Florida Department of Transportation
605 Suwannee Street
Tallahassee, FL 32399-0450

RICK SCOTT
GOVERNOR

ANANTH PRASAD
SECRETARY

STRUCTURES DESIGN BULLETIN 12-14
(FHWA Approved: November 20, 2012)

DATE: November 20, 2012

TO: District Directors of Operations, District Directors of Production, District Design Engineers, District Construction Engineers, District Geotechnical Engineers, District Structures Design Engineers

FROM: Robert V. Robertson, P. E., State Structures Design Engineer

COPIES: Brian Blanchard, Tom Byron, Duane Brautigam, David Sadler, Jeffrey Ger (FHWA), Charles Boyd

SUBJECT: Modification of Design Process for Polymeric Fender Systems

REQUIREMENT

2012 Structures Manual, Volume 1: Structures Design Guidelines (SDG)

Remove SDG, Section 3.14 and replace it with the new SDG, Section 3.14 as provided in Attachment A.

BACKGROUND

The current procedure for implementing polymeric bridge fender system designs on FDOT projects was set by the release of Structures Design Bulletin C11-08 in July, 2011. This procedure requires the use of QPL listed piling configurations which are predesigned by the manufacturers for various ranges of energy absorption capacity. There are inherent issues with the current system which do not allow for manufacturers to maximize the efficiency of their fender systems. As with many other foundation elements, the design is relative to the site-dependent soil conditions and, in the case of the fender systems, the freestanding pile length which is affected by the depth of the channel and tidal fluctuations. The SDG specifies assumptions for soil and freestanding height that must be used by the manufacturers for the design of their QPL listed piling configurations. These assumptions do not typically match the actual site conditions and thus in many cases the QPL listed piling configurations cannot be used and a project specific design must be developed. In addition, the sizes of the wales are restricted to 10” x 10” plastic members which, in many cases, control the design and do not allow for optimum efficiency of the system.

After meeting with industry representatives, we have determined the best way to provide more cost effective systems and optimized designs is to remove the QPL listing requirement and shift acceptance criteria toward an Approved Fabricator's list. This new process will take time to implement; therefore, in the interim, at the Contractor's option, either a QPL listed piling configuration may be used or a Contractor-developed custom fender system design may be used. The SDO will review Contractor-developed designs for acceptance based on site-specific soil and pile free standing height parameters. This interim process will allow the SDO to ensure uniformity in design methodologies while allowing better optimization of fender designs.

IMPLEMENTATION

This policy is effective for all projects let after July 1, 2013 containing bridge fender systems. Implementation of this policy is at the District's discretion for all projects let prior to July 1, 2013 under the Cost Savings Initiative Proposal provisions of Specification Section 4-3.9.

For all projects having letting dates scheduled after January 1, 2015, all projects will be Contractor design only.

See the Basis of Estimates Manual, Sections 471-1 thru 471-3 for Pay Item information.

Construction Specifications: Specifications Sections 471 and 973 will be revised for the July 2013 Workbook as shown in Attachment B.

CONTACT

If you have any questions, please contact:

Gevin J. McDaniel, P.E.
Senior Structures Design Engineer
Florida Department of Transportation
605 Suwannee Street, MS 33
Tallahassee, FL 32399-0450
Phone (850)-414-4284
gevin.mcdaniel@dot.state.fl.us

RVR/ gjm
Attachments (as required)

Attachment A

Structures Design Guidelines
Section 3.14

3 SUBSTRUCTURE, RETAINING WALLS AND SOUND BARRIERS

3.14 FENDER SYSTEMS

3.14.1 General

A. Bridge fender systems serve primarily as navigation aids to vessel traffic by delineating the shipping channel beneath bridges. Fender systems must be robust enough to survive a multitude of bumps and scrapes from barge traffic, while being sufficiently flexible to absorb kinetic energy when redirecting an errant barge or other vessel. It is expected that this type of design will minimize the potential for damage to vessels and fenders during a minor collision while being able to redirect some vessel impacts that would otherwise destroy a more rigid style fender system. To maintain the flexibility of the fender system and its ability to absorb kinetic energy and smoothly redirect errant vessels, do not connect the fender system to a pier or footing. Limit deflections to avoid contact with pier footings when possible and to allow for vessel impacts without potential for pocketing or snagging and to avoid unnecessary damage to, and maintenance of, the fender system. Coordinate with the District Structures Design Engineer or District Structures Maintenance Engineer to determine the maximum allowable deflection of the fender system acceptable for the project. Place these required fender system deflection limitations in the plans.

