System Operations Advisory

SOA 2014-001
April 22, 2014

From Mark Geib, Engineer of Operations Field Services Division

MDOT
Division of Operations
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Section:
Operations Field Services Division

Questions regarding this Operations Advisory should be directed to:

Angie Kremer, P.E.
Traffic Incident Management Engineer
(517) 636-0247
KremerA@michigan.gov

Or

Chris Brookes
Work Zone Delivery Engineer
(517) 636 -0300
Brookesc@michigan.gov

Use of Lag Screws on Temporary Breakaway Wood Supports

FHWA has accepted that the use of lag screws in lieu of through bolts on temporary breakaway wood supports as a substitute to through bolt connections. The attached FHWA letter SS-36A provides the proper documentation to show that the crash test and evaluation criteria of the National Cooperative Highway Research Program (NCHRP) Report 350, is satisfied, and the device is eligible for reimbursement under the Federal-aid highway program.

Attached – SS-36A.

U.S. Department
of Transportation
**Federal Highway
Administration**

1200 New Jersey Ave., SE
Washington, D.C. 20590

April 22, 2014

In Reply Refer To:
HSST/SS-36A

Mr. Chris Brookes
Work Zone Delivery Engineer
Michigan Department of Transportation
P.O. Box 30050
Lansing, MI 48909

Dear Mr. Brookes:

This letter is in response to your request for the Federal Highway Administration (FHWA) to review a roadside safety system for eligibility for reimbursement under the Federal-aid highway program.

Name of system:	Breakaway wood sign supports with lag screws
Type of system:	Ground mounted breakaway sign support
Test Level:	NCHRP Report 350 Test Level 3
Testing conducted by:	(Federal Outdoor Impact Laboratory)
Task Force 13 Designator:	PDP20-24
Date of request:	January 23, 2014
Date of completed package:	April 3, 2014

Decision
The following device is eligible, with details provided in the form which is attached as an integral part of this letter:

- Breakaway wood sign supports with lag screws in lieu of through bolts.

Based on a review of crash test results certifying the device described herein meets the crash test and evaluation criteria of the National Cooperative Highway Research Program (NCHRP) Report 350, the device is eligible for reimbursement under the Federal-aid highway program. Eligibility for reimbursement under the Federal-aid highway program does not establish approval or endorsement by the FHWA for any particular purpose or use.

The FHWA, the Department of Transportation, and the United States Government do not endorse products or services and the issuance of a reimbursement eligibility letter is not an endorsement of any product or service.

Requirements
To be found eligible for Federal-aid funding, roadside safety devices should meet the crash test and evaluation criteria contained in the NCHRP Report 350 or the American Association of State Highway and Transportation Officials' Manual for Assessing Safety Hardware (MASH).

Description
The device and supporting documentation are described in the attached form and "Lag Screw and Through Bolt Connections."

Summary and Standard Provisions
Therefore, the system described and detailed in the attached form is eligible for reimbursement and may be installed under the range of conditions tested.

Please note the following standard provisions that apply to FHWA eligibility letters:

- This letter provides a AASHTO/ARTBA/AGC Task Force 13 designator that should be used for the purpose of the creation of a new and/or the update of existing Task Force 13 drawing for posting on the on-line 'Guide to Standardized Highway Barrier Hardware' currently referenced in AASHTO Roadside Design Guide.
- This finding of eligibility does not cover other structural features of the systems, nor conformity with the Manual on Uniform Traffic Control Devices.
- Any changes that may influence system conformance with NCHRP Report 350 criteria will require a new reimbursement eligibility letter.
- Should the FHWA discover that the qualification testing was flawed, that in-service performance reveals safety problems, or that the system is significantly different from the version that was crash tested, we reserve the right to modify or revoke this letter.
- You are expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.
- You are expected to certify to potential users that the hardware furnished has the same chemistry, mechanical properties, and geometry as that submitted for review, and that it will meet the crash test and evaluation criteria of the NCHRP Report 350.
- To prevent misunderstanding by others, this letter of eligibility is designated as number SS-36A and shall not be reproduced except in full. This letter and the test documentation upon which it is based are public information. All such letters and documentation may be reviewed at our office upon request.

