STRONGWELL®

EXCLUSIVELY MADE IN THE USA

DESIGN MANUAL

METRIC

EXTREN® AND OTHER PROPRIETARY PULTRUDED PRODUCTS

The design information in this manual is to be used exclusively with Strongwell's proprietary products which are described herein.

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ATTENTION DESIGNERS!

If you are designing with the Strongwell Design Manual, assure that only Strongwell fiberglass products are used on the structure or structures you have designed.

It's all too common! Strongwell gets a call about a problem with EXTREN® structurals. By a site visit or by samples sent in for testing we make an interesting discovery - the shapes are not EXTREN®. Yes, the Strongwell Design Manual was used, and yes, EXTREN® was specified — but the seller or contractor substituted an "equal"— sometimes without the knowledge of the designer or the owner.

Please consider the following questions:

1. All fiberglass structural shapes have the same properties?
   True or False

2. All structural shape manufacturers have rigorous quality assurance systems and procedures in place to assure quality?
   True or False

3. All structural shape manufacturers test each lot of material and will certify compliance with published properties?
   True or False

4. In comparing EXTREN® with a fiberglass structural shape produced by another pultrusion company, in what ways are the EXTREN® shape and the competitive shape likely to be equal?
   a) glass reinforcement percentage
   b) glass reinforcement location
   c) glass reinforcement type
   d) degree of reinforcement wet out
   e) resin formula
   f) pull speed
   g) none of the above

As you might suspect by now, the answers are:

1. False
2. False
3. False
4. g - none of the above

Designing with the Strongwell Design Manual and allowing other products to be used is analogous to designing in one grade of steel and allowing another grade with different properties to be substituted.

Insist that EXTREN® and other Strongwell products be used, especially if your PE stamp is on the design drawings.

To assist engineers, architects and others using the Strongwell Design Manual, Strongwell has implemented a logo identification program to eliminate confusion with other products appearing similar to EXTREN®. Since July 1, 1993, all fiberglass structural shapes and plate have been imprinted with the EXTREN® logo every three feet down the length of the part. Square and round tube have the logo imprinted inside the shape. Small and unobtrusive, the logo assures customers that they are getting EXTREN® when EXTREN® is specified and that the product has all advertised EXTREN® properties backed up by corrosion, mechanical and structural testing as conducted by Strongwell.

Thank you for using the Strongwell Design Manual for FRP structural designs. If you have comments or questions, please call the Customer Relations Department at Strongwell (276) 645-8000.

LIST OF REFERENCES

1. Salmon, C. G. and Johnson, J. E., *Steel Structures*, 2nd Edition, Harper and Row, 1980.

2. *Structural Plastics Design Manual*, American Society of Civil Engineers, 345 East 47th Street, New York, NY, 10017, Volumes 1 and 2, September 1981.

3. The *BOCA Basic Building Code*, Issued by Building Officials and Code Administrators International, Inc.,19726 So. Halsted Street, Homewood, Illinois 60430.

4. *Building Code Requirements for Reinforced Concrete* (ACI 318-77), American Concrete Institute, Box 19150 Redford Station, Detroit, Michigan 48219.

5. Gaylord, E. H. and Gaylord, C. N., Editors, *Structural Engineering Handbook*, 2nd Edition, McGraw-Hill, 1979.

6. *AISC Manual of Steel Construction*, American Institute of Steel Construction, Inc., 400 North Michigan Avenue, Chicago, IL 60611, 8th Edition, 1980.

7. Timoshenko, S. P. and Gere, J. S., *Mechanics of Materials*, Van Nostrand, 1972.

8. Tsai, S. W. and Hahn, H. T., *Introduction to Composite Materials*, Technomic Publishing Co., 1982.

9. Jones, Robert, *Mechanics of Composite Materials*, McGraw-Hill, New York, 1975.

10. Selection Manual for Structural Plastics, American Society of Civil Engineers, 345 East 47th Street, New York, NY 10017, 1985.

11. Timoshenko, S. and Woinowsky-Krieger, S., *Theory of Plates and Shells*, 2nd Edition, McGraw-Hill, 1959.

12. *Building Code Requirements for Minimum Design Loads in Buildings and Other Structures*, American National Standards Institute A58.1, Latest Edition.

13. *Engineered Materials Handbook*, Vol. 1, "Composites", ASM International, Metal Parks, Ohio 44073, 1987.

PREFACE

The Strongwell *Design Manual* has had various titles since its introduction as the EXTREN® Engineering Manual in 1979. At that time, the EXTREN® Engineering Manual contained information pertaining only to EXTREN® structural shapes and plate.

The manual's name changed to the EXTREN® *Design Manual* in 1989 and was restructured to emulate the format of the American Institute of Steel Construction (AISC) manual used for structural steel designs. The new format made it easy for design engineers to understand the information and helped create greater acceptance of fiber reinforced polymer (FRP) structural shapes and plate. Information relating to pultruded grating, DURASHIELD® foam core panels and SAFRAIL™ handrail and ladder systems were added to the manual as well.

Strongwell's current manual is entitled the Strongwell *Design Manual*. EXTREN® structural shapes and plate remain the core of the manual, but the *Design Manual* now contains information regarding most of Strongwell's pultruded products and can be used as a comprehensive reference guide for the structural engineer.

The new Strongwell *Design Manual* reflects much more than a title change. Strongwell has accumulated a tremendous amount of knowledge through decades of manufacturing experience, application monitoring, and most importantly, through extensive product testing. Strongwell's testing efforts have resulted in more definitive information on product performance and have helped the company develop additional empirical formulas to accurately reflect the performance of its pultruded FRP materials under applied loads. Improved product performance, which is a result of both advancements in the pultrusion process and the quality of raw materials available, is also reflected throughout the new *Design Manual*.

