Guideline to Core and Sandwich

Diab

Introduction to sandwich

This document has been written to spread knowledge about sandwich and understanding of its behavior.

1.1 Why sandwich?

It has long been known that by separating two materials with a lightweight material in between it will increase the structure's stiffness and strength at very low weight and cost (see further explanation in "The sandwich principle" below). This distinction, along with many other drivers such as the environmental benefits, extreme cost savings, and freedom of design, are causing sandwich to become more and more popular in structural design.

1.1.1 Weight benefits

One of the most driving reasons to use sandwich is that the concept enables lightweight construction. The energy-saving benefits are described in the previous section, but it also enables faster and more effective solutions in many cases. Sports equipment is one segment for which strength and speed are important. Another is racing, such as sailing, speed boats etc. In industry, a lightweight solution enables faster and smaller robots. Within theatre, it enables fast set changes between scenes. In construction, a bridge or façade facilitates fast, effective installation. In transportation, lower weight in containers or vessel construction enables higher payloads. Clearly, the benefits of lightweight solutions go on and on.

1.1.2 Environmental benefits

Obviously, anything that moves consumes energy, and the heavier it is, the more energy consumed. Since using sandwich makes structural designs lighter, sandwich solutions are extremely environmentally friendly. With a sandwich solution, less material is consumed in the construction, thus saving resources as well as weight in the final construction, making the construction less energy consuming over its lifetime.

To illustrate the impact weight has on the environment, follow any kind of vessel – whether airplane, bus, train or a car – through its lifetime (25 years). Every kilo saved in its construction results in less energy needed to move people or materials around the world. Less energy expended every day for 25 years saves the environment from enormous amounts of pollutants. Due to increasing fuel costs, industries in many segments are also realizing that it is not only good for the environment, but it also costs less to design with lightweight solutions. The environmental impact of material choice in the beginning (energy) and in the end (recycling) of a vessel's life cycle is minor (as long as the material choice saves weight) in comparison with the vessel's fuel savings over its lifetime.

In addition to this, there are other savings when designing with sandwich:

- "Lower consumption of natural resources while building the vessels
- "More efficient transportation of material to the production facilities, more loading per shipment
- "Lighter equipment in the assembly line

A simplified comparison between a steel panel and a composite panel is shown under the heading "Basics of sandwich composite," demonstrating and explaining the potential weight savings from using sandwich.

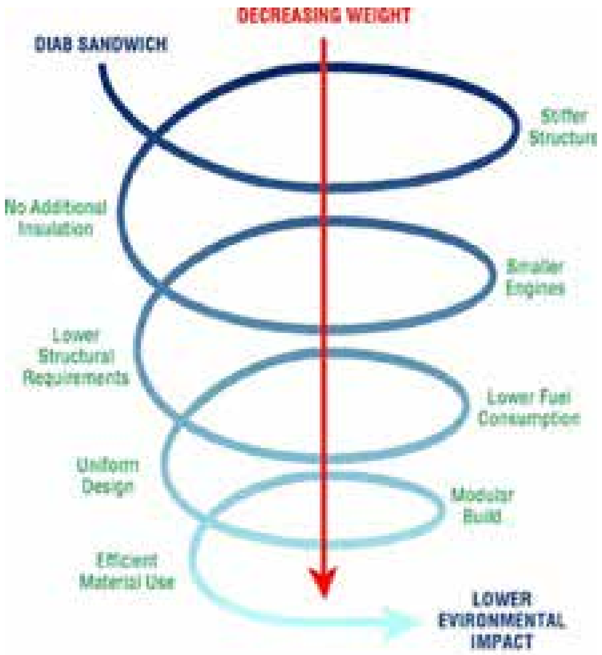


Figure 1.1: A weight spiral showing the value of the Diab Sandwich Concept.

1.1.3 Design benefits

Sandwich is appreciated for allowing freedom in design, as opposed to conventional construction materials such as metals and wood, which are usually limited in their shape from the beginning. When building composite sandwich structures, the materials are shapeable in almost any kind of form until the final stage of production in which it gets its final shape (see manufacturing processes to gain a better understanding). This allows for non-linear and smooth designs, which can be done not only for esthetic reasons but also for aerodynamic reasons.

1.1.4 Additional benefits

Although the properties listed below are not always among the driving factors behind the decision to design in sandwich, they save cost and increase the value of the design.

- Thermal insulation
- Sound insulation
- Non corrosive
- Very low water absorption

Figure 1.2: An example of creative design with sandwich composites, Ascalon sculpture, St. George's Cathedral, Australia

1.2 Basics of composite sandwich

The intention here is not to help design engineers with how to design sandwich panels, but to give a basic introduction to how sandwich works using illustrations and simplifications for those who are new to sandwich.

1.2.1 The sandwich principle

Sandwich-structured composites are a special class of composite materials with the typical features of low weight, high stiffness, and high strength. Sandwich is fabricated by attaching two thin, strong, and stiff skins, laminates to a lightweight and relatively thick core.

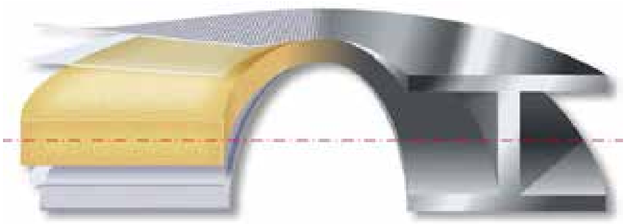


Figure 1.3: Illustration showing the analogy between a sandwich composite beam and a I-beam made of steel.

