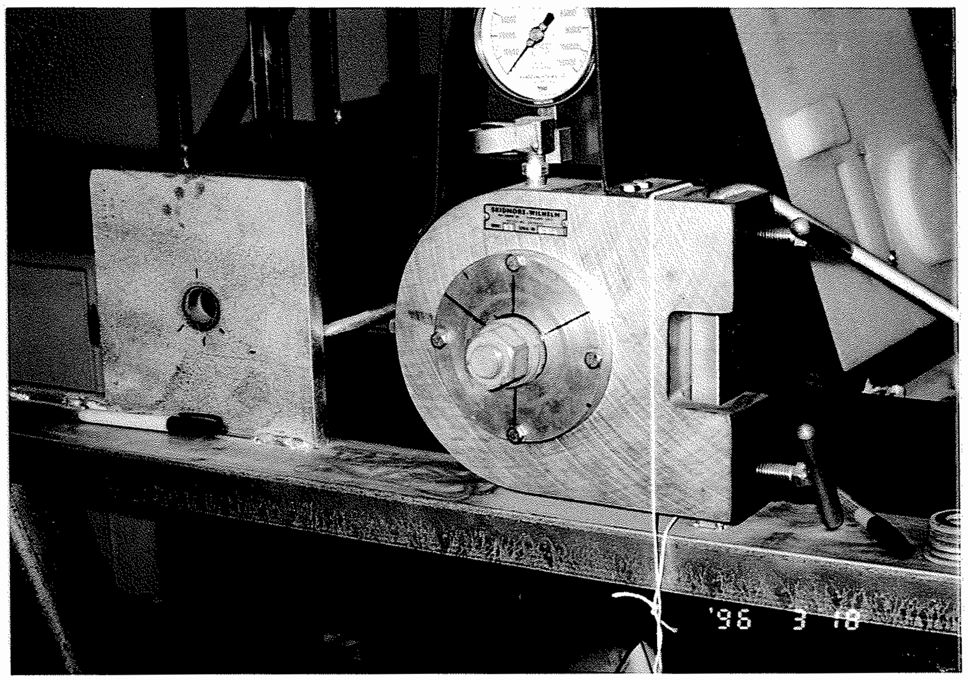

Figure 4.1 Skidmore-Wilhelm bolt tensioning calibrator

Inspection of the installed lock-pins is done by sight and sound. The collars are checked for snugness and are pinged by striking them with a hammer (See Figure 4.2). A metallic ring indicates a tight fit while a dull thud means a loose connection. Loose lock-pins must be removed with a special tool made to break the collar. (It is called a "nut cracker" by the manufacturer).

The manufacture of the lock-pin collar system has published a chart of deformed dimensions for the collars. The swaged length, width and shape of the collar are checked for proper installation. If they are within the guide lines, the fastener meets ASTM standards. If its outside of the specifications then the fastener has been installed "out-of-grip" and needs to be reinstalled.

Although shipments of standard ASTM 325 bolts are accepted on manufactures certification, they are also tested every day during bolting operations. The special provisions for the Y-3 ramp include the following:

> ". . . a minimum of three bolts shall be selected at random for testing during each days' bolting operation. The bolts shall be placed in a tension measuring device and tightened with a manual socket wrench until nil gap, unless shown otherwise is achieved. (sic). The bolt tension indicated by the calibrator shall be not less than 5 percent greater than that required in Table 510.36A for the size of bolt. Failure to meet this specified tension shall be grounds for suspension of bolting operations until the cause of the failure can be determined."
>
> Inspection of conventional nuts and bolts is time consuming. ODOT specifications for this project states:"

Upon completion of a bolted joint, the Engineer will determine that all bolts have been tightened. A minimum of 10 percent but not less than two bolts in each joint will be inspected. If all gaps checked are nil or as specified on the plans, the joint will be accepted as properly tightened. If gaps checked are in excess of the above, the contractor shall re-inspect all bolts and re-tighten bolts in the joint, as required, and resubmit the joint for inspection."