- This letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented system for which the applicant is not the patent holder. The FHWA does not become involved in issues concerning patent law. Patent issues, if any, are to be resolved by the applicant.

Sincerely yours,

Michael S. Griffith

Michael S. Griffith
Director, Office of Safety Technologies
Office of Safety

Enclosures

Request for Federal Aid Reimbursement Eligibility Of Highway Safety Hardware

Submitter			
	Date of Request:	1/23/2014	○ New ○ Resubmission
	Name:	Chris Brookes Work Zone Delivery Er	Signature:
	Company:	Michigan Department of Transportatoin	
	Address:	Brookesc@michigan.gov Phone: 517-636-0300 Cell: 517-242-6486	
	Country:	USA	
	To:	Michael S. Griffith, Director FHWA, Office of Safety Technologies	

I request the following devices be considered eligible for reimbursement under the Federal-aid highway program.

System Type	Submission Type	Device Name / Variant	Testing Criterion	Test Level
'SS': Breakaway Sign Supports, Mailboxes, & other small sign supports	◉ Physical Crash Testing ○ FEA & V&V Analysis	Lag screw to fasten signs on wood posts	NCHRP Report 350	TL3

By submitting this request for review and evaluation by the Federal Highway Administration, I certify that the product(s) was (were) tested in conformity with the NCHRP Report 350 (Report 350) and that the evaluation results meet the appropriate evaluation criteria in the Report 350.

Identification of the individual or organization responsible for the product:

Contact Name:	Chris Brookes Work Zone Delivery Engineer	Same as Submitter ☒
Company Name:	Michigan Department of Transportatoin	Same as Submitter ☒
Address:	Brookesc@michigan.gov Phone: 517-636-0300 Cell: 517-242-6486	Same as Submitter ☒
Country:	USA	Same as Submitter ☒

PRODUCT DESCRIPTION

Modification to Existing Hardware null
The Michigan Department of Transportation is requesting FHWA's approval to use 3/8 lag screws in substitution of a 3/8 through bolts on a 1:1 basis on 4x6 wood post/sign configuration. The Attached Excel spreadsheet with calculations shows that for a 0 to +/-10 degree crash angle range, 3/8 lag screws substituted for 3/8 through bolts on a 1:1 basis is expected to have no adverse effects on the crashworthiness of the 4x6 wood post/sign configuration. The document also contains the Mathcad worksheet for reference.

CRASH TESTING

A brief description of each crash test and its result:

Required Test Number	Narrative Description	Evaluation Results
3-60 (820C)		WAIVER REQUESTED

Required Test Number	Narrative Description	Evaluation Results
S3-60 (700C)		WAIVER REQUESTED
3-61 (820C)	NCHRP Report 350 does not contain a pass/fail requirement for ground-mounted sign supports. Therefore the substitution of fasteners is allowed if the alternative is shown to have equivalent holding strength.	WAIVER REQUESTED
S3-61 (700C)		WAIVER REQUESTED

Full Scale Crash Testing was done in compliance with Report 350 by the following accredited crash test laboratory (cite the laboratory's accreditation status as noted in the crash test reports.):

Laboratory Name:	Federal Outdoor Impact Laboratory	
Laboratory Contact:		Same as Submitter ☐
Address:		Same as Submitter ☐
Country:		Same as Submitter ☐
Accreditation Certificate Number and Date:	ISO 17025; Cert. # AT-1565	

ATTACHMENTS

Attach to this form:

1) A copy of the full test report, video, and a Test Data Summary Sheet for each test conducted in support of this request.
2) A drawing or drawings of the device(s) that conform to the Task Force-13 Drawing Specifications [Hardware Guide Drawing Standards]. For proprietary products, a single isometric line drawing is usually acceptable to illustrate the product, with detailed specifications, intended use, and contact information provided on the reverse. Additional drawings (not in TF-13 format) showing details that are key to understanding the performance of the device should also be submitted to facilitate our review.