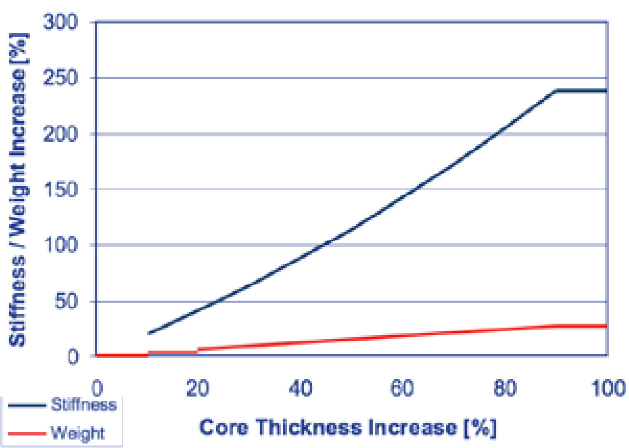


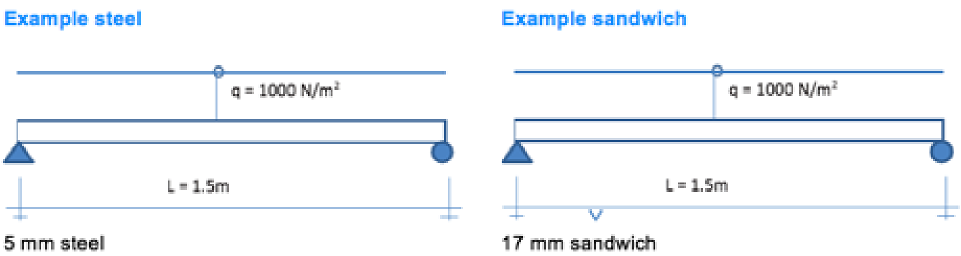
Figure 1.4: Comparison of composite panel and steel panel made of "standard materials"

The sandwich is analogous to an endless I-beam in the sense that when subjected to bending, the flanges carry in-plane (as do the sandwich skins or laminates) compression and tension loads and the web carries shear loads (as does the structural sandwich core). As with a traditional I-beam, when the flanges (skins) are further apart, the structure gains more proportional stiffness. A thicker core achieves the same, but it also provides an overall low density, resulting in a high stiffness-to-weight ratio.

The comparison between a steel panel and a composite sandwich panel illustrated below indicates the potential of weight savings from using sandwich.

With the same criteria for deflection, the weight savings with sandwich design is almost 90%. Additional benefits with sandwich construction are thermic insulation, acoustic dampening, buoyancy, non-corrosiveness, and increased impact resistance.

As with all beams or panels the stiffness is closely related to the thickness. One of the big differences between designs with conventional materials and a sandwich composite solution is the small weight penalty an increased thickness yields.



Weight 39 kg/m²
Deflection 30 mm
Safety factor 3

Weight 4.3 kg/m²
Deflection 30 mm
Safety factor 5.7

Figure 1.5: Graph illustrating the effect on stiffness and weight in a sandwich panel with increasing thickness of the core material.

1.2.2 Description of Sandwich

A typical sandwich consists of upper and lower skins with a, in comparison, much thicker core in between.

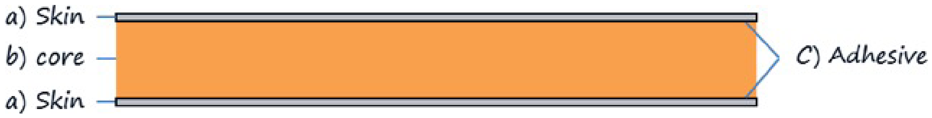


Figure 1.6: Illustration of sandwich panel

Each part in a sandwich has its particular function and is described below.

a) Faces

The faces carry the tensile and compressive stresses in the sandwich. The local flexural rigidity is so small it can often be ignored. Conventional materials such as steel, stainless steel and aluminum are often used for face material. In many cases, it is also suitable to choose fiber or glass-reinforced plastics as face materials. These materials are easy to apply. Reinforced plastics can be tailored to fulfill a range of demands like anisotropic mechanical properties, freedom of design, excellent surface finish, etc.

Faces also carry local pressure. When the local pressure is high, the faces should be dimensioned for the shear forces connected to it.

b) Core

The core's function is to support the thin skins so that they do not buckle (deform) inwardly or outwardly and to keep them in relative position to each other.

To accomplish this, the core must have several important characteristics. It has to be stiff enough to keep the distance between the faces constant. It must also be so rigid in shear that the faces do not slide over each other. The shear rigidity forces the faces to cooperate with each other. If the core is weak in shear, the faces do not cooperate and the sandwich will lose its stiffness.

It is the sandwich structure as a whole that gives the positive effects. However, it should be mentioned that the core has to fulfill the most complex demands. Strength in different directions and low density are not the only properties that the core has to have. Often there are special demands for buckling, insulation, absorption of moisture, ageing resistance, etc.

The core can be made of a variety of materials, such as wood, aluminum, and a variety of foams.

c) Adhesive (bonding layer)

To keep the faces and the core cooperating with each other, the adhesive between the faces and the core must be able to transfer the shear forces between them. The adhesive must be able to carry shear and tensile stresses. It is hard to specify the demands on the joints. A simple rule is that the adhesive should be able to take up the same shear stress as the core.

Structural core material's

2.1 Scope

There is a variety of core materials available on the market and many of them claims to be suitable also as structural core materials. There is no valid definition or line between pure insulation core material and structural core materials, in fact anything that carries a load can be claimed to be a structural core material. However in the following core materials which's main purpose usually are in structural load carrying designs are described.

2.2 Structural foam Cores

There are many different foam core available on the market, based on different chemistry and processing techniques, but only a few will be covered shortly in the following. Insulation materials and other core materials which main purpose are aimed to other than structural design are not covered.

2.2.1 IPN, Inter Penetrating Network foams

The unique combination of cross linked polyurea and PVC yields impressive mechanical performance to a very low weight. PVC foam has almost become a trade name even though it actually is a combination of almost equal parts of polyurea and PVC –thus the label IPN, inter penetrating network. The material does not contain hazardous plasticizers or substances. Diab have a wide range of cores which almost all springs from the traditional Divinycell H grade which has been available on the market for many decades.

The original recipe of cross-linked foam goes a long way back and since then there has been a lot of development in both process and chemistry of Cross Linked PVC's. The range has developed into new grades to meet customer needs and demands.

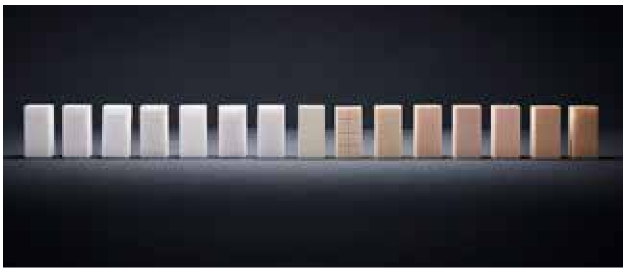


Figure 2.1: Divinycell PVC Foams

2.2.2 PET foam

PET foam, or Divinycell P, is manufactured of thermoplastic polyethylene terephthalate which results in a thermoplastic foam. PET has excellent thermal stability. However, to achieve physical properties comparable with IPN/PVC, higher product densities needs be used.