Figure 4.2 Lock-pins installed at bottom of flange

5.0 COST COMPARISON

5.1 MATERIAL

Lock-pin and collar system has a higher initial cost than standard nuts and bolts. The following prices shown in Figure 5.1, are based on 1995 costs per 100 and were supplied by Huck Fastener and Portland Bolt Company.

Table 5.1 Lock-in and Standard bolt costs.

Item	Cost/EA	Item	Cost/EA
Lock-Pin (C50LR, 2 inch grip)	$ 1.87	4" bolt, hardened washer, and nut	$ 1.04
Collar (3LC)	$ 1.03	7/8" DTI Washer	$ 0.91
Total	$ 2.90		$ 1.95

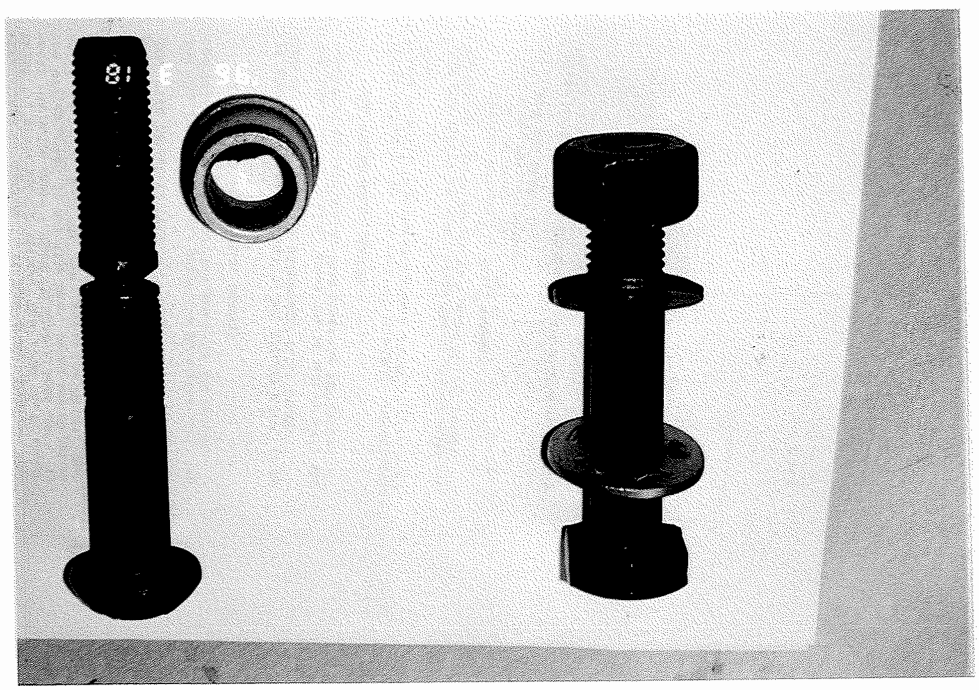

Figure 5.1 Lock-pin and 3LC collar (left). A Standard Hex bolt, nut, washer and a silver DTO (right).

5.2 INSTALLATION EQUIPMENT

Standard bolts are usually installed with compressor driven impact wrenches. The cost for the compressor and the impact tool, based on local equipment rental costs, was estimated to be $0.15 per bolt on this project. Also, a torque wrench and feeler gauge would be required, but these costs would be minimal.

LPC fasteners required special equipment for installation. The equipment rental on this project was $1000.00 for 1200 lock-pins, or about $0.83 per pin.

5.3 CONTRACTORS LABOR

Labor is reduced when the LPC system is used. On this project it was stated that labor was reduced, generally, one worker was needed to install lock-pins, where standard bolts require two workers.

5.4 STATE INSPECTION TIME

Inspection time for the project manager's inspector is reduced. After installation, the inspection is a quick, visual one-ping test. This is much faster than checking each bolt with a torque wrench or measuring the DTI nil gap.

5.5 PERCENT OF TOTAL COST OF BRIDGE.

Although the material and equipment cost is higher for the lock-pin system, the total cost for the project did not change significantly. The higher material and equipment cost is offset by reduced labor expenses. Inspection time is also less which reduced the overall engineering costs.

