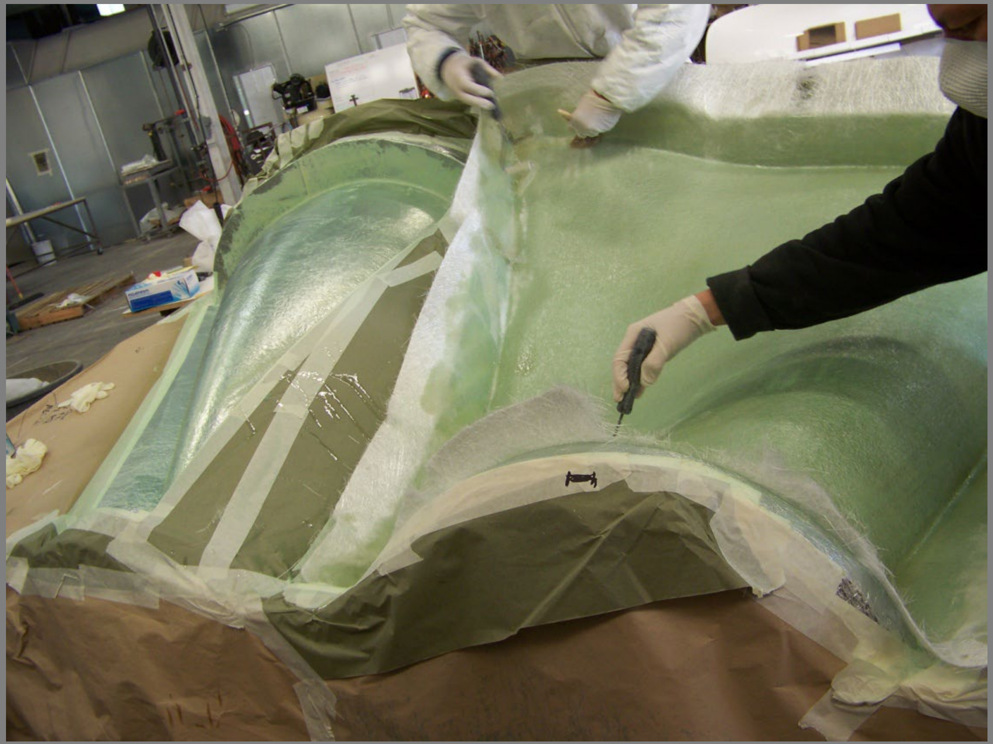
KREYSLER & ASSOCIATES

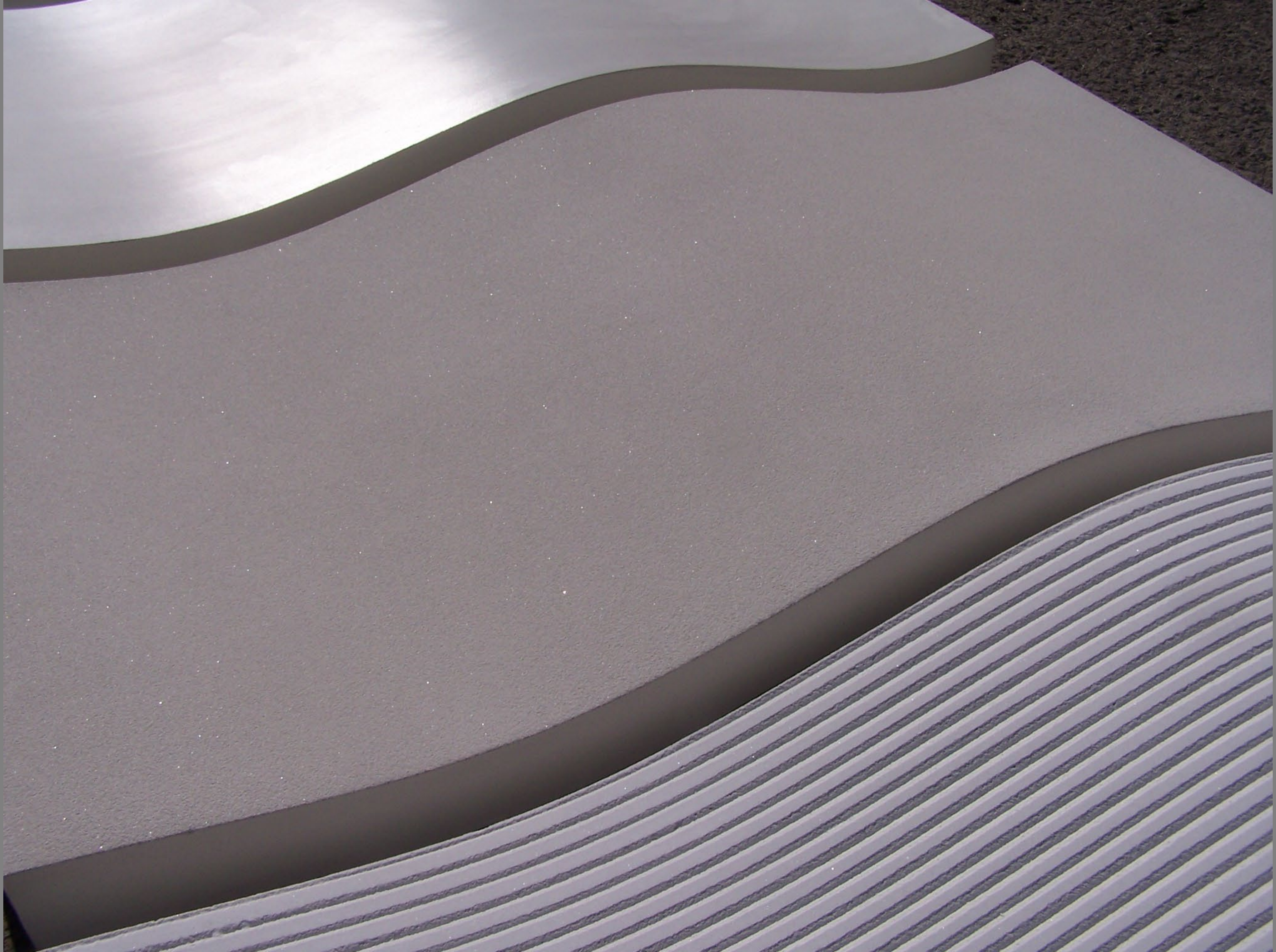
FRP is:

- Reinforcements
- Matrix
  - Thermoplastic vs Thermoset
- Fillers
- Gelcoat
- Cores
- Finishes
  - In-mold, post-applied, sand blasted, wet sanded, PC, translucent, painted, other (rabbit, perlite)



Fabrication processes:

- Open mold
- Closed mold
- Filament Winding
- Pultrusion
- Vacuum bagging
- Vacuum infusion
- Bladder molding

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© ORACLE TEAM USA / Photo : Guilain GRENIER