FHWA Official Business Only:

Eligibility Letter		AASHTO TF13	
Number	Date	Designator	Key Words
SS-36A	April 10, 2014		Wood Sign Supports Lag Screw

Calculation sheet to determine acceptable use limits of lag screw substituted sign connections for temporary signs mounted to wood posts

Prepared by S. Kahl 1/22/2014

Description	Value	Source
3/8 lag screw O.L.Y. strength (lb)	418	from mathcad sheet
3/8 lag screw withdrawal load (lb)	3461	from mathcad sheet
3/8 bolt O.L.Y. strength (lb)	1573	from mathcad sheet
3/8 bolt withdrawal load (lb)	1702	from mathcad sheet
sign mass (slug)	3.1	assumed 100 lb weight
car mass (slug)	61.6	NCHRP report 553 section 8.4 vehicle weight 1,984 lb with occupant
Maximum delta V after impact (ft/s)	16.4	NCHRP report 350 maximum occupant collision velocity

Notes: Impact force = m*dV/dt, where m = post mass, dV = change in velocity, and dt = vehicle transit time for a 3.5 in wood post (0.29 ft) at impact velocity. Impact velocity and delta v taken from test results outlined in FHWA approval letter HNG-14/SS-36

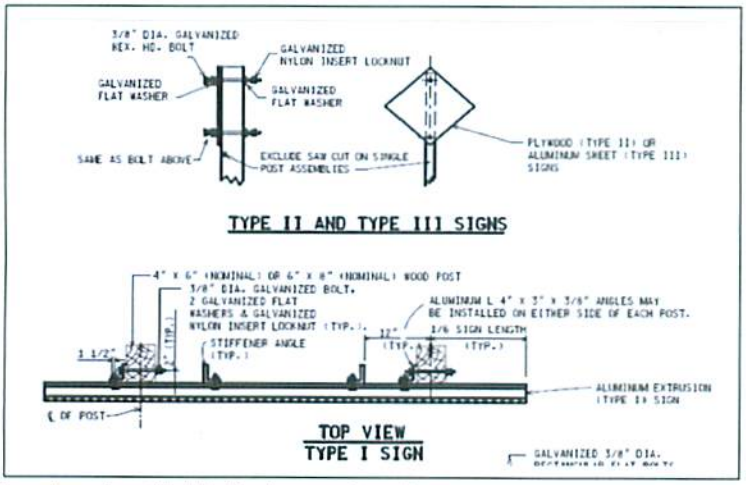
head-on impact crash test post configuration	V at impact (ft/s)	dV after impact (ft/s)	dt (transit time, s)	head-on impact force (lb)	# bolts 0 degrees	# lag screws 0 degrees
single unmodified	30.3	13.2	0.010	4269	2.51	1.23
	89.3	5.0	0.003	4774	2.80	1.38
dual-modified (holes drilled)	29.3	8.6	0.010	2698	1.59	0.78
	85.9	7.5	0.003	6890	4.05	1.99
dual-modified (holes drilled), one post hit	31.4	7.4	0.009	2487	1.46	0.72
	88.8	3.0	0.003	2847	1.67	0.82

test case for angled impact	angle (degrees)	sin angle	lateral force (lb)	# lag screws	target
single unmodified, 30.3 ft/s	6.5	0.1132	483	1.16	2
	8.0	0.1392	594	1.42	
	10.0	0.1736	741	1.77	
	12.0	0.2079	888	2.12	
	15.0	0.2588	1105	2.64	
	20.0	0.3420	1460	3.49	
	25.0	0.4226	1804	4.32	
single, unmodified, 89.3 ft/s	6.5	0.1132	540	1.29	2
	8.0	0.1392	664	1.59	
	10.0	0.1736	829	1.98	
	12.0	0.2079	992	2.37	
	15.0	0.2588	1235	2.96	
	20.0	0.3420	1633	3.91	
	25.0	0.4226	2017	4.83	
dual,modified (holes drilled), 29.3 ft/s	6.5	0.1132	305	0.73	4
	8.0	0.1392	375	0.90	
	10.0	0.1736	468	1.12	
	12.0	0.2079	561	1.34	
	15.0	0.2588	698	1.67	
	20.0	0.3420	923	2.21	
	25.0	0.4226	1140	2.73	
dual,modified (holes drilled), 85.9 ft/s	6.5	0.1132	780	1.87	4
	8.0	0.1392	959	2.29	
	10.0	0.1736	1196	2.86	
	12.0	0.2079	1433	3.43	
	15.0	0.2588	1783	4.27	
	20.0	0.3420	2357	5.64	
	25.0	0.4226	2912	6.97	
dual, modified (holes drilled), one post hit, 31.4 ft/s	6.5	0.1132	780	1.87	4
	8.0	0.1392	959	2.29	
	10.0	0.1736	1196	2.86	
	12.0	0.2079	1433	3.43	
	15.0	0.2588	1783	4.27	
	20.0	0.3420	2357	5.64	
	25.0	0.4226	2912	6.97	
dual, modified (holes drilled), one post hit, 88.8 ft/s	6.5	0.1132	780	1.87	4
	8.0	0.1392	959	2.29	
	10.0	0.1736	1196	2.86	
	12.0	0.2079	1433	3.43	
	15.0	0.2588	1783	4.27	
	20.0	0.3420	2357	5.64	
	25.0	0.4226	2912	6.97	