6.0 LABORATORY TESTS

Laboratory testing has been done on the LPC system by both ODOT and Huck Bolt. The Huck Company performed Junkers vibration tests , while ODOT checked breaking tensile strength. The results of these tests are presented in the following sections.

6.1 TENSILE STRENGTH TESTS

Two types of Huck bolts were tested for tensile strength: the annular grooved C50L and the spiral grooved C50LFR. This testing was precipitated by the introduction of the spiral grooved lock-pins on an ODOT bridge construction project at Hood River, Oregon in 1996. ODOT was concerned that the spiral grooves would not hold as well as the annual grooves.

The following statement was made by ODOT Physical Testing Laboratory:

"Hulk" Bolt (Lock Pin & Collar) Study

Results of tests conducted on 7/8" lock pin and collars are not conclusive but tend to indicate a possible problem with uneven or point loading. Several of the fastening systems tested, released early before reaching their minimum desired tensile strength. It would appear that when uneven loading occurs in the collar swaging process, the collars tend to release early. The firstswaged grove at the top of the collar, closest to the steel being fastened, must be even and uniform for the collar to reach its maximum potential. If this does not occur, a cascading or domino effect result. causing premature failure when maximum loading is applied. If there is no uneven or point loading and the fastening loads are applied evenly, there should be no problem with this type of fastening system.

One other problem was noted. The locking pin is slightly tapered and becomes thicker towards its routed head. When the head of the pin is locked down onto the steel, moderate deformation and surface cracking occurs around the circumference of the hole. Whether there will be a problem with corrosion or metal fatigue at this time is unknown. This metal deformation was one of the reasons California Transportation Department rejected the use of this type of lock pin and collar in their bridge construction.

Gary Barguist
Physical Testing
State Materials Lab

Table 6.1 Tensile strength tests.

SAMPLE NUMBER	TENSILE STRENGTH PA X 10^6	TYPE OF PIN	TYPE OF COLLAR	WEDGE OR POINT LOAD
1	697	C50LFR	3LC	10° WEDGE
5	732	C50LFR	LC	10° WEDGE
7	753	C50LFR	3LC	3° POINT LOAD
6	798	C50LFR	LC	6° POINT LOAD
4	803	C50LR	LC	10° WEDGE
13	804	C50LFR	3LCH-2DR	10° WEDGE
8	807	C50LFR	3LC	1° POINT LOAD
9	808	C50LFR	3LC	NONE
12	848	C50LFR	3LC	6° POINT LOAD
14	859	C50LFR	3LC	6° POINT LOAD
11	864	C50LFR	3LCH-20R	3° POINT LOAD
3	890	C50LFR	3LC	NONE
2	898	C50LR	3LC	NONE
10	923	C50LFR	3LCH-20R	NONE

The results of the tensile strength tests, indicate that spiral grooved lock-pins work as well as annual grooved lock pins.. Note that the item in failing bolts (ODOT specifies 827 PA X 10^6 for 19 mm. bolt) was the point load or wedge.

6.2 VIBRATION TESTING

Vibration testing was performed by the Huck bolt Company.using the Junkers transverse vibration machine.(Figure 6.1) Three fasting systems were tested: 1. The annular grooved lock-pin system, 2. The spiral grooved lock-pin system , and 3. A standard hex bolt and nut system. All testing was witnessed and verified by an independent consultant .

The junkers transverse vibration testing device uses a motor drive concentric to induce controlled loads into the fasting system under test. The standard bolts are tightened to an initial clamp load with a torque wench. The lock-pins are installed using the xx456 installation tool. A load cell measures the clamp load after the vibrations are started. The loads are then plotted against time using an x-y plotter.(see Figure 6.2)

In the initial tests the standard bolts were tightened to a torque of 279 ft-lbs. The initial clamp dropped to almost zero in less then a minute., while both the LF50 and the LFR50 only about 10% the initial clamp . Further tests were conducted using ODOT's structural torque specification of 435 ft-lb. In these tests , the standard hex bolts only about 30% of the initial clamp.