To increase its mechanical properties as much as possible it is favorable to turn the foam in the perpendicular direction of the sheet. This achieved by welding the sheets together and then cut it up in desired sheet thicknesses.

Another benefit with PET is that it is possible to reuse process scrap in production.

2.2.3 PES foam

Divinycell F is made from extrusion of thermoplastic polyethersulfone (PES). It has a unique high service temperature for thermoplastics. It offers excellent fire, smoke, and toxicity properties. Furthermore, it is non-hygroscopic, superior damage/impact performance and improved dielectric properties.

Divinycell F offers a lot of benefits in several aerospace segments, which usually focus on honeycombs due to fire regulations and prepreg compatibility. However, PES not only provides the same benefits, but it is also offers other benefits such as; heat- and cold form, very low water absorption. Since it is foam it is easy to shape and trim to desired shape, which takes away the need of edge filling. The closed cell structure reduce moisture uptake over time considerably.

Process scrap such as off-cuts is recycled in production.

2.3 Balsa cores

Balsa, or as Diab product is labeled, Divinycell ProBalsa is still a very popular structural core material which is used in many different applications. To utilize the balsa wood properties it needs to be trimmed, weighed, sorted and glued.

To get the most out of balsa the natural fibers needs to be oriented in the perpendicular direction of the sheet, which is done by gluing the timber together, turn it and slice it up in correct thicknesses. The effect of this reorientation of the "balsa cells" is that it increases the shear and compression properties of the balsa vastly.

A concern with balsa is the risk of moisture uptake as with all wood materials, which makes it susceptible to rot if not properly installed or maintained.

Figure 2.2: Balsa core material

Mechanical properties – terminology

There is a lot of technical data available on core materials, presented and published in a variety of ways. However, there are rarely any fundamental explanations in the information provided. The following is a simple introduction to core materials, describing their mechanical behavior and typical material characteristics with the aim to get to a basic understanding of core materials and mechanical engineering.

Terminology

In materials science is a material's ability to withstand an applied load without failure, i.e., strength is a material's capacity to carry loads. Strength in structural core materials is measured through mechanical testing (see example in "Core material behavior under loading" on page 17), and there are several standards to follow "Material information" on page 27. It is customary in the industry to public ally provide nominal values on strength values; however, when doing structural design, it is recommended to use certified minimum values to make sure correct safety factors are used. Strength is usually measured in compression, tensile and shear (see below).

Yield strength

Yield strength is the lowest strength that produces a permanent deformation in a material, i.e., a material's yield strength describes how much load stress it can take before having a permanent deformation (damage).

Stress

Stress describes the forces acting within a material due to an applied load, i.e., stress is a measurement of the amount of forces there are acting within a material at a certain load.

Deformation

Is a material's change in geometry due to an applied load.

Strain

Describes the trend of deformation and is measured as deformation per unit length.

Elastic modulus

Or modulus of elasticity, is the mathematical description of a material's tendency to be deformed elastically when a force is applied to it -commonly described as how "stiff" a material is. The relationship between deformation and stress determines a material's elastic modulus.

3.1 Strength and stress scenarios on core material

Compressive strength

A material's compressive strength describes how much compressive stress it can take in compressive loading before it deforms or brakes.

Compressive stress

When a material is subjected to a compressive load, the stress within the material increases.

Figure 3.1: Test specimens in compression test

Tensile strength

A material's tensile strength describes the limit of tensile stress it can take before failure.

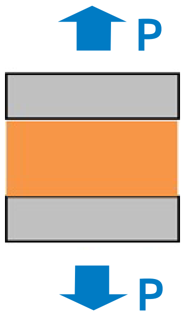
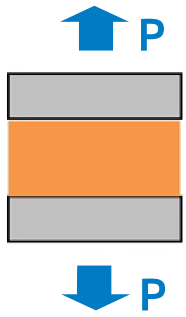


Figure 3.2: Test specimens in tensile test

Tensile stress

When a material is subjected to a tensile load, the stress within the material increases.



Shear

A material's shear strength describes how much stress it can take in shear loading before it deforms or brakes. Shear strength is probably the most common design criteria in sandwich construction and possibly also the most difficult to understand, but by using of the metaphor of a book, shear can be illustrated in a way that is easier to grasp.

Figure 3.3: A paper book before and after its pages has been glued together

Imagine the core consists of pages in a paperback book. It is easy to bend the book if there is no shear strength (glue or friction) between the pages, however it is almost impossible to bend if the shear strength is high (glued together). As with the skins in a sandwich structure, the covers of the book are relatively thin so they will not take much of the shear stresses as the pages in the book slide (shear) past each other.

Shear testing can be performed in several way's to determine a materials behavior in shear.

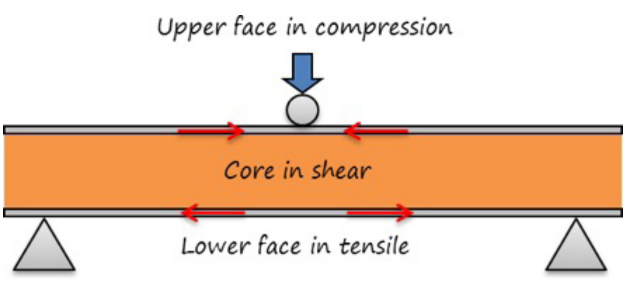


Figure 3.4: Three-point bending test can be used to measure a core materials' shear strength.

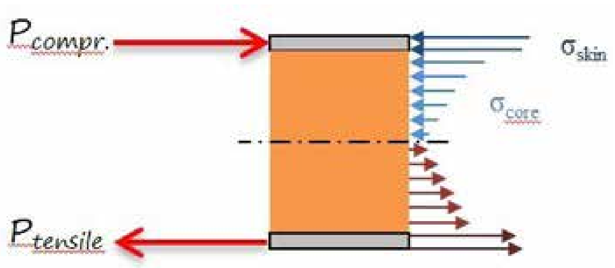


Figure 3.5: A cutout of the sandwich beam, showing stress reactions in core and skins du to loading.

Shear testing can also be performed as illustrated below, in which the specimen is glued in between two rigid steel brackets (shown in grey), which are then pulled apart to force the material to brake in shear.

Shear strength

A material's shear strength describes how much stress it can take in shear loading before it deforms or brakes.

Shear stress

When a material is loaded in shear, the stress within the material increases. That is, the material resists the "sliding" within the material.