08/04/2012


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ORACLE TEAM USA
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TAGHeuer
ORACLE TEAM USA
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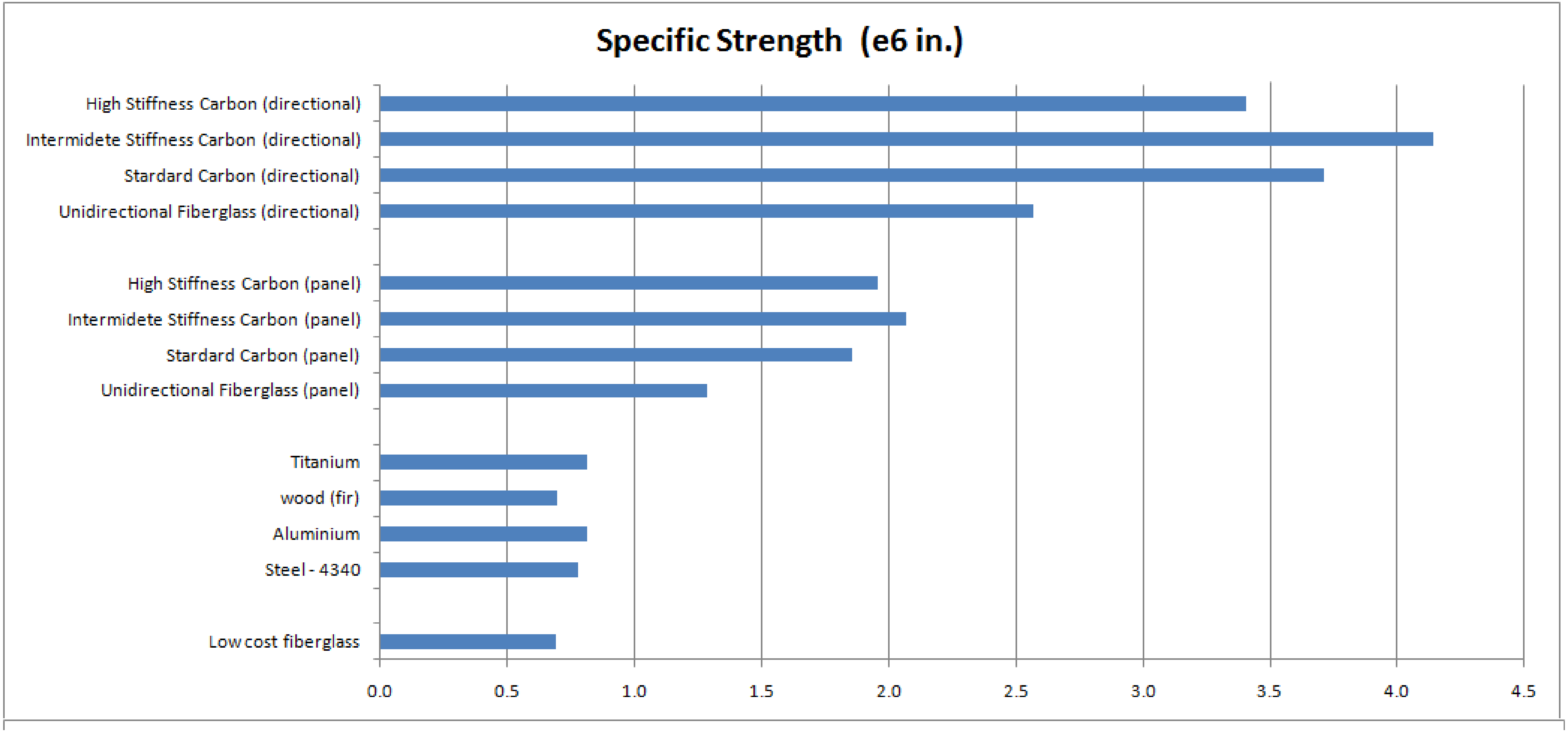
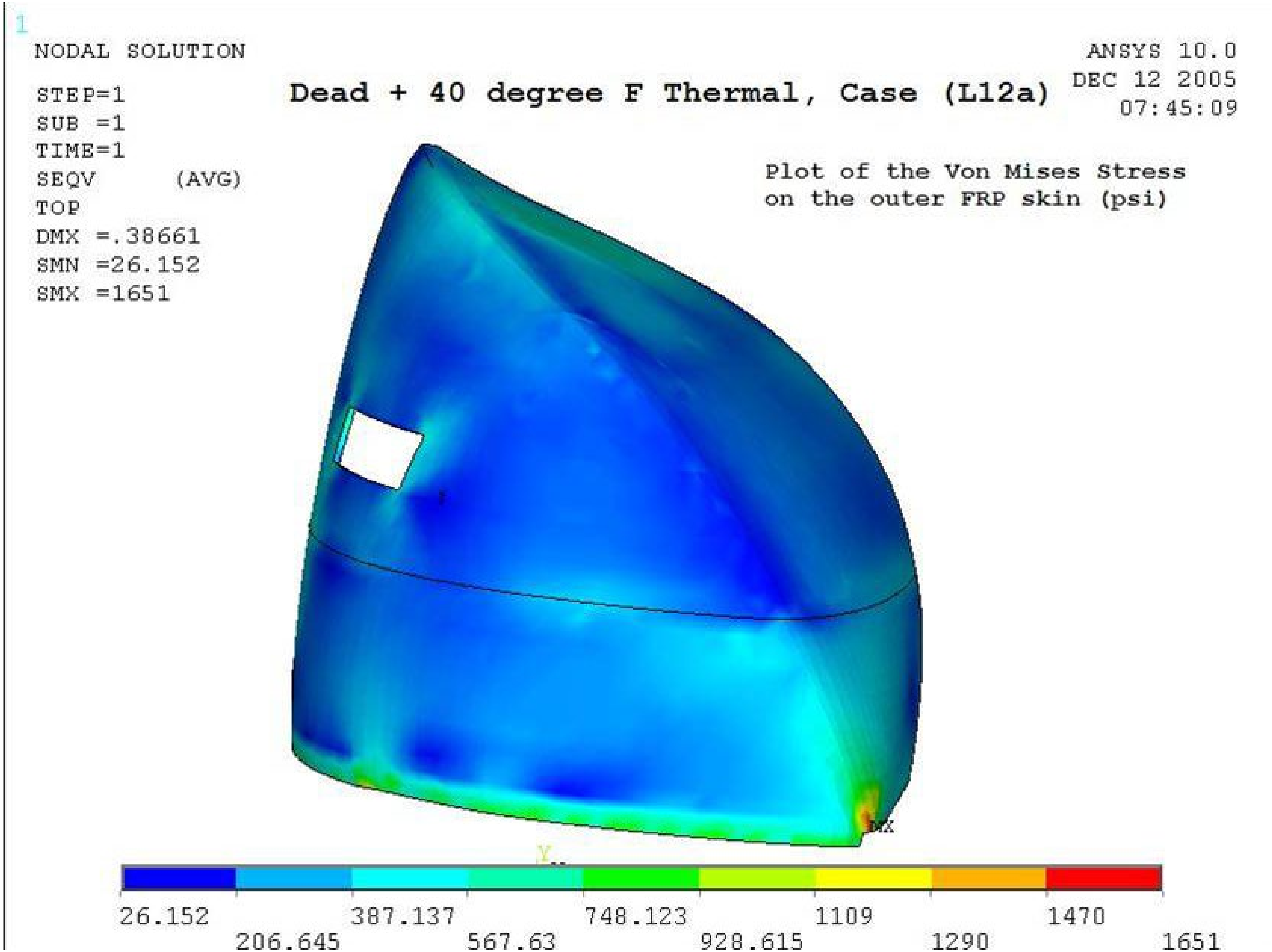


Specific Strength (e6 in.)
High Stiffness Carbon (directional)
Intermidete Stiffness Carbon (directional)
Stardard Carbon (directional)
Unidirectional Fiberglass (directional)
High Stiffness Carbon (panel)
Intermidete Stiffness Carbon (panel)
Stardard Carbon (panel)
Unidirectional Fiberglass (panel)
Titanium
wood (fir)
Aluminium
Steel - 4340
Low cost fiberglass
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5


1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (AVG)
TOP
DMX =.38661
SMN =26.152
SMX =1651
Dead + 40 degree F Thermal, Case (L12a)
ANSYS 10.0
DEC 12 2005
07:45:09
Plot of the Von Mises Stress
on the outer FRP skin (psi)
MX
26.152
206.645
387.137
567.63
748.123
928.615
1109
1290
1470
1651

Third party tests of K&A FRP products (Partial)

- NFPA 259-13
- NFPA 268
- NFPA 285 (With Mineral Wool and Gasket)
- NFPA 285 (With Open Joints and Air Space Behind Panel)
- ASTM E-84 – FSI: 15; SDI: 350
- ASTM E108-11/UL790- Class A)
- ASTM D1929-14
- BS 476 Part 6- (Class 0)
- BS 476 Part 7 – (Class 1)
- ASTM E488 Strength of Anchors in Concrete Elements
- ASTM E108-11/UL790- (Class A)
- ASTM D1929-14
- BS 476 Part 6- (Class 0)
- BS 476 Part 7 – (Class 1
- ASTM E488 Strength of Anchors in Concrete Elements
- ASTM E488 Shear strength T pin embed parallel
- ASTM D5961
- ASTM E1980
- ASTM E228
- ASTM G155
- ICC-ES AC92, Section 4.2
- ICC-ES AC92, Section 4.4
- ICC-ES AC92, Section 4.4
- ICC-ES AC92, Section 4.4
- ASTM B117
- ASTM D2247
- …

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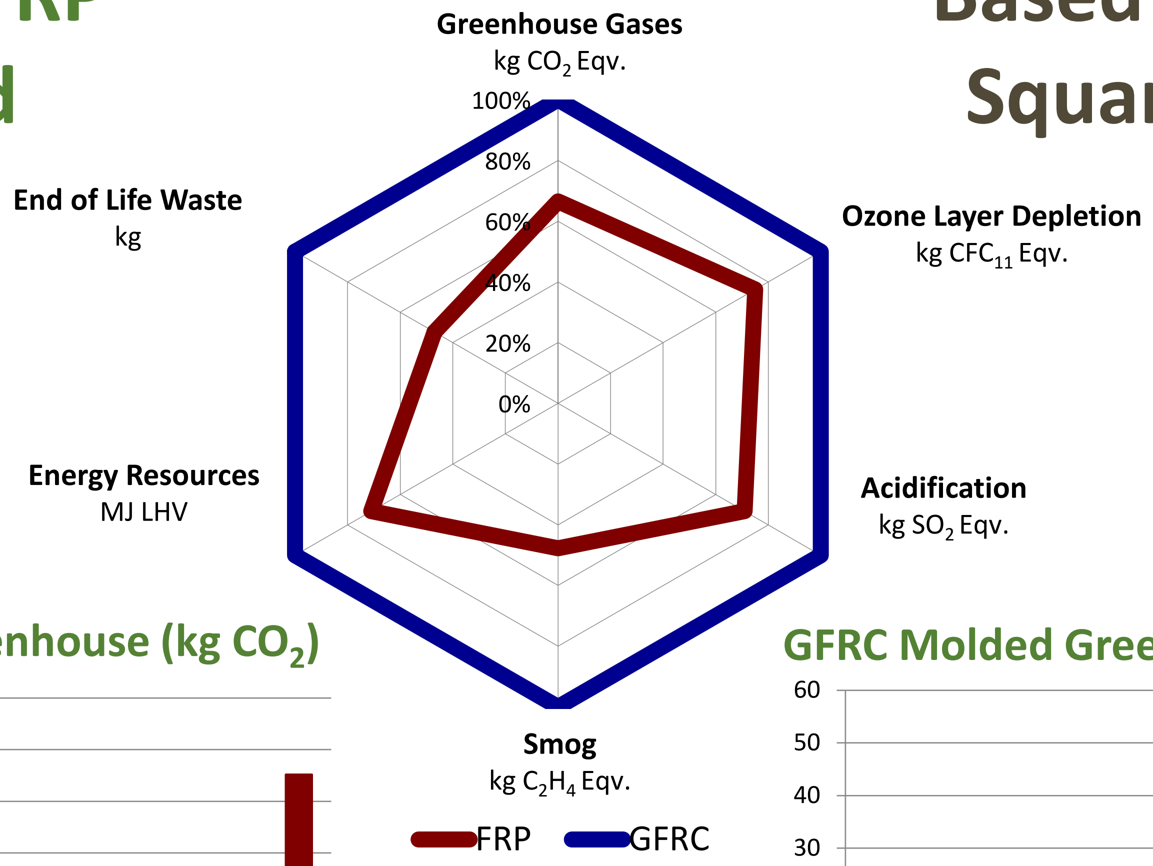
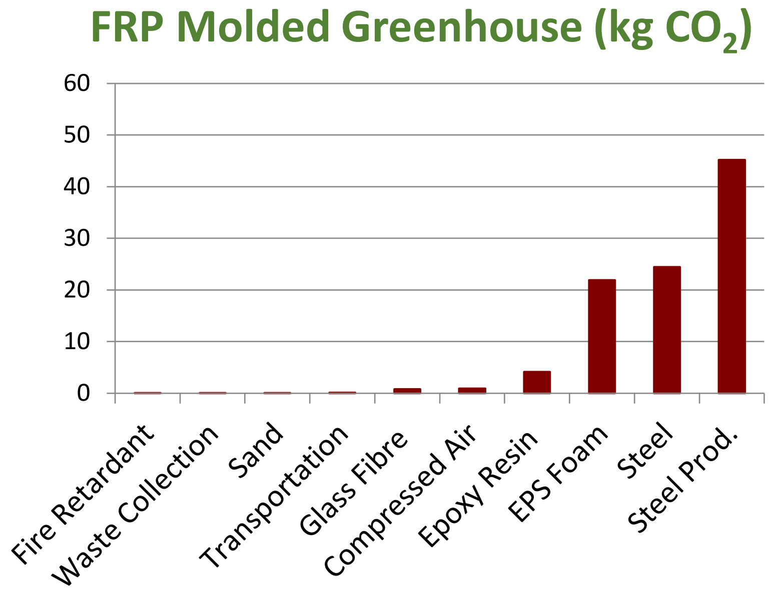
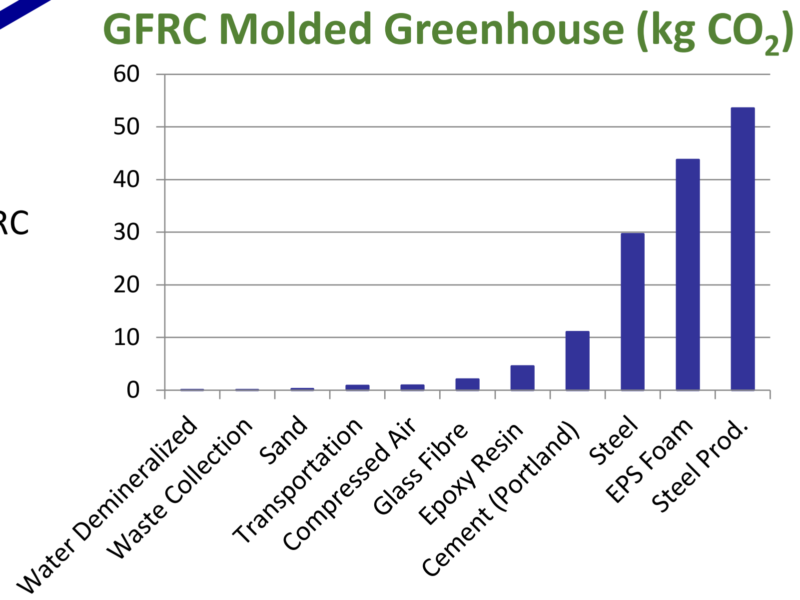
01 1778701 618
27 June 2013