Green shaded area represents anticipated acceptable performance with lag screw substitution for sign to post connection.

This solver is intended to provide the equivalent strength of lag bolts as compared to through bolts for temporary sign on wood posts on the typical WZD-100 page 9 of 11. References: 1. Forest Products Laboratory *"Wood handbook — Wood as an engineering material."* General Technical Report FPL-GTR-190. Madison, WI:, U.S.Department of Agriculture, Forest Service, Forest Products Laboratory, April 2010. 2. NDS 2001, American Forest and Paper Association, the American Wood Council.

Figure 1. Illustration of temporary sign details from WZD-100 page 9



Input section (highlighted = user input)

$D := 0.375 \cdot in$ — D = Lag screw shank diameter

$Dr := 0.271 \cdot in$ — Dr = Lag screw root diameter, 0.271 in for 3/8 in., and 0.371 for 1/2 in.

$Db := 0.375 \cdot in$ — Db = bolt diameter

$L_{lag} := 4.5 \cdot in$ — L_{lag} = nominal length of lag screw. **For all posts, use 4-1/2 in.** This length is sufficient for the full embedment of the threaded portion, and such that the withdrawal load will not exceed the tensile strength of the lag screw.

$L_{bolt} := 5.5 in$ — L_{bolt} is the bolt length in bearing against the wood surface, 5.5 in for a 4x6 post, and 7.5 in for a 6x8 post. This assumes the bolt is installed through the front face.

$Fyb := 45000 \cdot \frac{lb}{in^2}$ — Minimum bending yield strength of lag screw and,ASTM A307 Grade A (36 ksi Fy) bolt. Reference AITC technical note 8.

$F_t := 60000 \frac{lb}{in^2}$ — Tensile strength of ASTM A307 Grade A bolts and lag screws.

$L_t := \left(\frac{1}{2} \cdot L_{lag} + \frac{1}{2} \cdot in\right)$ — Lag screw threaded length (T) from NDS Appendix L (T = 1/2 x nominal length + 1/2 in)

$L_t = 2.75 in$

$ts := 0.50 \cdot in$ — ts is sign member thickness, 0.080 in. for aluminum sheet for Type III sign, or 0.50 in. for plywood Type II.

$G := 0.55$ — G = specific gravity of wood based on overdry weight and volume at 12% moisture content (unitless). Southern Pine is actually comprised of 4 primary mixes, longleaf, slash, loblolly, and shortleaf pine. G is averaged for Southerin Pine from the above species in Table 5-3b of FPL wood handbook.

$$Fc_{perp} := \left(\frac{790 + 960 + 820 + 1020}{4}\right)\frac{lbf}{in^2}$$

$$Fc_{par} := \frac{7130 + 8470 + 7270 + 8140}{4}\frac{lbf}{in^2}$$

Southern Pine (12% moisture) compressive strength is averaged from individual species for both perpendicular to grain and parallel to grain. FPL wood handbook table 5-3b.