Figure 3.6: Test specimens in shear test

Updated data on core materials mechanical properties are available on diabgroup.com

3.2 Core material behavior under loading

All materials behave differently under loading, which has a big impact on the performance of the final application.

There is a lot of excellent literature available that gets into real depth in materials science and sandwich theory, but rarely something from a "common sense manner". The intention with this chapter is not to learn how to engineer with core materials, but to get a basic understanding of differences in stiffness and strength between materials as well as to get an a background to the terminology used when describing core materials.

Brittleness, elongation, modulus, strain, stress, stiffness etc. are words commonly used to describe a core materials behavior, however many of these words are without a deeper meaning to many, hopefully the following can connect theory and reality a bit.

By the use of a fictive tensile test the mechanics and theoretical behavior of a material is described. In the following theoretical and practical reflections are done during the different stages of the fictive test to describe a core material's behavior.

Figure 3.7: Core material that has been tested in tensile.

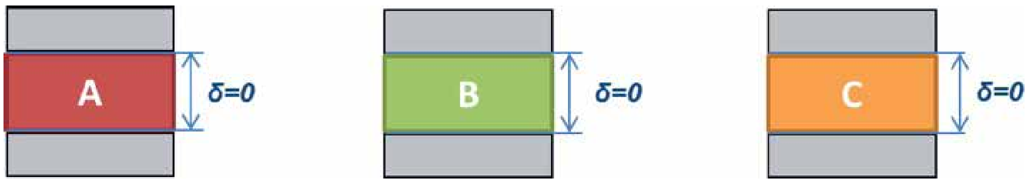
3.2.1 Fictive test

Three different materials are tested simultaneously, labeled as A, B, and C, the only difference among them at the beginning of the test is the color. To be able to get a feeling of the materials a stress-strain curve will be developed from achieved test results (described in more detail further on).

To get the data needed to do a stress-strain curve, the three materials are mounted in a pulling machine. The machine will pull the three materials apart while there is a continuous log of the force used to pull, as well as a continuous log of the deflection of the materials.

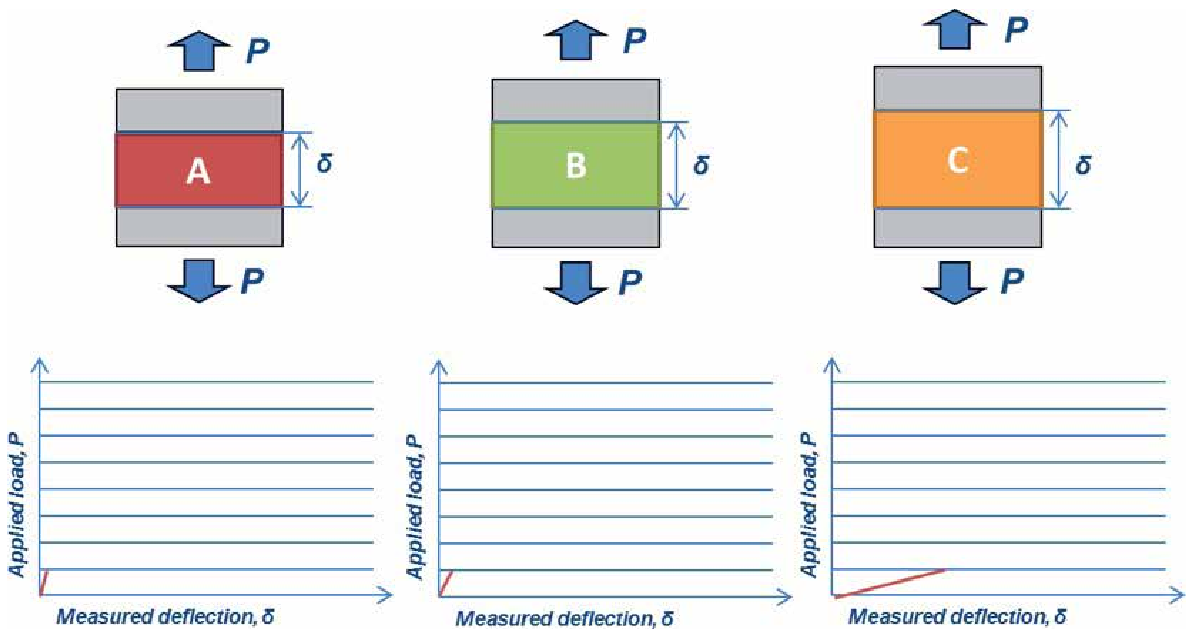
Sequence 1

As in the previous illustrations, the grey areas illustrate steel brackets used to apply the load. In the first illustrations, there is no load applied and the deflection, strain is 0 mm, as is the time.



Sequence 2

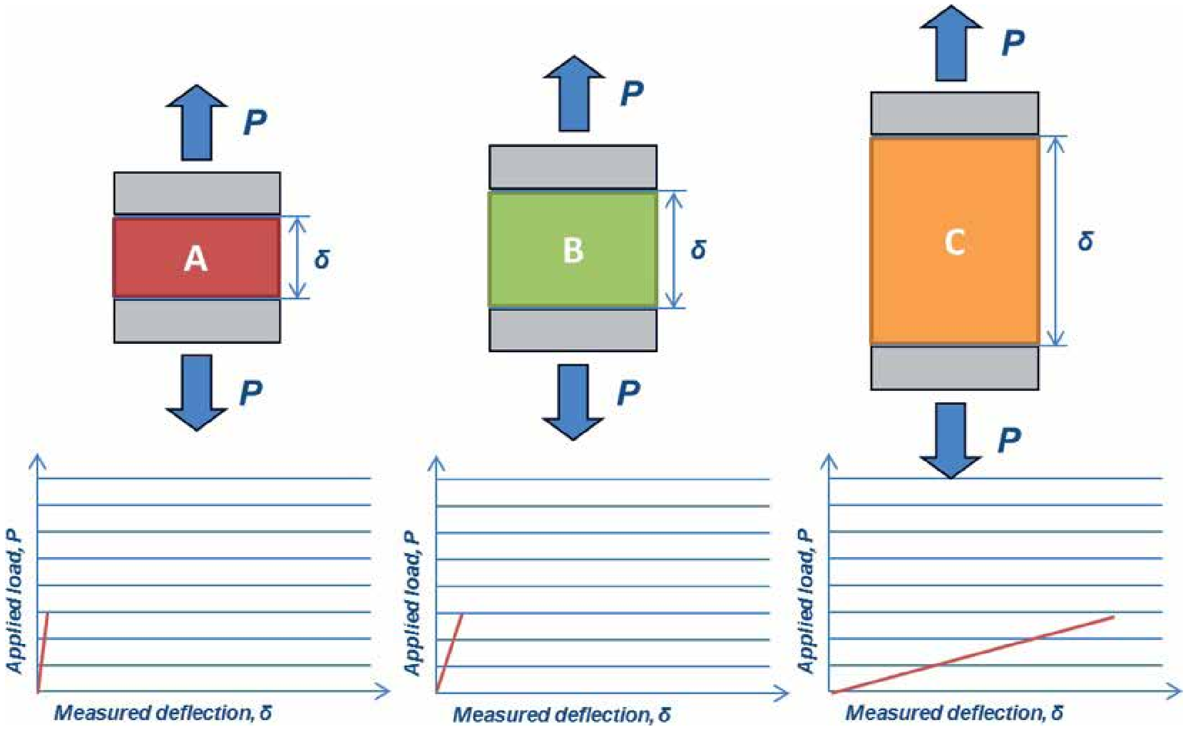
In sequence 2, a load has been applied (the same for all three samples) and some time has elapsed. Applied force and deflection, elongation (how much it has moved) is recorded in the graphs below the illustration. As can be noted, there are different amounts of deflection, where sample C has stretched out a bit more than the others.