GFRC vs. FRP Molded

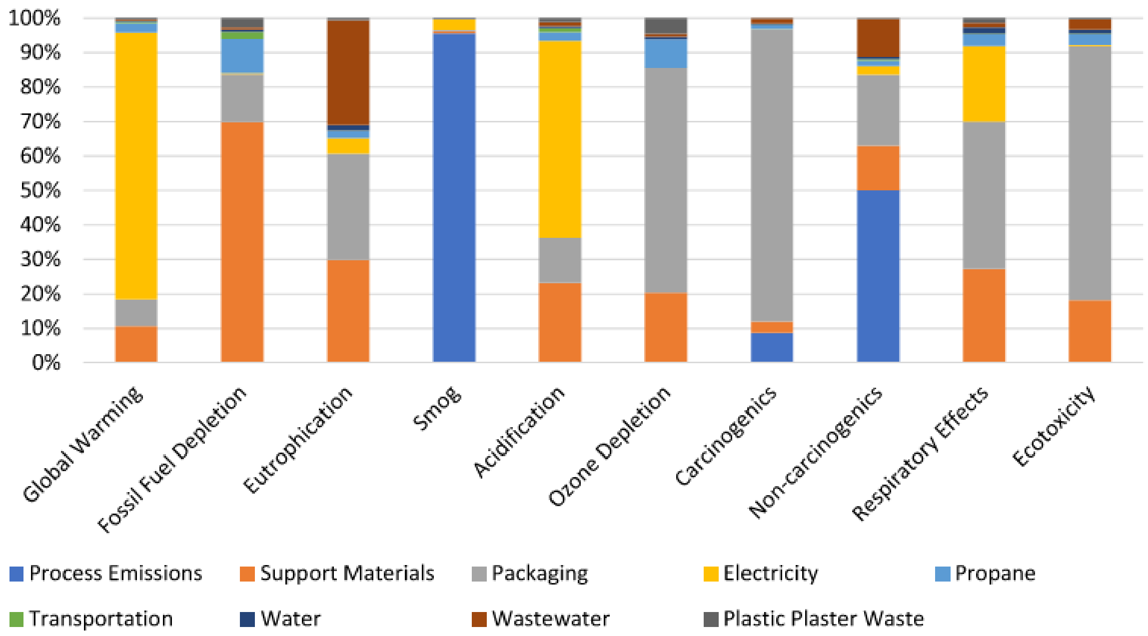
Based on One Square Yard



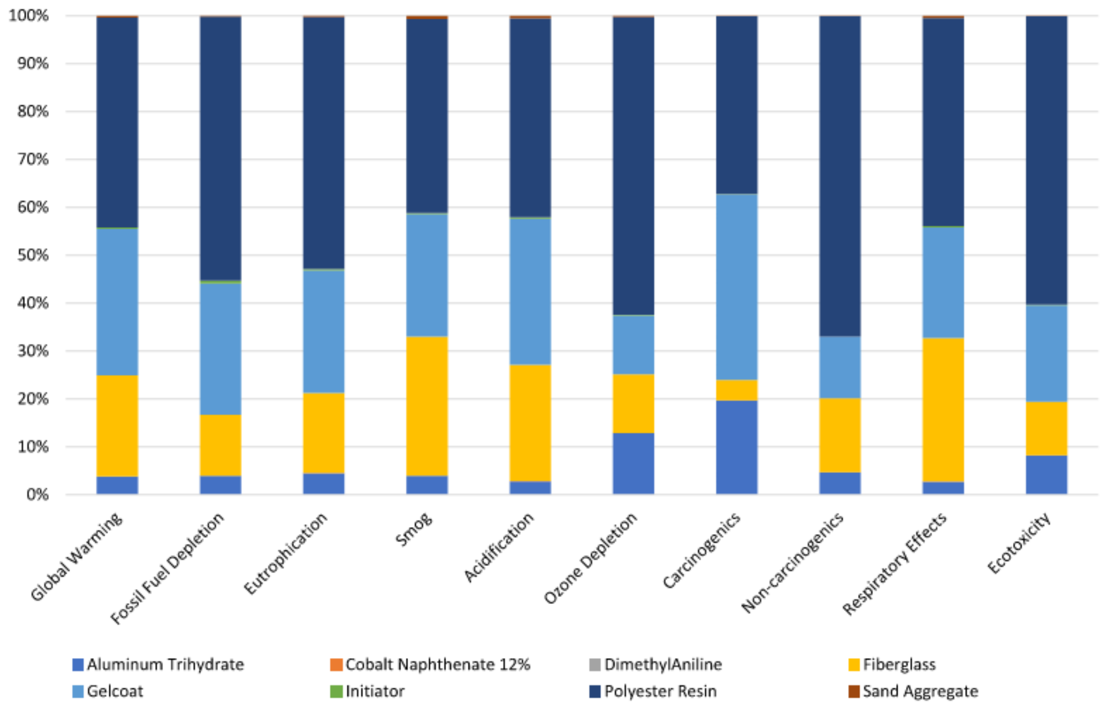




By Production Phase

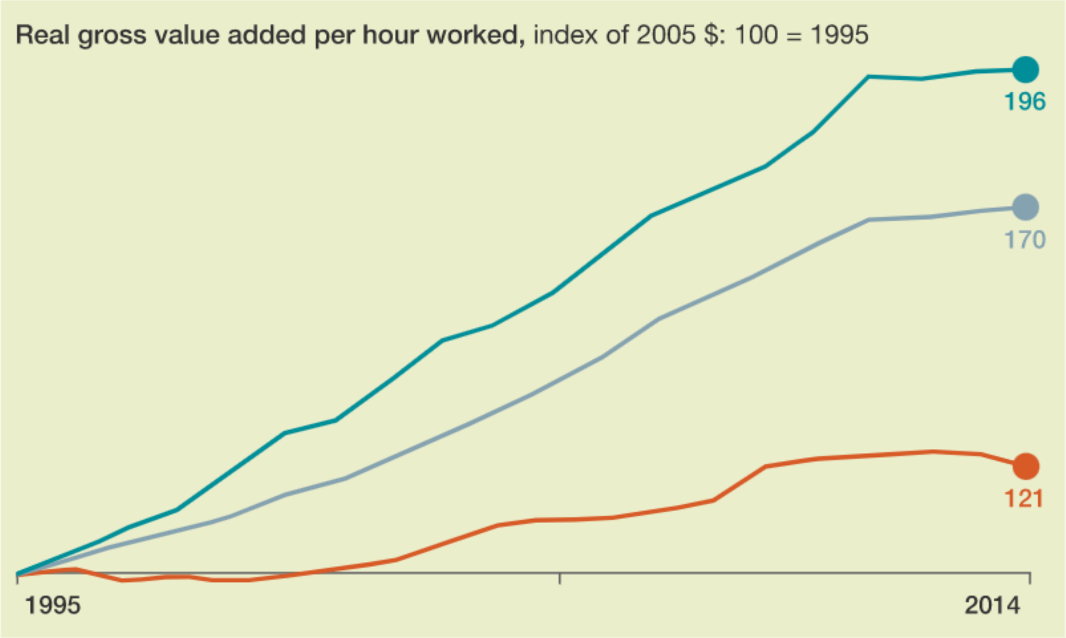


By Raw Material



Construction vs Manufacturing

Globally, labor-productivity growth in construction lags far behind that of manufacturing or the total economy.

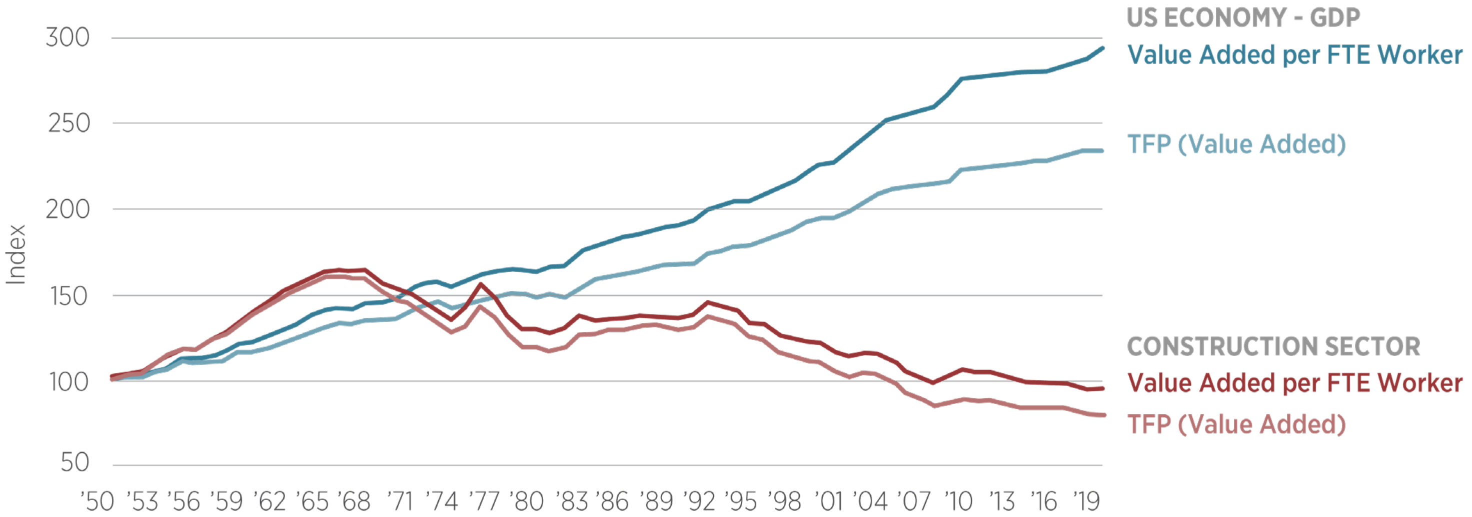


Source: GGCD-10; national statistical agencies of Turkey, Malaysia, and Singapore; OECD, Rosstat; US Bureau of Economic Affairs; US Bureau of Labor Statistics; WIOD; World Bank; McKinsey Global Institute analysis