B. The Department determines when fender systems or other protective features are required and requests U.S. Coast Guard (USCG) concurrence with plan details and locations. Coordination with the Army Corps of Engineers and local government agencies is also encouraged as they may have plans that could affect the channel alignment/depth and/or type/volume of vessel traffic.

C. A fender system will be required for the majority of bridges over navigable waterways in Florida under the jurisdiction of the USCG. In some cases, circumstances such as deep water, poor soil conditions and /or heavy vessel traffic will lead to long span designs of bridges. If the bridge span is approximately 2.5 times the required navigation channel and the navigation channel is centered on the span, omit a fender system unless required by the USCG. Each bridge site is unique and the USCG will evaluate the Department's plans based on local characteristics such as accident history, water velocities and cross currents, geometry of the channel, etc. If a fender system is omitted, a conservative approach should be taken with respect to the minimum pier strength requirements as developed with the Vessel Collision Risk Analysis.

D. Acceptable delivery methods of fender system plans include:

1. Design Standards Index 21900 with associated QPL listed pile configurations for use at locations with or without steel-hulled commercial barge traffic.

2. A Contractor prepared custom designed fender system based on site-specific design information for use at locations with or without steel-hulled commercial barge traffic. A Contractor prepared custom design is required where:
    a. The "Required Freestanding Pile Height" is greater than the "Freestanding Pile Height" assumed in Paragraph 3.14.3.E.1.
    b. The standard geometry shown on Design Standards Index 21900 cannot be used.
3. If allowed by the District, Design Standards Index 21930 for use only at locations where steel-hulled commercial barge traffic is non-existent.

Commentary: A Contractor prepared custom design will be allowed, at the Contractor's option, on all projects per the Specifications. The SDO and polymeric fender industry both prefer the use of Contractor prepared custom designs. This delivery method will ensure optimization and efficiency of the fender system, thereby reducing the cost.

E. Dolphins and islands can be used to protect existing bridge substructures that were not designed to resist vessel collision loads and in some cases are used to protect the substructures of bridges located at port facilities. Typically the use of dolphins and islands is discouraged as they also represent a hazard to vessels, aggravate scour and increase water flow velocities. The use of dolphins and islands will require customized designs and usually will include extensive hydraulic and geotechnical evaluations.

3.14.2 EOR's Design Procedure

A. Use the following procedure for determining the fender system type and associated “Required Energy” (required energy absorption capacity), as defined below, that are to be shown in the plans.