Section 1: ultimate withdrawal load (direct tension)

$$Lp_{ult} := \begin{cases} 7 \cdot D & \text{if } G \geq 0.61 \\ 7 \cdot D + 26.3 \cdot (0.61 - G)in & \text{otherwise} \end{cases}$$

Penetration length (Lp_{ult}) of the threaded part to develop the lag screw tensile (ultimate) strength, 7 times the shank diameter for G ≥ 0.61, and 10 to 12 times the shank diameter for G < 0.42, with interpolation between. FPL wood handbook pages 8-12 and 8-13.

$$Lp_{ult} = 4.203\,in$$

$$L_p := L_{lag} - ts - \frac{1}{4}in - \frac{5}{16}in$$

$$L_p = 3.438\,in$$

Penetration length of the lag screw threaded portion, subtracting the aluminum or plywood sign thickness, 1/4 in. washer thickness, and the 5/16 in. tapered portion of the threads (dimension E from NDS Appendix L). Pullout resistance does not include tapered part of threads..

$$Check := \begin{cases} \text{"OK"} & \text{if } L_p \leq Lp_{ult} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

In determining the withdrawal resistance, the allowable tensile strength of the lag screw at the net (root) section should not be exceeded (FPL wood handbook page 8-12).

Check = "OK"

$$p_{ult} := 8100 \cdot G^{\frac{3}{2}} \cdot D^{\frac{3}{4}} \cdot L_p \cdot \frac{lb}{in^{1.75}}$$

p_{ult} is the ultimate withdrawal load (lb). FPL wood handbook equation 8-14b. The tensile strength (Ft) of the lag screw at the net (root) section is exceeded if the use ratio (U) > 1.0, indicating failure of bolt before pullout. Note that the leading constant is different from NDS Equation 11.2-1, as the FPL equation gives ultimate withdrawal load versus NDS allowable design withdrawal loads.

$$p_{ult} = 5442\,lb$$

$$\sigma := \frac{p_{ult}}{\pi \cdot \frac{Dr^2}{4}} \qquad \sigma = 94355\frac{lb}{in^2} \qquad U := \frac{\sigma}{F_t} \qquad U = 1.573$$

$$p_{lag} := \frac{p_{ult}}{U}$$

p_{lag} is the adjusted lag screw withdrawal load based on the limiting tensile strength of the lag screw.

$$p_{lag} = 3461\,lb$$

$$\frac{L_{bolt}}{Db} = 14.667$$

Used for calculating long to short bolt bearing stress ratios (FPL wood handbook figures 8-9 through 8-11).

$$p_{bolt} := \pi \cdot \left[\frac{(1.25in)^2 - (0.4060in)^2}{4} \cdot 0.5 \cdot 0.40 \cdot Fc_{par}\right]$$

p_{bolt} calculates bolt withdrawal load based on the net cross section area (wood bearing area) multiplied by the adjusted parallel to grain compressive strength, Fc_{par}. Reductions of 0.50 and 0.40 from FPL wood handbook Figure 8-9 are applied. The bearing area is assumed to be the 3/8 in washer (i.d. 0.4060 in, o.d. 1.250 in).

$$p_{bolt} = 1702\,lbf$$

Section 2: Lateral resistance (shear)

$Fe := 16600 \cdot G^{1.84} \cdot \frac{lb}{in^2}$ Fe is the dowel bearing strength of wood and is empirically related to the specific gravity. FPL wood handbook Equation 8-3b.

$Fe = 5526 \frac{lb}{in^2}$

$Fem := Fe$ Setting the dowel bearing strength of the main member equal to the bearing strength of the wood post

$Fes := 3350 \frac{lb}{in^2}$ The dowel bearing strength of Aluminum is 56,000 psi. For plywood signs, set Fes equal to 3350 psi (NDS Table 11.3.2B).

$Re := \frac{Fem}{Fes}$ Re is the ratio of dowel bearing strength of the main member to the side member.

$k3 := -1 + \sqrt{\frac{2 \cdot (1 + Re)}{Re} + \frac{Fyb \cdot (2 + Re) \cdot Dr^2}{2 \cdot Fem \cdot ts^2}}$ k3 is a constant in the offset lateral yield strength equation.

$k3 = 1.753$

$P_s := L_p - L_t$ P_s is the penetration length of the unthreaded portion of the shank, L_p accounts for the sign and washer thickness.