McKinsey&Company

Construction vs Manufacturing

Indexes of Value Added Per Full-Time-Equivalent (FTE) Worker and Total Factor Productivity (TFP), Overall US Economy and Construction Sector (BEA Data)



Note: This figure shows indexes of US construction sector labor productivity and total factor productivity (TFP) from 1950 to 2020. For comparison, it also plots the same indexes for the overall economy. Throughout the 1950s and well into the 1960s, both measures of construction sector productivity grew steadily. Indeed, they outpaced their whole-economy counterparts during that period. By 1970, however, the construction sector's labor productivity and TFP had both begun to fall. This downturn was not temporary; the decline has continued for the past half-century.

Becker Friedman Institute

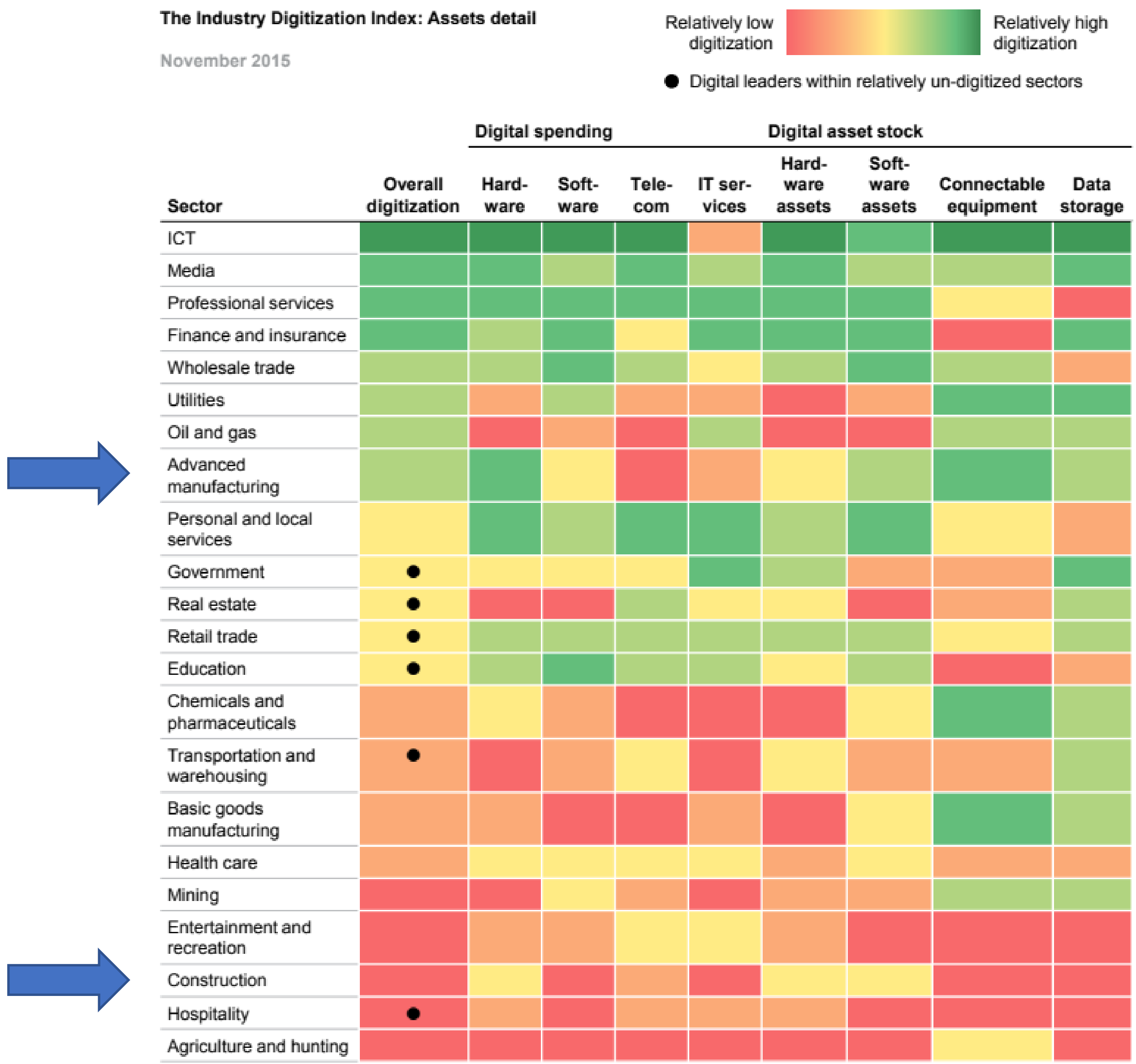
https://bfi.uchicago.edu/insight/research-summary/the-strange-and-awful-path-of-productivity-in-the-us-construction-sector/

Progress in Construction vs Manufacturing
McKinsey – "Digital America: A Tale of the Haves and Have-Mores" 2015

Exhibit A4

The Industry Digitization Index: Assets detail

November 2015



SOURCE: BEA; BLS; US Census; IDC; Gartner; McKinsey social technology survey; McKinsey Payments Map; LiveChat customer satisfaction report; Appbrain; US contact center decision-makers guide; eMarketer; Bluewolf; Computer Economics; industry expert interviews; McKinsey Global Institute analysis


SFMOMA
04-E-047
3D VIEW WITH QC DIMENSIONS
NO SCALE
*NOTE: SKETCH REPRESENT FINISHED PART
KREYSLER & ASSOCIATES


API

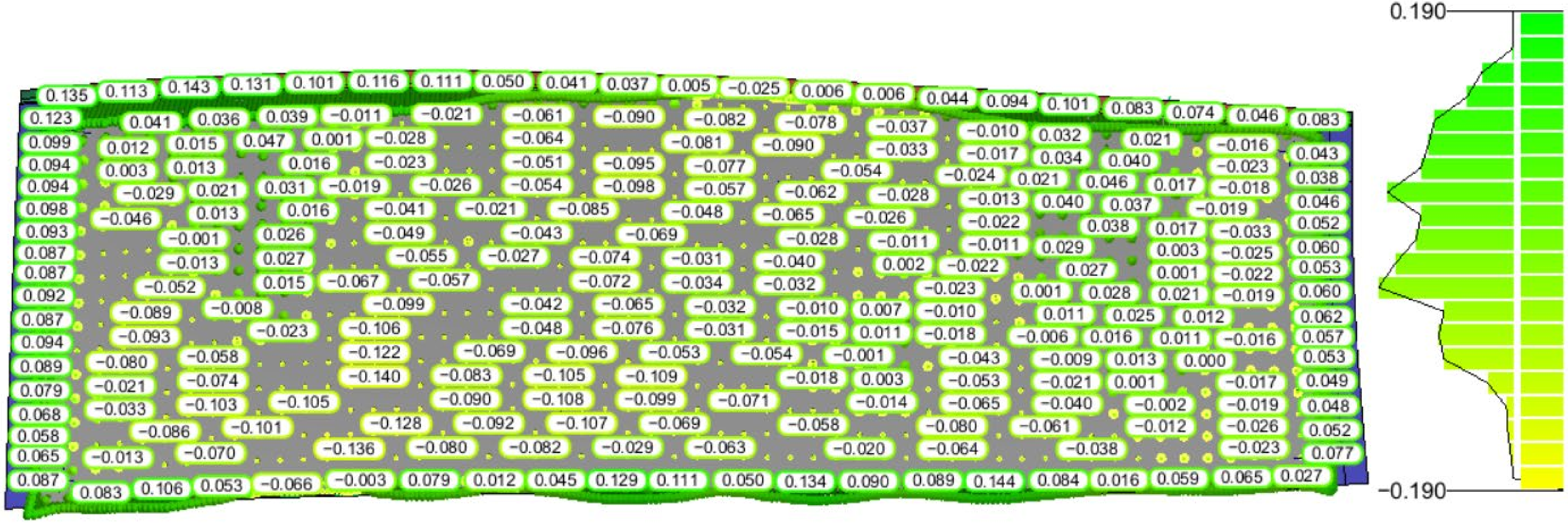

0.190
-0.190
0.135 0.113 0.143 0.131 0.101 0.116 0.111 0.050 0.041 0.037 0.005 −0.025 0.006 0.006 0.044 0.094 0.101 0.083 0.074 0.046 0.083
0.123 0.041 0.036 0.039 −0.011 −0.021 −0.061 −0.090 −0.082 −0.078 −0.037 −0.010 0.032 0.021 −0.016
0.099 0.012 0.015 0.047 0.001 −0.028 −0.064 −0.081 −0.090 −0.033 −0.017 0.034 0.040 −0.023 0.043
0.094 0.003 0.013 0.016 −0.023 −0.051 −0.095 −0.077 −0.054 −0.024 0.021 0.046 0.017 −0.018 0.038
0.094 −0.029 0.021 0.031 −0.019 −0.026 −0.054 −0.098 −0.057 −0.062 −0.028 −0.013 0.040 0.037 −0.019 0.046
0.098 −0.046 0.013 0.016 −0.041 −0.021 −0.085 −0.048 −0.065 −0.026 −0.022 0.038 0.017 −0.033 0.052
0.093 −0.001 0.026 −0.049 −0.043 −0.069 −0.028 −0.011 −0.011 0.029 0.003 −0.025 0.060
0.087 −0.013 0.027 −0.055 −0.027 −0.074 −0.031 −0.040 0.002 −0.022 0.027 0.001 −0.022 0.053
0.087 −0.052 0.015 −0.067 −0.057 −0.072 −0.034 −0.032 −0.023 0.001 0.028 0.021 −0.019 0.060
0.092 −0.089 −0.008 −0.099 −0.042 −0.065 −0.032 −0.010 0.007 −0.010 0.011 0.025 0.012 0.062
0.087 −0.093 −0.023 −0.106 −0.048 −0.076 −0.031 −0.015 0.011 −0.018 −0.006 0.016 0.011 −0.016 0.057
0.094 −0.080 −0.058 −0.122 −0.069 −0.096 −0.053 −0.054 −0.001 −0.043 −0.009 0.013 0.000 0.053
0.089 −0.021 −0.074 −0.140 −0.083 −0.105 −0.109 −0.018 0.003 −0.053 −0.021 0.001 −0.017 0.049
0.079 −0.033 −0.103 −0.105 −0.090 −0.108 −0.099 −0.071 −0.014 −0.065 −0.040 −0.002 −0.019 0.048
0.068 −0.086 −0.101 −0.128 −0.092 −0.107 −0.069 −0.058 −0.080 −0.061 −0.012 −0.026 0.052
0.058 −0.013 −0.070 −0.136 −0.080 −0.082 −0.029 −0.063 −0.020 −0.064 −0.038 −0.023 0.077
0.065
0.087 0.083 0.106 0.053 −0.066 −0.003 0.079 0.012 0.045 0.129 0.111 0.050 0.134 0.090 0.089 0.144 0.084 0.016 0.059 0.065 0.027