WARNING!

Fiberglass reinforced plastic structural shapes are nonhomogeneous, with strength and behavior dependent upon composite design, processing techniques, and quality standards. Other fiberglass structural shapes with a similar exterior appearance to EXTREN® shapes are likely not equal in any other way, including glass content, glass placement, glass type, wet-out, resin mixture, or pull speed. Do not use the Strongwell *Design Manual* to design a structure unless you assure that EXTREN® structurals are used.

CAUTION

Strongwell has assembled this manual as an aid to our customers and has employed available engineering information in connection with the load tables, formulas and other technical data concerning the products covered in the manual. The usefulness of the information contained in the manual may vary depending on the particular application of the product and the environment to which the product is subjected. Accordingly, Strongwell does not warrant the usefulness or the applicability of the information contained herein to any specific application. Moreover, Strongwell cannot assume liability for the accuracy of any data contained in this manual and makes no warranties of any type in connection therewith. The information contained in the manual may be changed without notice. The products manufactured or sold by Strongwell are subject to specific written warranties and exclusions, to which reference should be made.

GENERAL NOMENCLATURE

A	Cross-sectional area (mm^2)
A_w	Cross-sectional area of web or webs (mm^2)
B	Derived constant for use in Eq. B-5
C_1	Lateral buckling coefficient
CW	Crosswise (transverse) to the direction of pultrusion
D	Outside diameter of round tube (mm) Diameter of round rod (mm) Diameter of round hole in square tube (mm)
E	Modulus of Elasticity (N/mm^2)
F_a	Allowable compressive stress in short column mode (N/mm^2)
F_a'	Allowable compressive stress in long column mode (N/mm^2)
F_b	Allowable flexural stress (N/mm^2)
F_b'	Allowable flexural stress – laterally unsupported beams (N/mm^2)
F_u	Ultimate compressive stress (N/mm^2) Ultimate flexural stress – laterally supported beams (N/mm^2)
F_u'	Ultimate compressive stress – long column mode (N/mm^2) Ultimate flexural stress – laterally unsupported beams (N/mm^2)
F_v	Allowable shear stress (N/mm^2)
F.S.	Factor of Safety
G	Shear modulus (N/mm^2)
I	Moment of Inertia (mm^4)
I_x, I_y	Moment of inertia about X-X or Y-Y axis (mm^4)
J	Torsional constant (mm^4)
K	Effective length factor for buckling
K_b	Coefficient for flexural deflection
K_v	Coefficient for shear deflection
K_x, K_y	Effective length factor for buckling about X-X or Y-Y axis
L	Length of beam or column (center to center of supports) (m)
L_u	Unbraced length of beam or column (center to center of lateral braces) (m)
LW	Lengthwise (parallel) to the direction of pultrusion
M	Bending moment from applied loads (N-m)
N	Derived constant for use in Eq. B-5
P	Concentrated load on beam (N) Axial load on column (N)
P_a	Allowable axial load on column (N)
PF	Perpendicular to laminate face
R	Radius (mm) Reaction from applied loads (N)
R_f	Flange toe radius (mm)
R_i	Radius of inside corner (mm)
R_o	Radius of outside corner (mm)
S	Section modulus (mm^3)
S_b	Section modulus from the bottom of an unsymmetrical section (mm^3)

GENERAL NOMENCLATURE

S_1	Section modulus from the top of an unsymmetrical section (mm^3)
S_x,S_y	Section modulus about X-X or Y-Y axis (mm^3)
V	Shear from applied loads (N)
W	Uniform beam load (N/m)
Wt	Weight of section (N/m)
a	Long dimension of rectangular plate (mm)
b	Width of section (mm) Short dimension of rectangular plate (mm) Outside dimension of square tube or bar (mm)
b_f	Width of flange (mm)
b_i	Width between the flanges in the strut (mm) Top width of Hat Section (mm)
c	Concentrated load (N)
d	Full depth of section (mm)
d_i	Outside dimension of flanges in F-section (mm)
f_a	Axial stress from applied loads (N/mm^2)
f_b	Flexural stress from applied loads (N/mm^2)
f_v	Shear stress from applied loads (N/mm^2)
l	Length of beam, column or flat sheet (center to center of supports) (mm)
l_u	Unbraced length of beam or column (center to center of lateral braces) (mm)
r	Radius of gyration (mm)
r_x, r_y, r_z	Radius of gyration about X-X, Y-Y or Z-Z axis (mm)
s	Spacing between back to back channels or angles (mm)
t	Thickness of section (mm) Wall thickness of tubes (mm)
t_b	Thickness of depth dimension (mm)
t_d	Thickness of depth dimension (mm)
t_f	Thickness of flange (mm)
t_w	Thickness of web (mm)
u	Uniform load (N/m^2)
v	Poisson's ratio
w	Uniform beam load (N/mm^2)
x	Distance from the outside of the web to the minor axis (Y-Y) of a channel section or other similar unsymmetrical sections (mm) Subscript relating symbol to strong axis (X-X)
y	Distance from the neutral X-X axis to the outermost fibers of the cross section (mm) Distance from the back of flange to the major axis (X-X) of a tee section or other similar unsymmetrical sections (mm) Subscript relating symbol to weak axis (Y-Y)
Δ	Deflection (mm)
Δ_c	Deflection due to concentrated load (mm)
Δ_u	Deflection due to uniform load (mm)
v	Poisson's ratio