B. Determine if steel hulled barge traffic is present using the Past Point map link below:

   http://www.dot.state.fl.us/structures/pastpointmaps/vppm.shtm

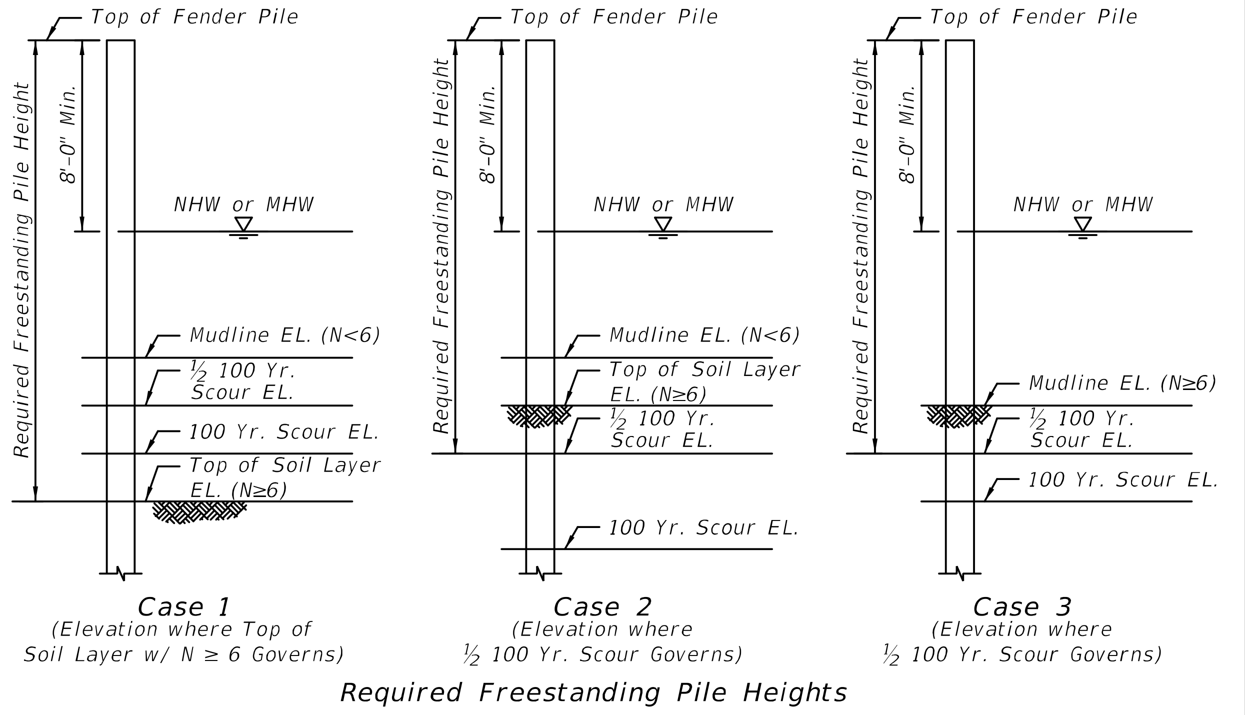
   If there is a Past Point at the fender location, steel-hulled commercial barge traffic is present.

C. Determine the "Required Freestanding Pile Height" as shown in Figure 3.14.2-1 using project specific conditions. The "Required Freestanding Pile Height" is defined as the following:

   High water elevation plus 8' minimum (from Index 21900), minus the lesser of:

   - Elevation of top of soil layer with N ≥ 6, OR
   - Elevation of top of existing ground line minus ½ predicted 100 year scour depth.

Figure 3.14.2-1 Required Freestanding Pile Heights



D. Fender system design and energy absorption requirements where steel-hulled commercial barge traffic exists:

1. Use fender systems with polymeric piles. These fender systems should resist the “Required Energy” which is defined as the “Minimum Energy” (minimum energy absorption capacity) obtained from Table 3.14.2-1 plus any “Additional Energy” (additional energy absorption capacity) at the discretion of the District Structures Design Engineer or District Structures Maintenance Engineer. The “Minimum Energy” is based on the fender system location and the 90th percentile of barge traffic at that location. When determining the need for “Additional Energy” requirements, consider site conditions, past accident history, maintenance records, volume and size of vessel traffic and bridge main span length relative to channel width. Contact the SDO for assistance in determining the magnitude of “Additional Energy” and/or if the 100th percentile of barge traffic is desired.

2. Determine the Past Point of the fender system using the Past Point map link provided above.

3. Using the Past Point of the fender system obtained from the appropriate Past Point map, enter Table 3.14.2-1 to determine the “Minimum Energy”.

4. When QPL listed pile configurations are being considered for use, verify that the project specific “Required Freestanding Pile Height” is within the design assumptions listed in 3.14.3.E.1 and the fender height requirements shown on Design Standards Index 21900, and that a QPL listed pile configuration is available that provides the necessary “Required Energy”. Include half of the scour

depth determined for the 100-yr storm when determining "Required Freestanding Pile Height". Where "Required Energy" values exceed the "Energy Capacity" (energy absorption capacity) of the QPL listed polymeric pile configurations, configurations having the highest "Energy Capacity" of all approved polymeric pile configurations may be used at the discretion of the District. Otherwise use a custom fender system design.

5. Use Design Standards Index 21900 unless a custom design is required. See the Instructions for Design Standards (IDS) Index 21900 for more information and plan content requirements.

6. Establish fender location so as to provide the required horizontal navigation clearance and where economically feasible also provide an offset of 10 feet between the back of the fender and the near face of the adjacent pier or footing.