TABLE 6.4-1: Typical Product Fabrication Tolerances

Type	Application	Tolerance	Comment
Length and Width	<10 ft (3m)	±1/8 inch (3mm)	Overall length and width of units measured at the face adjacent to the mold.
	10 ft – 20 ft (3-6m)	±3/16 inch (5mm)	
Variation from Square	0 ft–10 ft (0-3m)	±1/4 inch (6mm)	
	>10 ft	Length/1000	
Out of Plane	<10 ft (3m)	±1/4 inch (6mm)	
Warping or Bowing	<10 ft^2 ($3m^2$)	±1/4 inch (6mm)	
Gelcoat Thickness	Outer surface	–.002 /+.010 (–.05 /+.254mm)	
Position of Integral Items	Mounting devices	±1/4 inch (6mm)	
	Internal supports/stiffeners	±1/2 inch (12mm)	
	Steel studs and tracks	±1/4 inch (6mm)	
	Flashing reglets (panel edge)	±1/4 inch (6mm)	
	Reglets for glazing gaskets	±1/8 inch (3mm)	

ACMA Guidelines and Recommended Practices for Architectural FRP Products

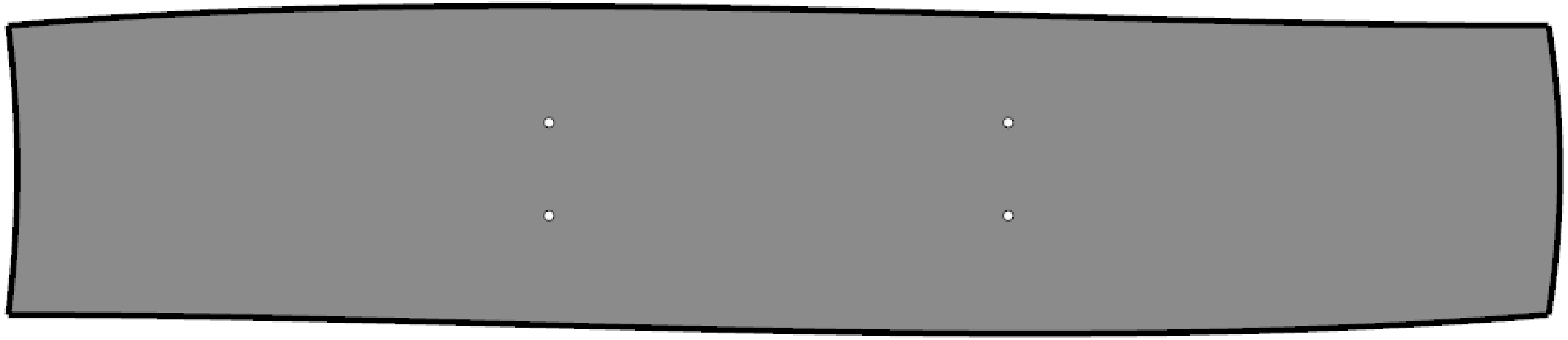
TABLE 6.5-1: Typical Installation Tolerances

Type	Tolerance	Comment
Warpage	±1/8 inch (3mm) per foot (305mm) 3/8 inch (10mm) total	There is a maximum allowable warpage of each panel corner relative to other corners of the same panel.
Bowing	< L/200	
Maximum offset from true alignment	±1/4 inch (6mm) in 20 ft. (6.1m)	
Maximum variation from true position	±1/2 inch (13mm) in 20 ft (6.1m) of length	

All structural frames and building facades (steel concrete, wood, etc.) have an inherent erection tolerance described in the contract documents, building code, or other codes of standard construction practice. The design team should provide sufficient allowances in panel spacing to accommodate this tolerance plus the fabrication tolerances of the FRP panels. If clearances are realistically assessed, they will solve many installation tolerance problems.

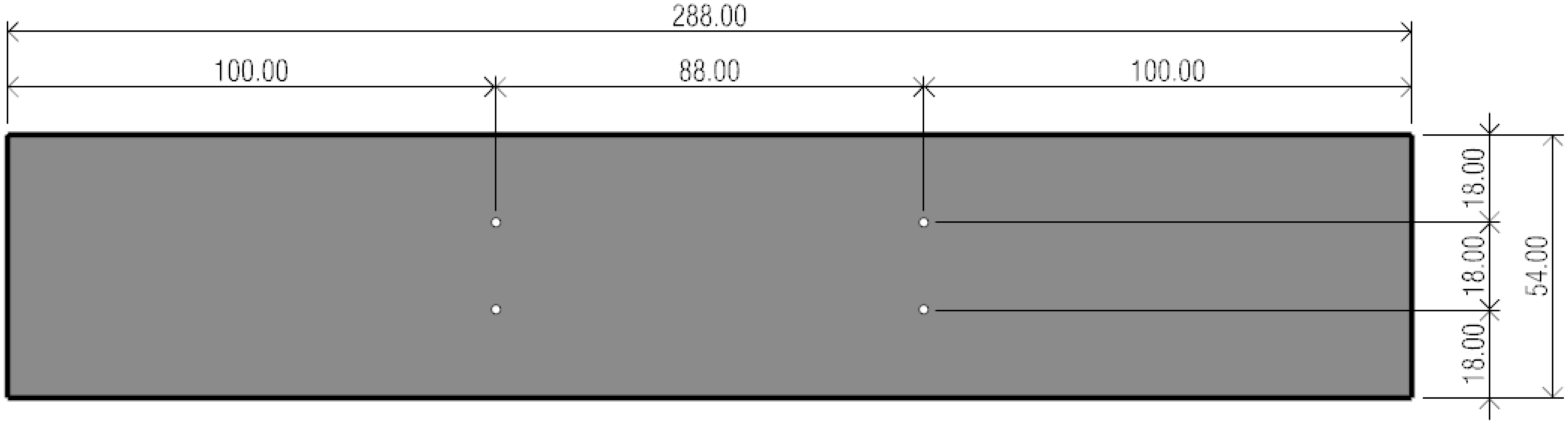
Gap tolerances for integrally molded and field-cut joint flanges should be maintained at ±1/16 inch (1.5mm) relative to intended design width. The joint gap between installed panels need not exceed the values shown in Table 6.5-2.

Digital Product Definition

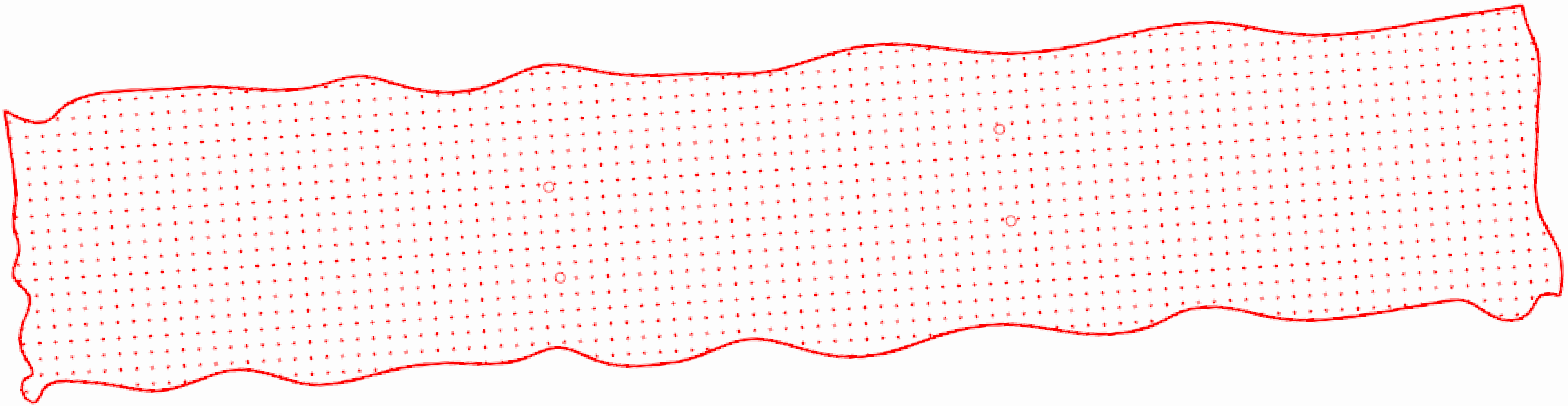


Digital Product Definition

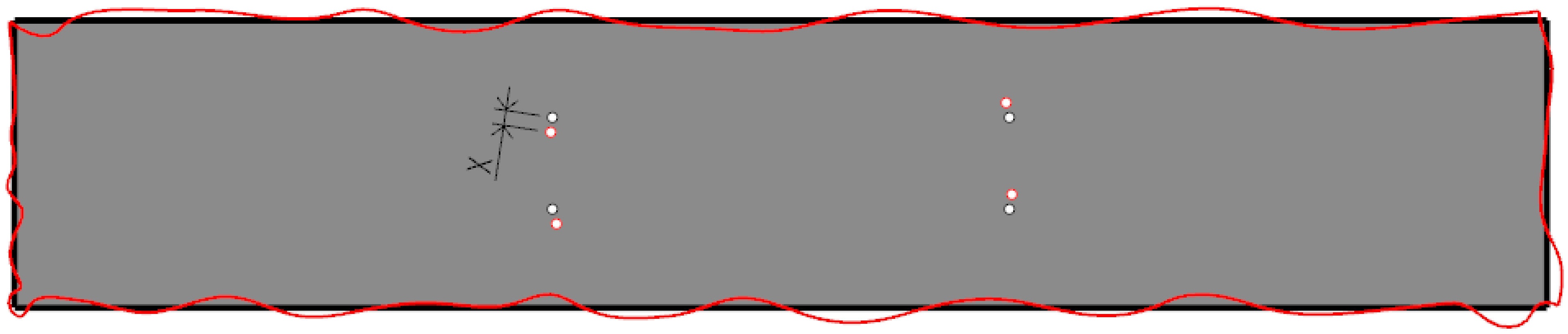
Typical “Coordinate Dimensions”