Sequence 3

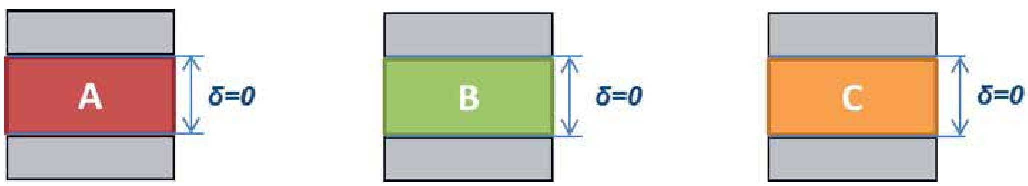
In snapshot three of this simulation, there is a noticeable difference between the three samples. It can be noticed in the plots that there is still a very linear behavior in the materials. The ratio between force and deflection is constant at this stage.

This far in the testing, the materials still have not reached the plasticity area. They are still in the elastic area. In other words, there is still no permanent damage to the test materials (see sequence 3b).



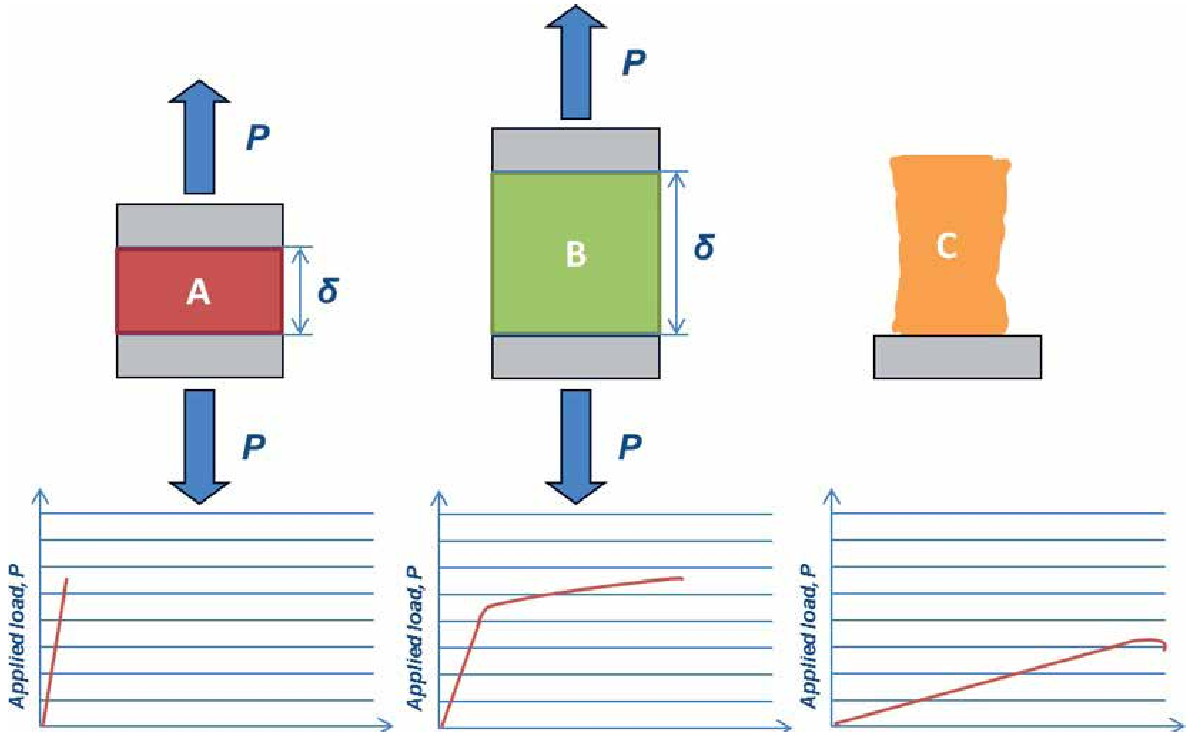
Sequence 3b

If the loads on the test specimen are released this far into the test, see above, the materials will go back to their original states as well as their mechanical performance - or at least very close to their origin. The reason for this is that the materials were subjected to loads below their plastic capacity. It can also be expressed in this way: the materials are loaded within their elastic capabilities.