Table 3.14.2-1 Table of Past Points and associated Minimum Energies

Past Point	Minimum Energy (k-ft)	Past Point	Minimum Energy (k-ft)	Past Point	Minimum Energy (k-ft)	Past Point	Minimum Energy (k-ft)
1	466	14	201	27	455	40	273
2	437	15	445	28	199	41	248
3	205	16	557	29	199	42	179
4	233	17	571	30	233	43	179
5	213	18	434	31	423	44	190
6	218	19	2426	32	206	45	190
7	218	20	244	33	218	46	199
8	492	21	237	34	188	47	261
9	179	22	179	35	218	48	261
10	54	23	412	36	221	49	206
11	54	24	199	37	273	50	209
12	54	25	458	38	1387	51	208
13	254	26	479	39	2426	52	208

Commentary: The "Minimum Energy" for each Past Point shown in Table 3.14-1 has been determined by following the procedure as outlined in the commentary of the AASHTO "Guide Specification and Commentary for Vessel Collision Design of Highway Bridges", Second Edition, 2009, Section C3.8. Assumptions made in determining the "Minimum Energy" are as follows:

μ = *0.15*

α = *15 degrees*

V = 6.4 fps

W = as determined by the maximum barge weight plus the tug weight specific to each Past Point (If needed, contact the SDO for more information).

E. At locations where barge traffic is nonexistent, use fender systems with either polymeric piles or prestressed concrete piles at the discretion of the District Structures Design Engineer or District Structures Maintenance Engineer. The “Required Energy” for these fender systems with polymeric piles is 38 (k-ft) which is equal to the “Energy Capacity” of the fender system shown in Index 21930. See the Instructions for Design Standards (IDS) Index 21900 or 21930, as applicable, for more information and plan content requirements.

F. When a Contractor prepared custom design is required and the use of polymeric piles is preferred by the District, fully detail the custom fender system geometry in the plans using the standard geometry shown on Design Standards Index 21900 to the maximum extent possible. The minimum length of a custom fender system using polymeric materials is 32 feet. If the fender system length is less than 32 feet and/or the angle breaks between adjacent panels exceed 8 degrees, follow the custom fender system design procedures described in the following section (3.14.2.G) or as directed by the District.

In the plans, list the "Required Energy", "Required Freestanding Pile Height" and the in-situ soil properties including unit weight, angle of internal friction (phi) and subgrade modulus.

Include the following associated Plan Notes:

1. This information is to be used by the Contractor's EOR to complete the custom fender system design utilizing "Required Energy", "Required Freestanding Pile Height" and site-specific soil properties using polymeric fender system members meeting the Specification requirements.
2. Submit shop drawings and associated calculations to the SDO for review and approval.

See also the Instructions for Design Standards (IDS) Index 21900 for examples of applicable information and plan content requirements. Develop and include in the plans package a Modified Special Provision for Specification 471 that deletes the requirements for using QPL listed pile configurations.

Commentary: In this scenario, the Contractor's EOR develops a custom fender system design using polymeric fender system members meeting the Specification requirements. The fender system geometry, “Required Energy”, “Required Freestanding Pile Height” and soils information will be shown in the plans. The custom fender system design is submitted by the Contractor to the SDO for review and approval using the shop drawing process. This will allow the SDO to ensure uniformity in design methodologies and act as a means for Quality Assurance in lieu of QPL listings.

G. When a custom fender system design is required and the District prefers the use of pile types or materials in lieu of polymeric, fully detail the custom fender system in the plans utilizing the selected pile type. Utilize the standard geometry, wales and dimensional lumber shown on Design Standards Index 21900 as applicable. Include custom Data Tables in the plans based on those used for Design Standards Index 21900 and place the “Required Energy” in the Data Table Notes. Delete from the Data Table Notes the note requiring that a QPL listed fender system configuration be used. See also the Instructions for Design Standards (IDS) Index 21900 for examples of applicable information and plan content requirements. Develop and include in the plans package a Modified Special Provision for Specification 471 that deletes the requirements for using polymeric piles. Develop and include in the specifications package a Modified Special Provision for the piles as required.

Commentary: In this scenario, the EOR develops a custom fender system design and pile configurations using piles other than polymeric piles and includes the complete design in the plans.

H. When a custom fender system design is required due to geometric constraints as specified in 3.14.1.D.2.b, fully detail the custom fender system geometry and list the “Required Energy” in the plans. When using polymeric piling configurations as listed on the QPL, the minimum length of a custom fender system is 32 feet. Utilize the standard geometry to the maximum extent possible, and the standard piles, wales and dimensional lumber shown on Design Standards Index 21900 or 21930 as appropriate. Include the Data Tables in the plans based on those used for Design Standards Index 21900 or 21930 as appropriate. See the Instructions for Design Standards (IDS) Index 21900 or 21930, as appropriate, for applicable information and plan content requirements.