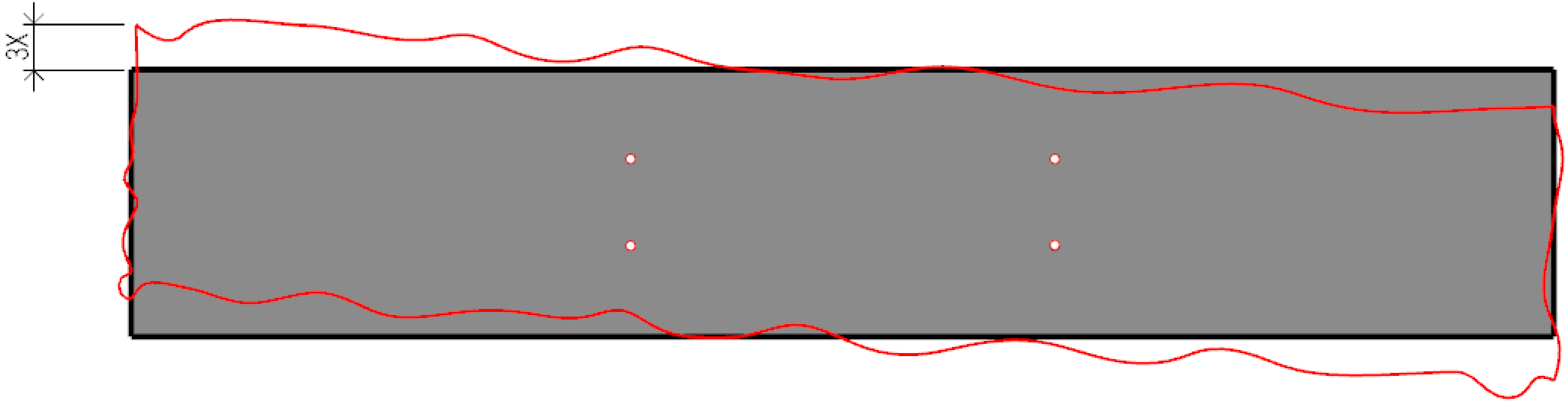
Laser Scan Data



Laser Scan Data – best fit to edges



Laser Scan Data – best fit to connections



Measuring Overall Width – average along edges?

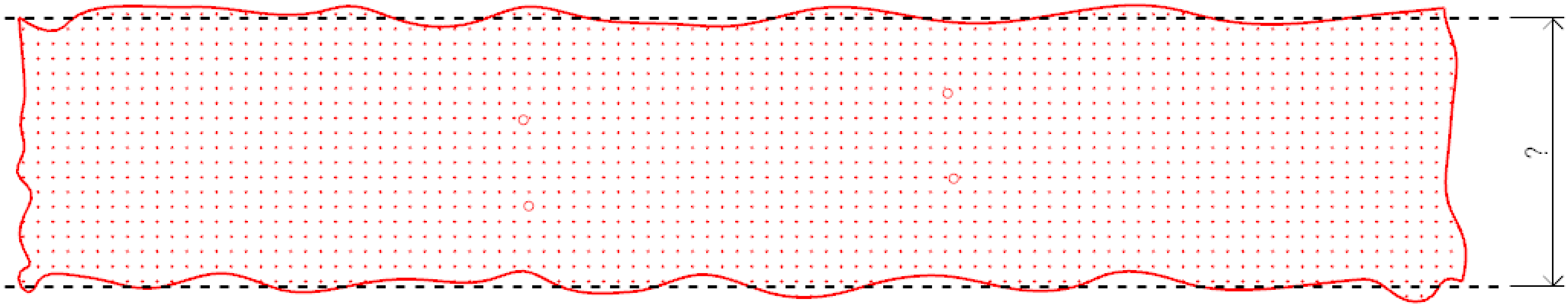
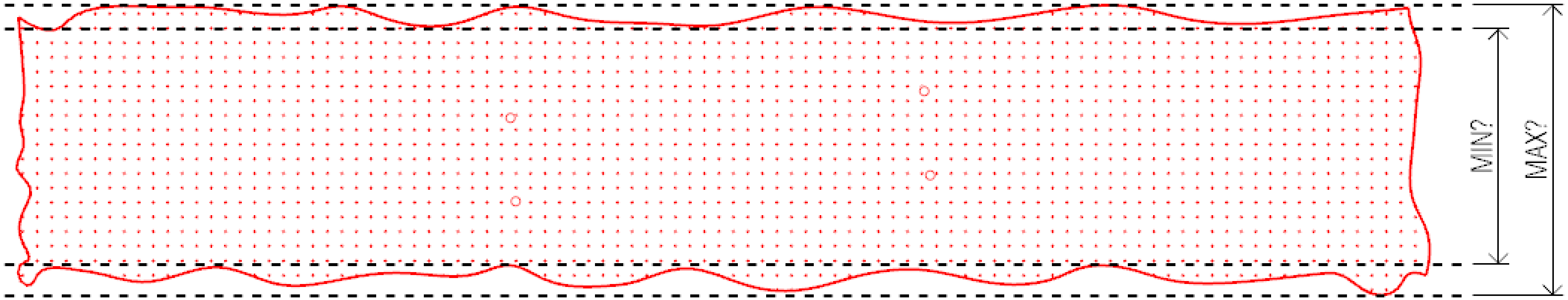


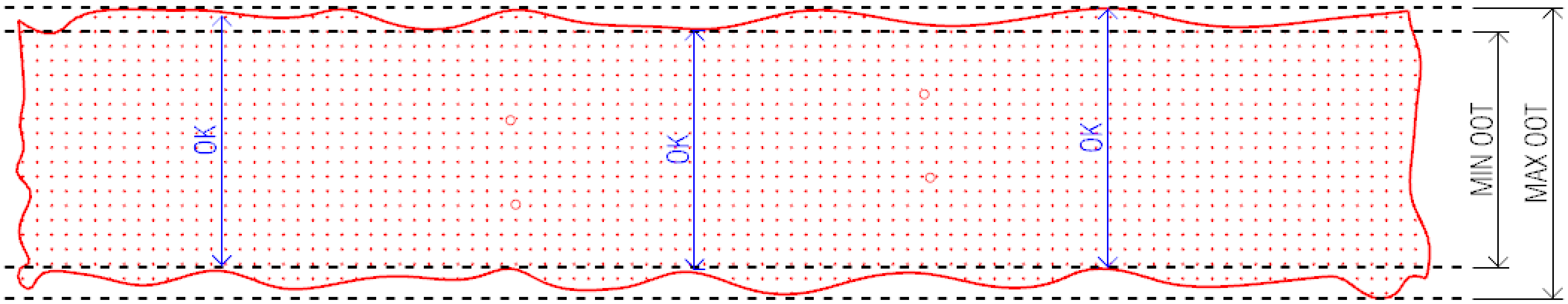
TABLE 6.4-1: Typical Product Fabrication Tolerances

Type	Application	Tolerance	Comment
Length and Width	< 10 ft (3m)	± 1/8 inch (3mm)	Overall length and width of units measured at the face adjacent to the mold.
	10 ft – 20 ft (3-6m)	± 3/16 inch (5mm)	

Measuring Overall Width – Min/Max?



Measuring Overall Width – Sampling?



FIT

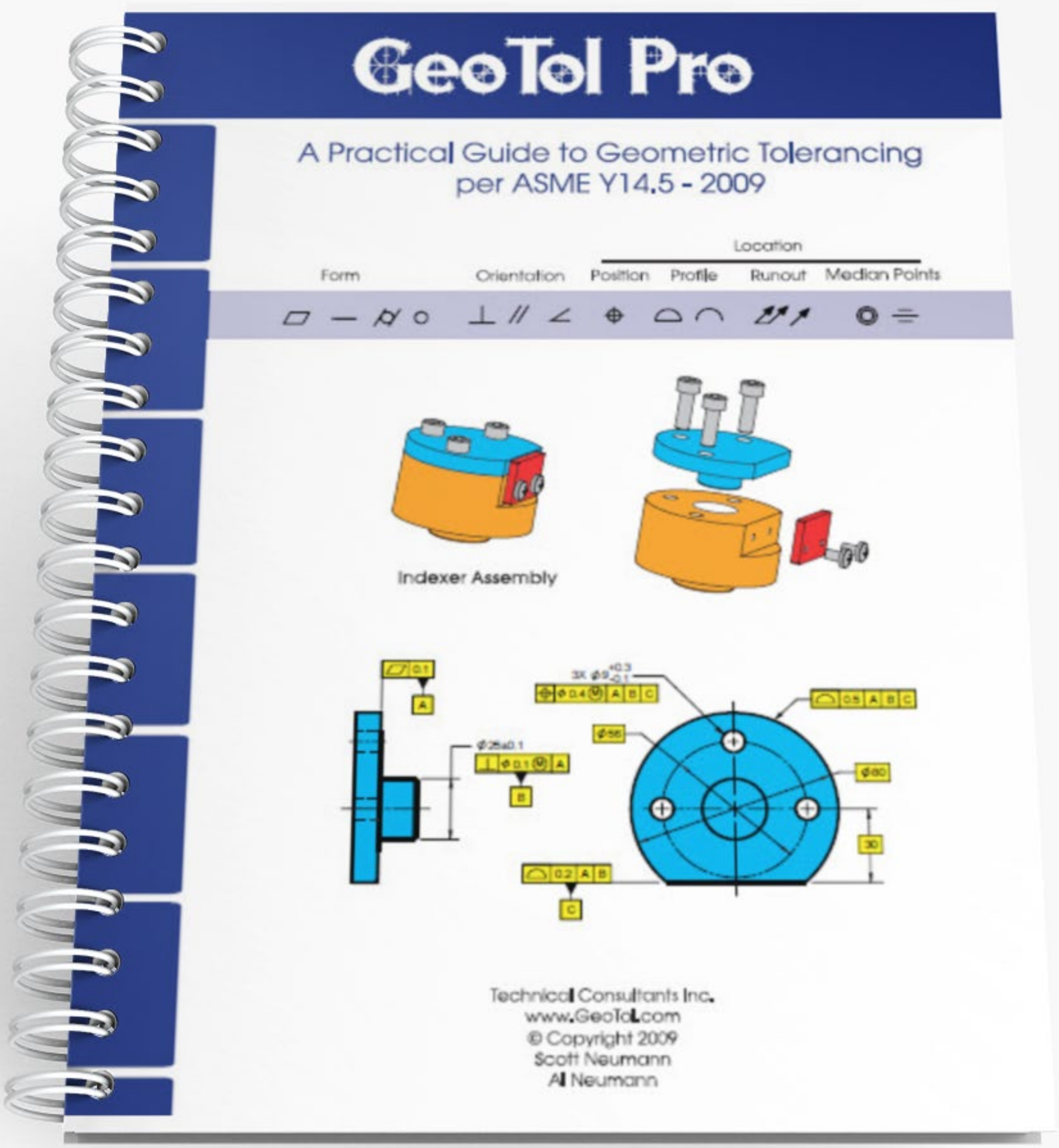
- Compatibility with other systems, environment
- Meets intended purpose
- Fits customer requirements