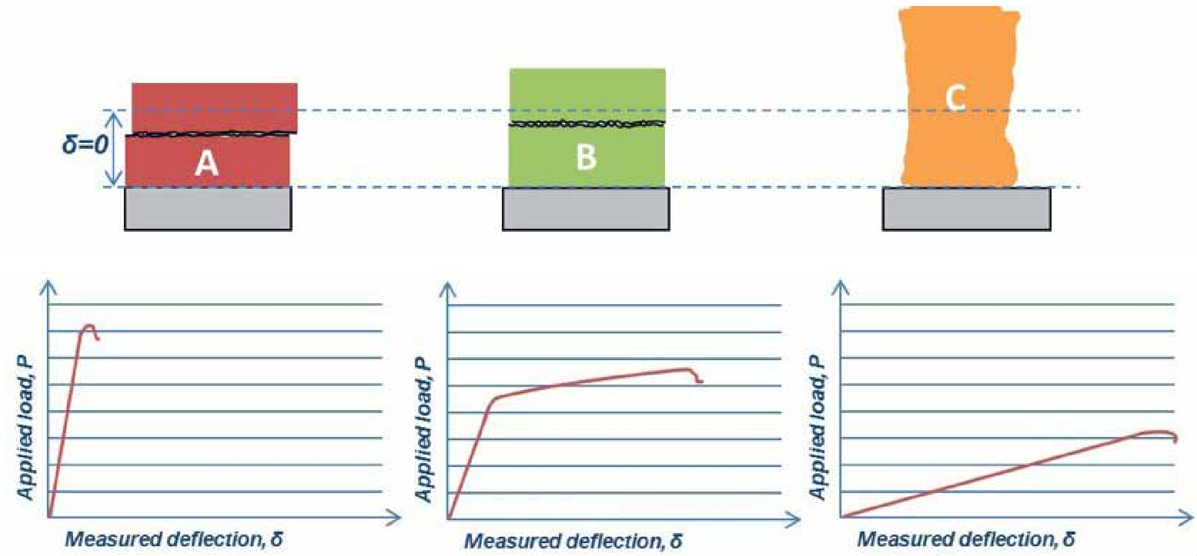
Sequence 4

Let's see what happens as the test continues. The illustration below shows that some time later material C has broken due to too high loading. Apparently, the material's strength was not strong enough to carry the load. Checking the plot from the test equipment, it can be seen that material A is still in a linear state while material B starts to get stretched out faster (elongation in the material has increased because the stresses in the material are not linear to the elongation anymore). Material A is still in the elastic region and the deflection in relation to the other materials is still minor.



Sequence 5

The test is finished, and material A and B have cracked into two parts, while material C is still in one unit but deformed and without any structural performance left. The testing yielded three plots, which can be used to further analyze the materials.



3.2.2 Stress-strain relation

There are three fictive graphs in the test illustrated above, which log force and deformation. These will be used further to learn more about the tested fictive materials.

But first, to be able to make a stress-strain curve, the stress and the strain need to be calculated.

Stress

The stress (forces in the material) can be calculated with the following well-known formula:

$$\sigma = P \div A$$

Where;

σ = Stress (MPa)

P = Load (N)

A = Area of test sample

The magnitude of the force and the area of the samples are known from the testing, thus the stress can be calculated over time or throughout the test cycle.

Strain

Strain is the deformation per unit length (how much a material deforms under loading.

$$\varepsilon = \delta l \div l$$

Where;

ε = Strain (%)

δl = Length of deformation (mm)

l = Original length (mm)

The deformation of the material is known through the logging of data during the test and the original length is known as well, which gives the strain values needed to create a stress-strain curve.

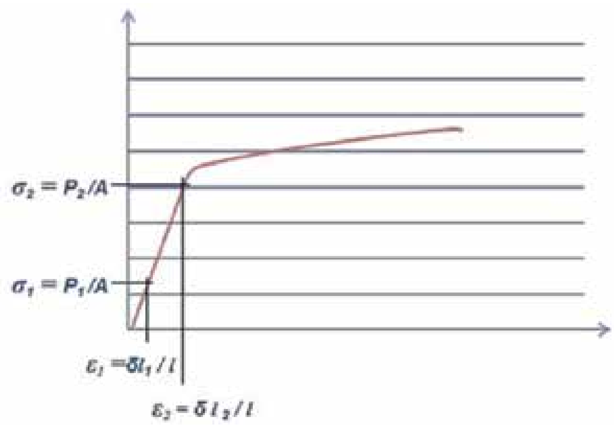


Figure 3.8: Measured load and deflection data -from which strain and stress can be calculated

By the use of the previous formulas to calculate stress and strain at the same moment over time, it is now possible to draw a graph, which shows the relationship between stress and strain, elongation in the test specimens. Material B provided a noteworthy stress-strain curve, which is interesting to analyze further (see graph).

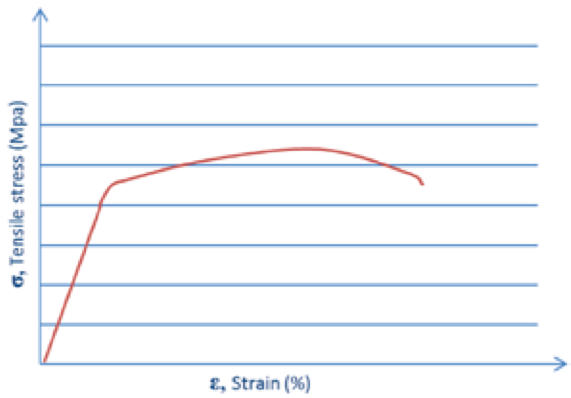


Figure 3.9: Obtained stress strain graph

As mentioned previously, the first slope in the graph shows the material's behavior in the elastic area, in which the stresses and elongation are in proportional relationship. This part is called the linear or elastic area. Elasticity is a material's ability to return to its shape after stress is released (i.e., as long as the material is strong enough to be within the linear area, it will return to its original status). However, this is only valid in static loading. If the load is applied repeatedly, the material will experience fatigue and other rules in mechanics come into play.

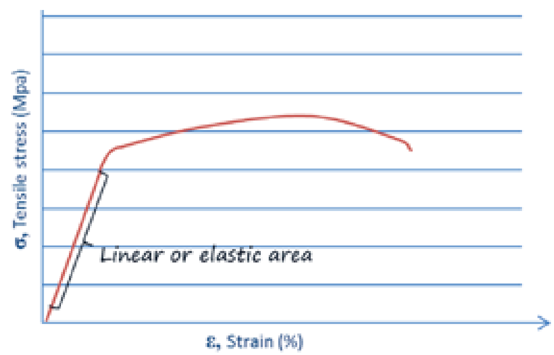


Figure 3.10: Stress -strain graph, pointing out where the material still is in its elastic region.

The slope of the line in the elastic area represents the material's elastic modulus (Young´s modulus). Note that elastic modulus is only valid in the elastic region.

Elastic modulus (linear area)

An elastic modulus, or modulus of elasticity, is the mathematical description of a material's tendency to be deformed elastically when a force is applied to it, that is, how tough a material is to reshape and still remain within the elastic area (without yielding permanent damage).
A stiffer material will have a higher elastic modulus.

$$\sigma = E \times \varepsilon$$

E = Elastic modulus
ε = Strain (%)
σ = Stress (MPa)

In many materials, test methods make it difficult to identify the point of yielding. Thus it is common to set the yield value at 0.2% strain, which is called a material's 0.2% proof stress.