$R_p := \frac{P_s}{D}$

$R_p = 1.833$ Rp is the ratio of penetration distance of shank into wood post to the shank diameter. Ratios greater than 1.0 allow for increase in the offset lateral yield strength. The strength multiplier S is calculated from FPL wood handbook Table 8-12.

$$S := \begin{cases} 1.0 & \text{if } R_p \le 1.0 \\ 1.0 + \left(\frac{-0.9881 \cdot R_p^2 + 13.083 \cdot R_p - 4.4286}{100} \right) & \text{otherwise} \end{cases}$$

$S = 1.162$

$Z1 := S \cdot Dr \cdot ts \cdot Fes$ Z1, Z3, and Z4 are the lag screw offset lateral yield strength wood bearing/fastener bending failure modes. Z1 is for mode Is, Z3 is for mode IIIs, and Z4 for mode IV. See Figure 2. All three evaluated for controlling (lowest strengh) mode. See FPL wood handbook Table 8-5. Also refer to NDS Table 11.3.1A, Yield Limit Equations.

$Z1 = 528\,lb$

$Z3 := \frac{S \cdot k3 \cdot Dr \cdot ts \cdot Fem}{2 + Re}$

$Z3 = 418\,lb$

$Z4 := S \cdot Dr^2 \cdot \sqrt{\frac{1.75 \cdot Fem \cdot Fyb}{3(1 + Re)}}$

$Z4 = 632\,lb$

$\min(Z1, Z3, Z4) = 418\,lb$

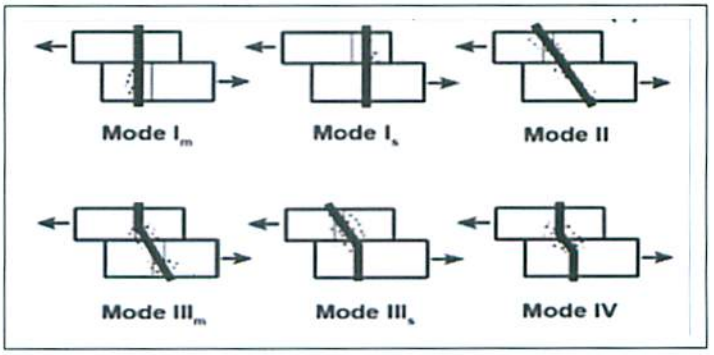


Figure 2. FPL wood handbook Figure 8-5, showing various failure modes for wood-bearing and fastener-bending yields.

Bolts

$p_{bt} := Fc_{perp} \cdot 1.7 \cdot 0.50 \cdot L_{bolt} \cdot Db$

$p_{bt} = 1573\,lbf$

p_{bt} calculates perpendicular-to-grain loading, by multiplying the species compression perpendicular-to-grain proportional limit stress (Fc.perp) by (a) the appropriate factor from Figure 8–11, (b) the appropriate factor from Figure 8–10, and (c) L_{bolt} x Db. FPL wood handbook, page 8-15.

Lateral force required to shear Type II plywood sign

$Fply := 3350psi \cdot 0.50in \cdot D$

$Fply = 628\,lbf$

$\min(p_{bt}, Fply) = 628\,lbf$

Dowel bearing strength of plywood (3,350 psi) multiplied by the sign thickness x lag screw diameter. This will be the limiting failure loading in lateral offset yield, as the sign will tear away from the connection.

Lateral force required to shear Aluminum sign

$Falum := 56000psits \cdot D$

$Falum = 10500\,lbf$

$\min(p_{bt}, Falum) = 1573\,lbf$

Dowel bearing strength of Al multiplied by the sign thickness x lag screw diameter. this will be the limiting failure loading in lateral offset yield, as the sign will tear away from the connection.

Summary

		withdrawal load (lb)		offset lateral yield strength (lb) - Type II signs		offset lateral yield strength (lb) - Type III signs		**Lag Screws required per bolt Type II signs**	**Lag Screws required per bolt Type III signs**
Fastener Type	diameter (in)	4x6 post	6x8 post	4x6 post	6x8 post	4x6 post	6x8 post	xxxxxxxxxxxxxxxxxxxxx	
Lag Screw (4.5 in. length)	0.375	3461	3461	418	418	715	715	this section not applicable	
	0.500	6486	6486	694	694	1249	1249		
3/8 in. Bolt	0.375	1702	1702	628	628	1573	1680	xxxxxxxxxxxxxxxxxxxxx	

***NDS 11.1.3 requires predrilling for lag screws with diameter greater than 3/8".** Lag screws must meet ANSI/ASME Standard B18.2.1 or ASTM A307 Grade A, with a minimum bending yield strength of 45,000 psi.