FORM

- Appearance
- Shape, size, color, texture
- User interface

FUNCTION

- Performance
- Usability, durability
- Meets codes (safety, fire resistance)
- Solves a problem, fills a need



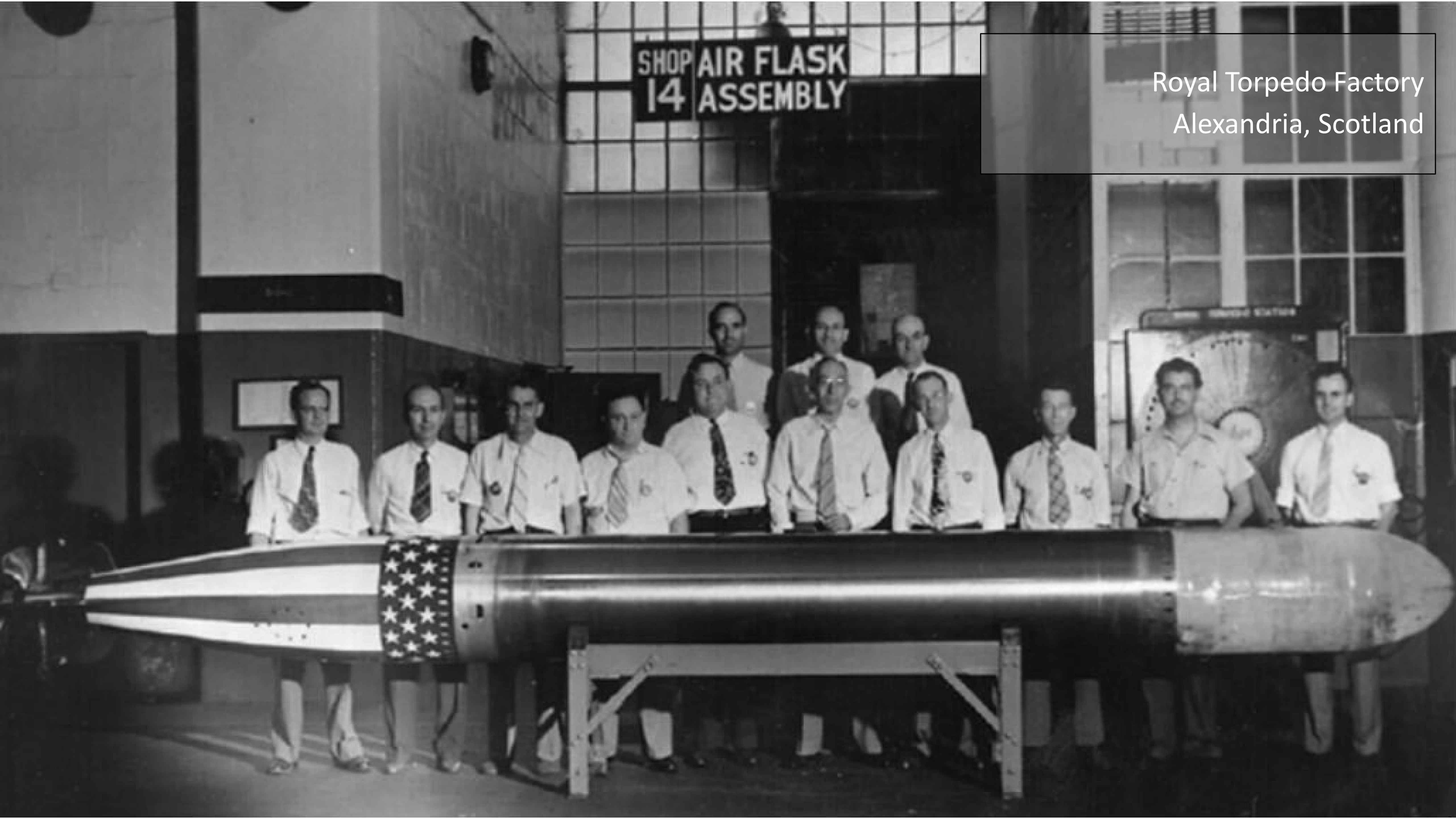
Geometric Tolerancing Characteristic Symbols

There are 12 geometric tolerancing characteristics with the corresponding symbols shown below. These symbols are placed in the first compartment of a feature control frame and define the geometry characteristic of the feature that is to be controlled.

The characteristics are grouped into four types of tolerance: form, orientation, location, and runout. The general primary control with a few notes is also shown. This is only a quick summary and a more complete definition can be found later in the text.

SYMBOL	GEOMETRIC CHARACTERISTIC	TYPE OF TOLERANCE	PRIMARY CONTROL
⏥	FLATNESS	Form	Controls shape of a surface or feature of size Datum feature reference not allowed Does not control relationship between features
—	STRAIGHTNESS		
⌭	CYLINDRICITY		
○	CIRCULARITY		
⊥	PERPENDICULARITY	Orientation	Controls tilt/angle of a surface or feature of size Datum feature reference required *Optional: Angularity symbol may be used for all orientation controls*
//	PARALLELISM		
∠	ANGULARITY		
⌖	POSITION	Location	Locates features of size Also controls orientation
⌓	PROFILE OF A SURFACE		Locates surfaces Also controls form and orientation Can also control size
⌒	PROFILE OF A LINE		
⌰	TOTAL RUNOUT	Runout	Centers a surface of revolution around a datum axis Also controls form and orientation
↗	CIRCULAR RUNOUT		

Note: Geometric characteristic symbols of concentricity and symmetry were removed in ASME Y14.5-2018. See unit 13 for more explanation.

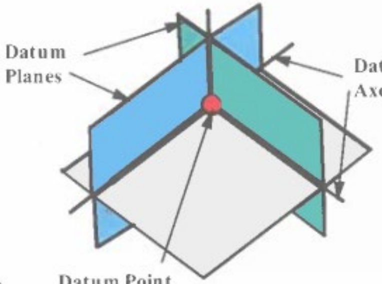


Royal Torpedo Factory
Alexandria, Scotland

Establishing a Datum Reference Frame

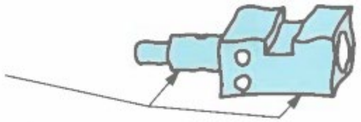
Establishing a datum reference frame on an imperfect part is done in a theoretical set of events: A design engineer will identify physical datum features that constrain the part in the assembly. These datum features are referenced in the rear compartments of a feature control frame, in an order of precedence. This order of precedence sets the sequence of how the perfect datum reference frame is related to the imperfect part. Since datum features have manufactured variations, perfect datums cannot be directly derived from these imperfect features. True geometric counterparts (TGC) are theoretically perfect inverse shapes of the datum features, and contact the datum features at their high points. These true geometric counterparts constrain the part's degrees of freedom, derive datums, and create a datum reference frame. The details and examples of establishing a DRF on a part are shown on the following pages of this unit. Below are important definitions to understand.

The **Datum Reference Frame (DRF)** is a three dimensional, Cartesian coordinate system. The engineers work in this theoretically perfect coordinate system to define their product and make necessary calculations. This DRF locates and orients part features. Basic dimensions and geometric tolerance zones are related to this DRF.

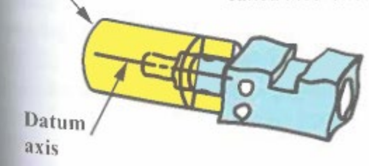


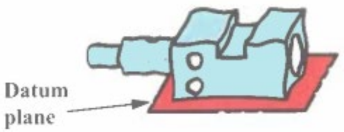
Datums are theoretically perfect points, axes, and planes that are components of the datum reference frame.

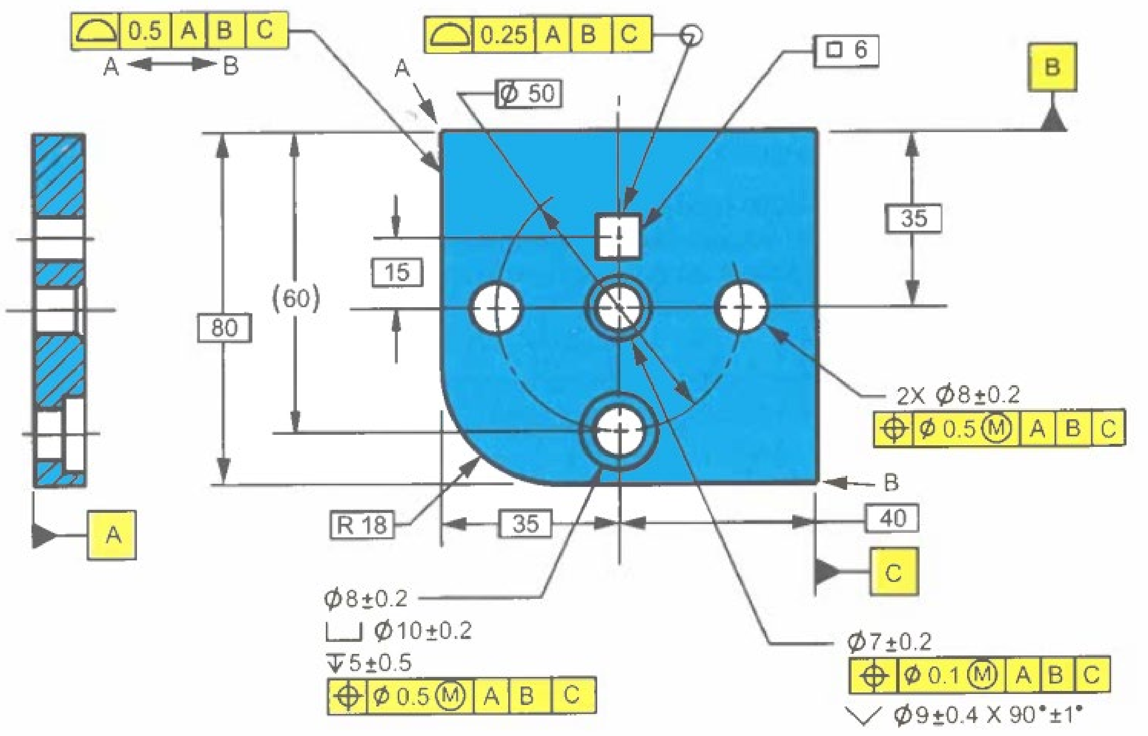
Datum features are the actual, physical features on the part (surface, hole, slot, shaft). They are not perfect and always have manufacturing variation.