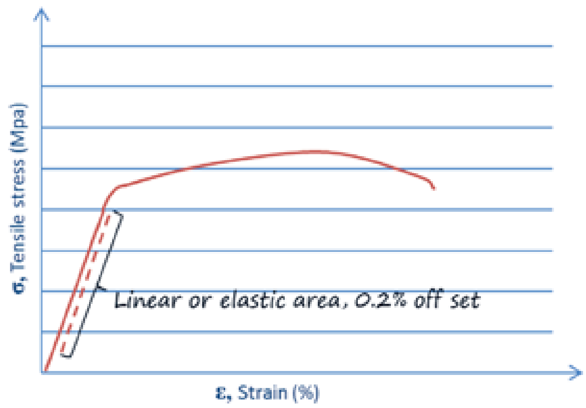


Figure 3.11: Illustration of 0,2% proof stress

Yield strength

The **yield strength** or **yield point** of a material is defined in engineering and materials science as the stress at which a material begins to deform plastically. Prior to the yield point, the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible.

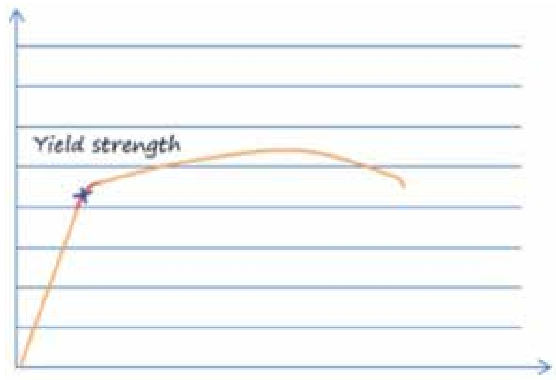


Figure 3.12: A materials yield strength is the point just before it starts to plasticize.

Below, the yield strength is determined at 0.2% strain.

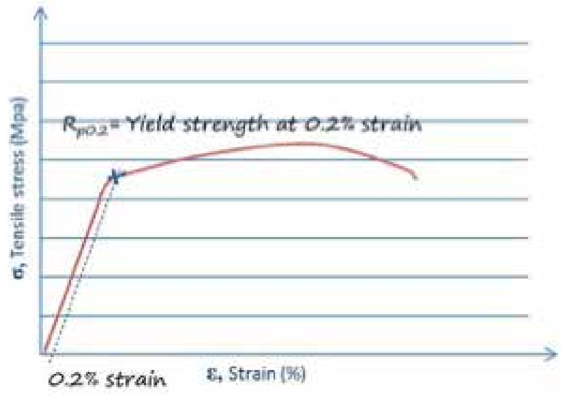


Figure 3.13: A materials yield strength at 0.2% strain

Plasticity (non-linear area)

Plasticity or plastic deformation is the opposite of elastic deformation and is defined as unrecoverable strain. If a material is loaded into the non-linear area, it will have permanent deformation. The fracture or ultimate strength point is the point where the material collapses or brakes apart.

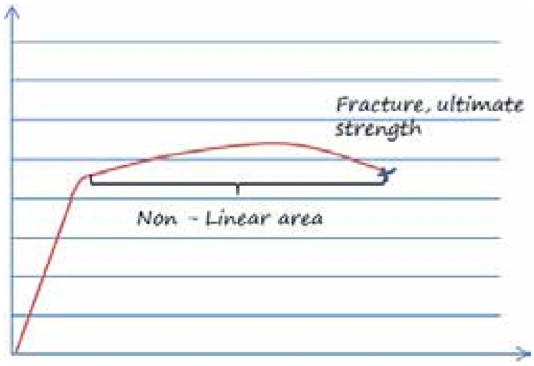


Figure 3.14: Graph, showing the region where a material will have a permanent deformation.

Summary of stress-strain

Through mechanical testing in tensile, compression, or shear, interesting information can be obtained, as previously described. With the use of a scientific laws and mathematics, a stress- strain curve can be obtained (see below).

$\varepsilon = \delta l \div l$

$\sigma = P \div A$

$\sigma = E \times \varepsilon$

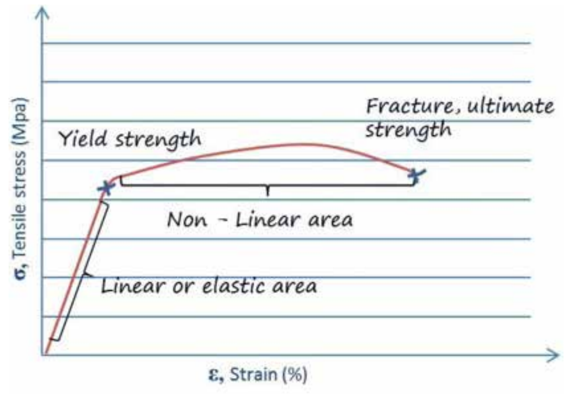
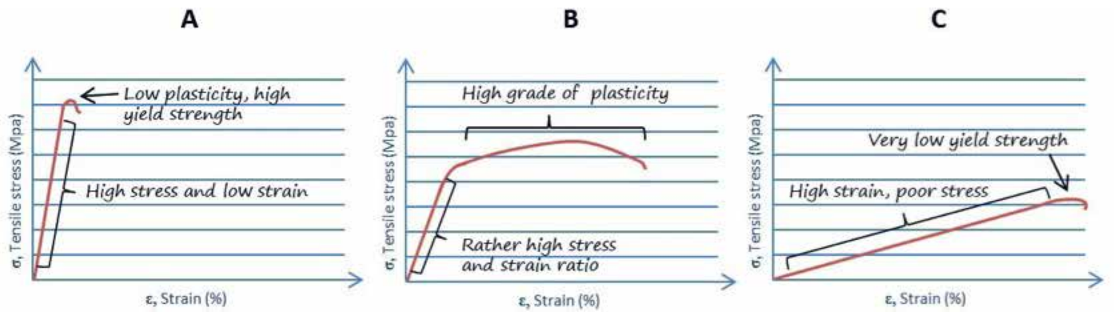


Figure 3.15: Stress – strain graph

3.2.3 Reflections on results of fictive testing

We have described three different, fictive mechanical tests made in tension. The laws and principles would have been the same if the tests had been made in compression or shear, but the curves would have been different.

Below are rough conclusions made on the mechanical performance of materials A, B and C, just by studying the stress-strain curves.