I. Miscellaneous Considerations:

1. The fenders should flare at the same points directly opposite each other measured perpendicular to the centerline of the navigation channel. The minimum distance from the superstructure coping to the beginning of the fender flare is 10 feet.
2. At the discretion of the District, alternate materials may be used for piles or wales when determined by life cycle cost analysis to be more feasible. The use of alternate materials will necessitate a custom design.
3. A Pile Installation Constructability Review must be performed by the Geotechnical Engineer to verify that the pile tips shown in the plans can be reasonably obtained by the Contractor, and the use of any penetration aids (jetting, preforming, etc.) will not jeopardize adjacent structures.
4. Investigate and resolve conflicts between the proposed fender system and existing utilities or structures.
5. Prestressed concrete fender piles generally have a short life expectancy, are considered sacrificial, and no corrosion protection is required beyond the use of concrete class as shown in Table 1.4.3-1.

3.14.3 Polymeric Pile Supplier Engineer's Development Procedure for QPL Listed Pile Configurations

A. Use the following procedure and the requirements in Specification 471 for developing individual pile configurations for each “Energy Capacity” level intended for listing on the QPL.

B. Develop pile configurations and connection details for fender systems that result in flexible, energy absorbing structures maximizing the efficiency of the proprietary polymeric pile. Use the basic geometry of the fender system, standard connection details if possible, and limitations for pile spacing and pile clusters as shown in Design Standards Index 21900. The minimum designed clear spacing between pile clusters is 30 inches. Include capacities of, and interaction between, the wales and piles in the analysis.

C. Pile configuration drawings submitted for listing on the QPL shall be based on the design methodology listed below and shall include but not be limited to the following:

- Energy Capacity” of the fender system with the applicable pile configuration
- Pile configuration and layout based on and compatible with the standard geometry shown on Design Standards Index 21900
- General notes
- Minimum pile embedment into soils having an N value greater than or equal to 6
- Pile material properties including fill material used for hollow piles (when required by design) and required admixtures
- Pile physical properties, e.g., modulus of elasticity, yield strength, moment of inertia, etc.
- Pile-to-wale and pile-to-pile connection details for pile sections remaining hollow under service conditions and/or if different from those shown on Design Standards Index 21900
- Any supplier required limitations regarding pile installation techniques or other typical construction practices permitted by FDOT construction specifications, e.g., full length pile driving versus jetting/driving combination
- A note for each pile configuration stating: “The pile configuration shown is to be used with Design Standards Index 21900.”

D. Resistance Factors: For piles having a non-ductile failure mode, reduce the flexural resistance of the pile determined in accordance with Specification 471 by 20%. A non-ductile pile is one that has a ductility factor less than 1.25. The ductility factor is defined as the ratio of the ultimate displacement to the yield displacement.

E. Use the following design methodology as:

1. Use the following assumptions in the design of the pile configurations:

   a. “Freestanding Pile Height” = 30 ft.

   b. Soil properties are to be a weak submerged sand with phi = 30 degrees and a subgrade modulus of 20 pounds per cubic inch. These values correspond to a soil having a blow count, N, of approximately 6.

   c. Limit fender system deflection to where the uppermost wale remains above the high water elevation.

   d. Length of fender system = 32 ft. total length minimum (two 16 ft. interior sections) plus any number of additional 16 ft. interior sections as required so as to balance and optimize the design for a given "Energy Capacity" considering the interaction between the piles and wales.

   e. Utilize a straight fender system with no angle break between sections.

   f. Use eight 10" x 10" wales separated by 8" x 8" spacer blocks

2. Design a trial fender system using the assumptions listed above. Use a computer program that allows modeling of cantilevered piles embedded in weak soil while incorporating soil strengths using P-Y curves and that allows modeling of pile-to-wale interaction, e.g., FB-MultiPier. Consider both wale and pile moment capacities to determine magnitude(s) and location(s) of the critical load(s). Create multiple load cases applying incrementally increasing lateral static load(s) located between and directly at the pile clusters. Apply the concentrated load(s) for each load case within 8 ft. of the center of the fender model. These loads may be equally distributed between the two uppermost wales. Develop a force versus displacement diagram from the analysis, then compute the energy based on the area under the curve. This area represents the fender system's potential energy available to redirect or possibly bring an errant vessel to rest. Report the minimum calculated “Energy Capacity” from the multiple load cases as the “Energy Capacity” for the subject pile configuration.