True geometric counterparts (TGC) are the perfect inverse of a datum feature (smallest circumscribed cylinders, largest inscribed cylinders etc.) They engage with datum features and establish datums. Formerly called *theoretical datum feature simulator* in ASME Y14.5-2009.





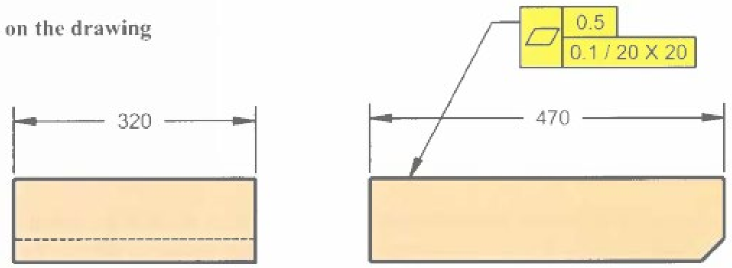


Flatness Per Unit Area

Flatness may be applied per unit area to prevent an abrupt surface variation within a small area. This can be thought of as a rate of change control. The per unit variation may be applied in combination with a total tolerance or alone. The feature units can be specified as a square or diameter.

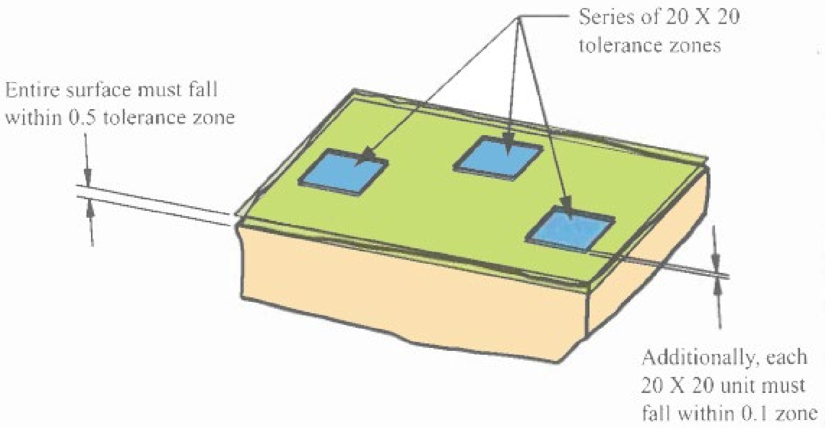
Note: This type of unit basis control may be used with straightness, perpendicularity, profile, and other geometric controls to obtain similar effects.

This on the drawing



The entire surface must lie within two parallel planes 0.5 apart. In addition, each 20 X 20 unit of the feature (infinite overlapping units) must lie within two parallel planes 0.1 apart.

Means this

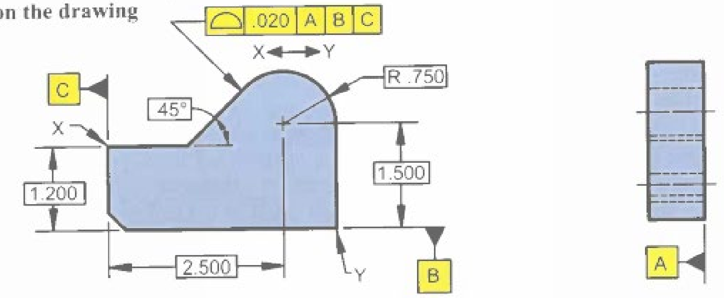


The 0.1 flatness per unit controls each section separately and can produce a cumulative effect if allowed to continue over the entire length of the feature. The overall flatness of 0.5 limits this cumulative effect.

Profile Tolerance

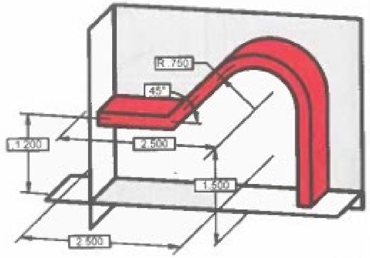
Profile tolerance controls the location of a surface to the datum reference frame. In the example below, it is also controlling the form, orientation, and size of the feature between points X and Y.

This on the drawing

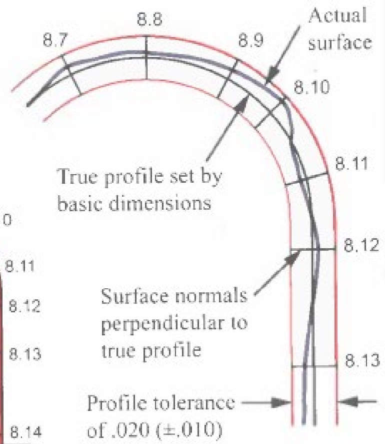


Creates this tolerance zone

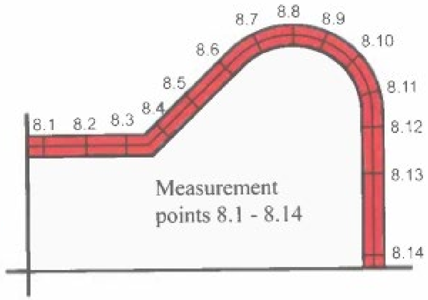
Profile of a surface creates a 3D tolerance zone equally distributed about the true profile set by the basic dimensions. All points of the actual surface must lie within this tolerance zone. The above value of profile is expressed as a total of .020. Therefore the surface may be ±.010 of the true location.



Each point on the theoretical surface creates a *surface normal*. The profile tolerance is equally distributed along this line. The deviation (Dev) of the actual surface at each point along the *surface normal* may be recorded.



Pt	Dev
8.1	+.002
8.2	+.003
8.3	+.003
8.4	-.002
8.5	+.001
8.6	+.003
8.7	+.004
8.8	+.002
8.9	+.005
8.10	+.009
8.11	-.002
8.12	+.003
8.13	-.004
8.14	-.006



Measured profile value = 2(max deviation)

Measured profile zone = .018

*The location and number of measurement points are set by the dimensional measurement plan.

Article

Deploying Geometric Dimensioning and Tolerancing in Construction

Saeed Talebi [1,*], Lauri Koskela [1], Patricia Tzortzopoulos [1], Michail Kagioglou [2] and Alex Krulikowski [3]

[1] Innovative Design Lab, School of Art, Design and Architecture, University of Huddersfield, Huddersfield, United Kingdom, HD1 3DH; S.Talebi@hud.ac.uk (S.T); L.Koskela@hud.ac.uk (L.K.); P.Tzortzopoulos@hud.ac.uk (P.T.)

[2] School of Engineering, Western Sydney University, Sydney, Australia, NSW 2751, M.Kagioglou@westernsydney.edu.au (M.K.)

[3] Krulikowski Consulting LLC, Florida, United States, 34202, Alex@krulikowskiconsulting.com (A.K.)

* Correspondence: S.Talebi@hud.ac.uk

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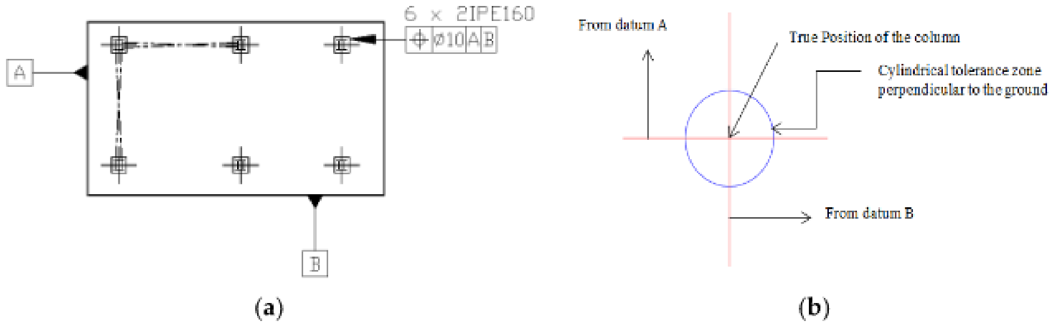

Figure 13. (**a**) TOP control applied to the columns; (**b**) demonstration of how to control the location of a feature of size.

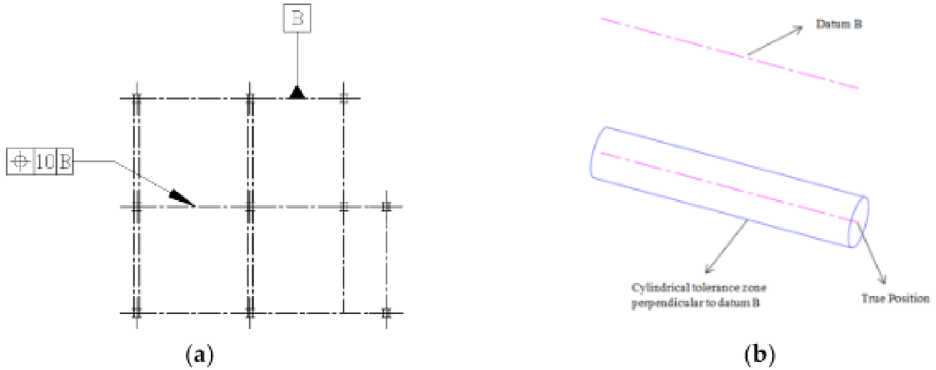

Figure 14. (**a**) TOP control applied to the beams; (**b**) demonstration of how to control the distance between features of size.


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