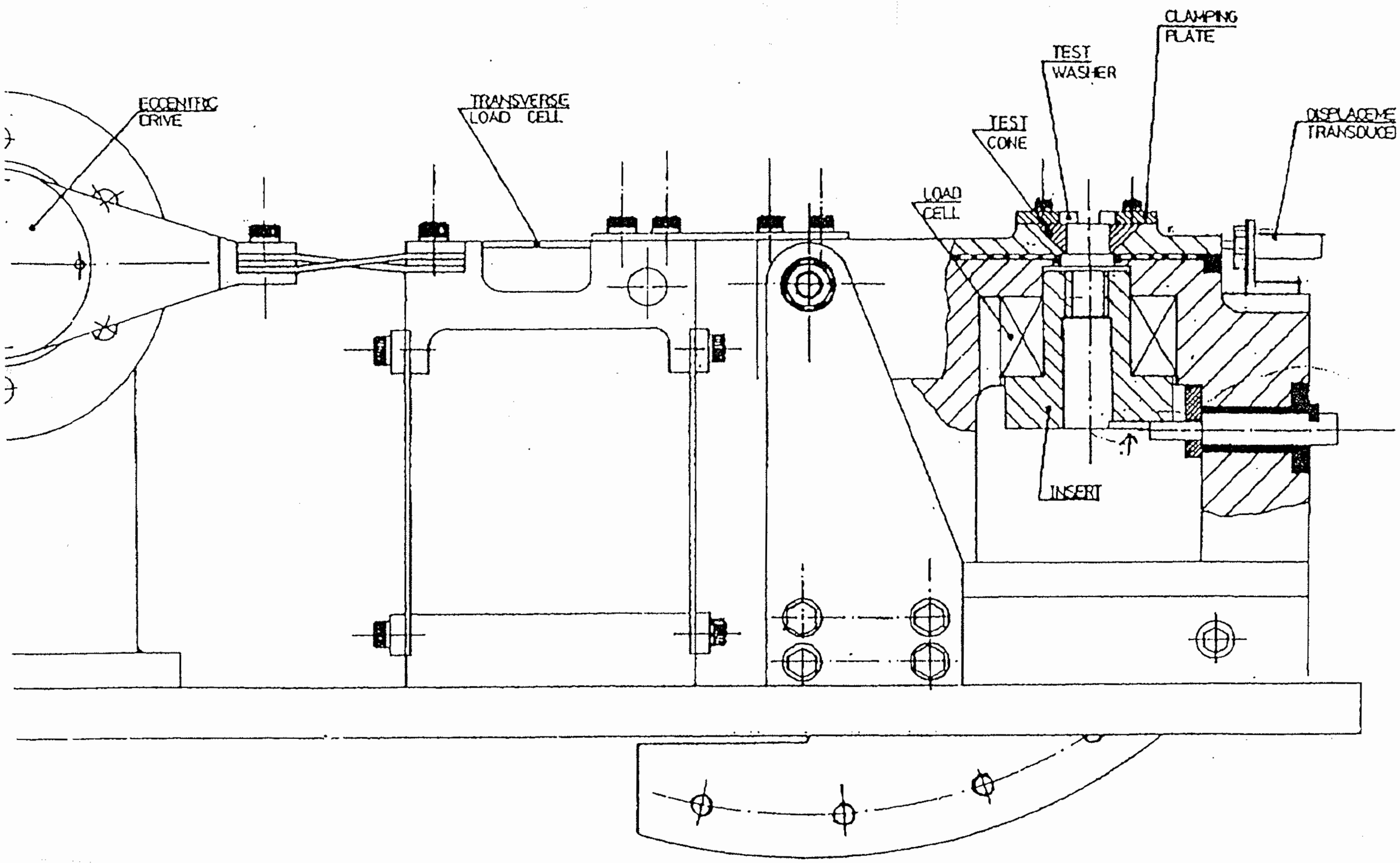

Figure 6.1 Junker Transverse Vibration Test Machine used by Huck Bolt Tech Center.