Commentary: In FB-MultiPier, select "Gross Properties" for the Section Type and "Linear" for the behavior of the main structural members. By selecting these choices, the P-Delta effects will be ignored; therefore, the resulting displacements will be due to the applied load only. When using other software packages to model the fender system, select the comparable settings as appropriate for that software so as to emulate the settings described above for an FB-MultiPier analysis.

3. Determine the Safe Embedment (E_f) as follows:

   To verify stability, use a computer program that allows non-linear modeling of a single cantilever pile embedded in weak soil (N=6) while incorporating soil strengths using P-Y curves, e.g., FB-MultiPier, LPILE. Load the top of the pile with a transverse load that generates the pile’s ultimate moment. Raise the pile tip elevation until pile deflections, especially at the pile tip, become unreasonable or the program does not converge. Assume the unstable embedment (E_o) is one foot greater than the embedment that causes unreasonable deflections. Add an additional embedment of 5 feet or 20% of the unstable embedment (E_o), whichever is greater, to E_o to determine the safe embedment (E_f). E_f shall in no case be taken less than 10 feet.

4. Perform a constructability review including manufacturing, transportation and installation.

3.14.4 Ladders and Platforms

A. Contact the District Structures Maintenance Engineer for ladder, platform, and catwalk requirements.

B. Generally, where fender lighting maintenance access is not provided or possible by boat, provide ladders and platforms from the bridge to the fender catwalk.

C. Design ladders and platforms per ***OSHA*** and the ***Code of Federal Regulations (CFR) Title 29, Part 1910, Section 27***. The clearance between rungs and obstructions should be 12-inches but not less than 7-inches (OSHA minimum.)

3.14.5 Navigation Lighting Details

A. Bridges over waterways with no significant nighttime navigation may be exempted from lighting requirements by the proper authorities; however, most bridges over navigable waterways will require some type of lighting. Refer to ***Code of Federal Regulations (CFR) Title 33 Part 118***.

B. For navigation lighting requirements, see the ***USCG Bridge Lighting and Other Signals Manual***.

Attachment B

Construction Specifications
Section 471
Section 973

Table 2 Plastic Material Properties - FFRCL		
	No. 2 Diesel	<6.0% weight increase
Tensile Properties	ASTM D638	~~Minimum~~ 3000 psi at break min.
Static Coeffecient of Friction	ASTM D2394	~~Minimum~~ 0.25, wet or dry min.
Nail Withdrawal or Screw Withdrawal	ASTM D6117	~~Minimum~~ 250 lb (nail) min. ~~Minimum~~ 400 lb (screw) min.

Table 3 Dimensions and Tolerances		
Structural Plastic	Dimension	Tolerance
Length	Per order (80 ft Maximum)	~~0/+~~minus 0, plus 6 inch
Width – SCL Width – FFRCL	See Contract Plans	~~±~~plus or minus 1/2 inch ~~±~~plus or minus 1/4 inch
Height – SCL Width – FFRCL	See Contract Plans	~~±~~plus or minus 1/2 inch ~~±~~plus or minus 1/4 inch
Skin Thickness	3/16 inch minimum	n/a
Distance from outer surface to center rebar elements (SCL)	2 inches	~~±~~plus or minus 1/2 inch
Straightness (gap, bend or inside while lying on a flat surface)		<1-1/2 inches per 10 feet

Table 4 ~~Minimum~~ Structural Properties for SCL		
Member Size		10 inches x 10 inches min.
Modulus of Elasticity	ASTM D6109	521 ksi min.
Stiffness, EI	ASTM D6109	4.05E+08 lb-inch^2 min.
Yield Stress in Bending	ASTM D6109	5.3 ksi min.
Weight		30-37 lb/ft

Table 5 Minimum Properties for FFRCL		
Modulus of Elasticity	ASTM D6109	300,000 psi
Flexural Strength	ASTM D6109	2,500 psi
Compressive Strength	ASTM D6108	2,200 psi
Compressive Strength Perpendicular to grain	ASTM D6108	700 psi

~~The values stated in these tables are the required minimums.~~