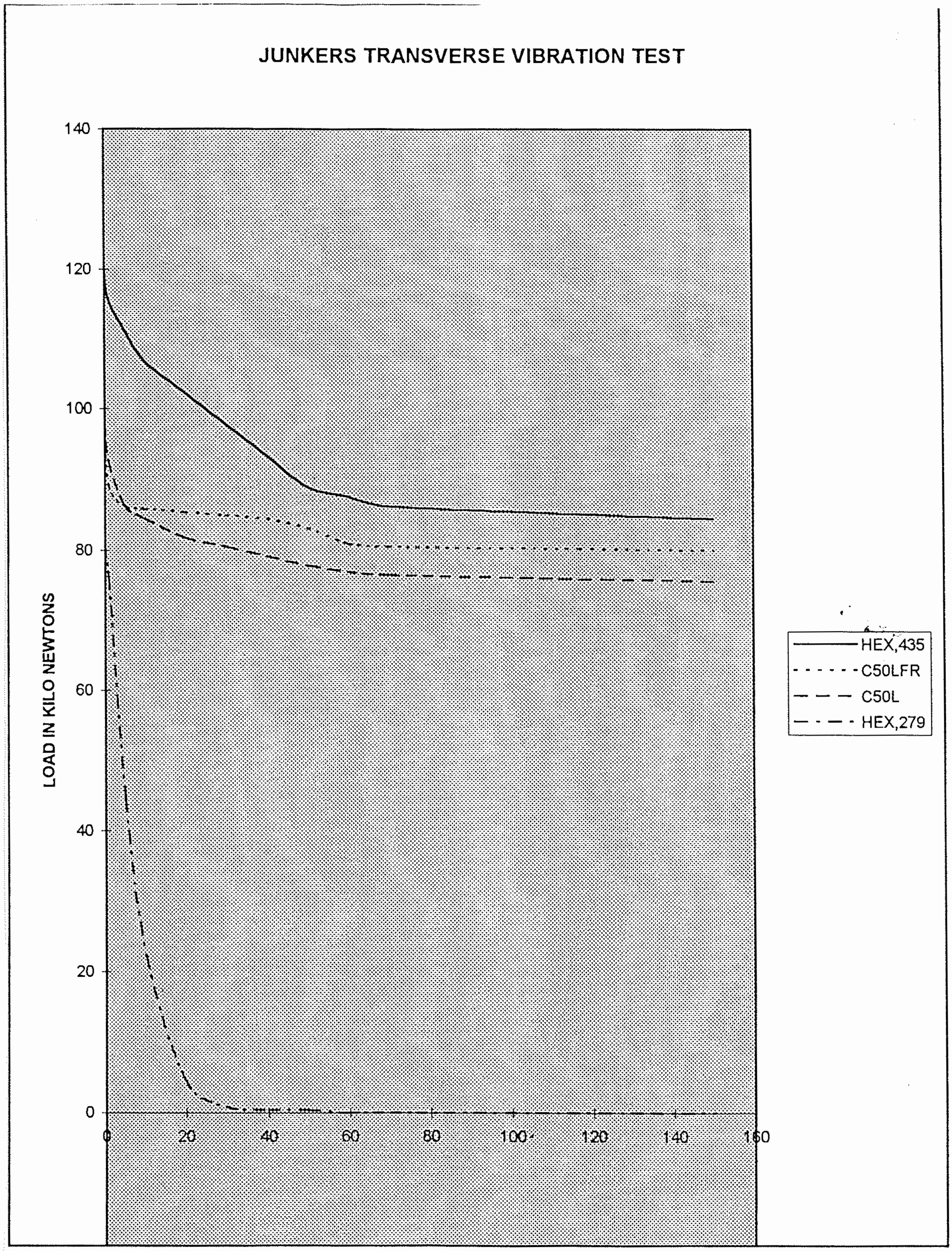

Figure 6.2 typical results of vibration testing by Hulk bolt

7.0 CONCLUSIONS

After three years of service, none of the LPC fasteners have vibrated loose. Total costs are about the same when higher material and equipment costs are balanced against lower installation and inspection costs. Thus the LPC system is an acceptable alternative for a standard nut and bolt system. Further results of Lab testing indicate that the LPC systems should only be used on flat surfaces such as those on the Morrison St Bridge ramp.

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