Material A is a tough and stiff material since it can take a lot of stress without any elasticity. It is most likely a steel or aluminum material and, thus, very heavy.

Material B is not very stiff or strong, but it can take high strain to high stress, which usually also means it can take up a lot of energy. It is probably a good material in dynamic loadings. (The area below the slope in the linear area usually correlates to this.) It is a tough material that is difficult to tear apart, but there will be a permanent deformation immediately after the yield point. It is most likely a lightweight foam core.

In material C, there is a high strain elongation, but it cannot take much stress. This means that it is experienced as a non- stiff material. A rubber band would behave in a similar way.

Material information

There is a lot of information stated on a materials data sheet and in the following a description of the different material characteristics are described to provide an explanation of how they are achieved, what they mean and how thoroughly tested they are.

Information on data sheets

Where it is relevant a materials typical characteristics are published on the data sheets to make it as accessible as possible. Density, compression, tensile and shear properties are a part of the production inspection testing and is tested on a frequent basis. Other characteristics like insulation properties are tested with much lower frequency and the information shall be treated as typical or indicative data.

The first page on Diab data sheet usually provides data of the structural performance or Figure 4.1 on page XX of the grade together with a description of its typical characteristics. The second page usually contains information which describes other characteristics of the material other than structural performance, but still characteristics, which can be of importance in many applications. These characteristics are referred to as "Technical Characteristics".

Diab core material is mostly used in structurally loaded applications where it of importance to provide reliable data on mechanical performance which makes it important to type approval core materials.

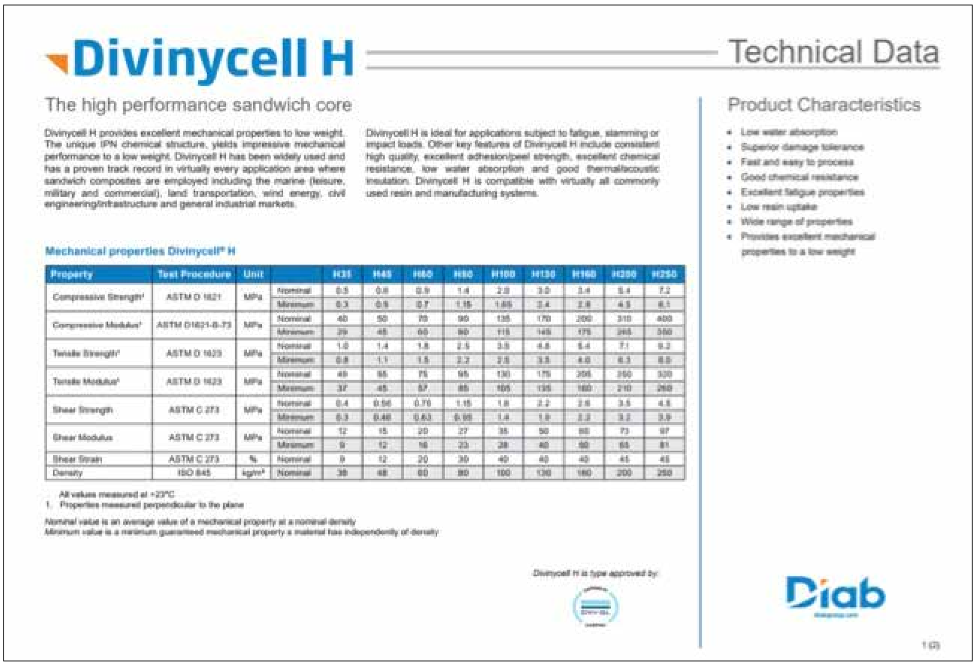
Type approvals

Material certification means that a certifying body issues a certificate stating that the material complies with the requirements of that certifying body. In several segment/industries there are certifying bodies which issues certificates on materials properties, mechanical data, to be used according to their design rules, i.e. DNV and Lloyds' in the maritime segments and Germanicher Lloyds in the Wind segment. To get a certificate on a material, usually material test data is reviewed and i.e. shear and compression testing are witnessed by the certifying body. The quality of the material also needs to comply to rule requirements. Some of the certifying bodies also demand that the manufacturer has an "approval of manufacturer" to be able to get a material certification.

The different certifying bodies prefers different test standards in their regulations, thus more than one test standards needs to be used to cover different certificates requirements. In production inspection many mechanical data are checked in a frequent interval to make sure that quality is maintained of the products and to build a useful database. This testing is following a test standard, which however not suits all of the certifying bodies, which as mentioned have their preferred standards. In other words where production testing standards and certifying bodies standard are the same there is an enormous amount of data available – and when not additional testing is needed according to fulfill requirements of that certifying body.

4.1 Mechanical properties

As mentioned the first page usually describes the mechanical properties, structural performance of the core material, see figure 4.1 below:



Divinycell H

Technical Data

The high performance sandwich core

Product Characteristics

- Low water absorption
- Superior damage tolerance
- Fast and easy to process
- Good chemical resistance
- Excellent fatigue properties
- Low resin uptake
- Wide range of properties
- Provides excellent mechanical properties to a low weight

Divinycell H provides excellent mechanical properties to low weight. The unique IPN chemical structure, yields impressive mechanical performance to a low weight. Divinycell H has been widely used and has a proven track record in virtually every application area where sandwich composites are employed including the marine (leisure, military and commercial), land transportation, wind energy, civil engineering/infrastructure and general industrial markets.

Divinycell H is ideal for applications subject to fatigue, slamming or impact loads. Other key features of Divinycell H include consistent high quality, excellent adhesion/peel strength, excellent chemical resistance, low water absorption and good thermal/acoustic insulation. Divinycell H is compatible with virtually all commonly used resin and manufacturing systems.

Mechanical properties Divinycell® H

Property	Test Procedure	Unit		H35	H45	H60	H80	H100	H130	H160	H200	H250
Compressive Strength[1]	ASTM D 1621	MPa	Nominal	0.5	0.6	0.9	1.4	2.0	3.0	3.4	5.4	7.2
			Minimum	0.3	0.5	0.7	1.15	1.65	2.4	2.8	4.5	6.1
Compressive Modulus[1]	ASTM D1621-B-73	MPa	Nominal	40	50	70	90	135	170	200	310	400
			Minimum	29	45	60	80	115	145	175	265	350
Tensile Strength[1]	ASTM D 1623	MPa	Nominal	1.0	1.4	1.8	2.5	3.5	4.8	5.4	7.1	9.2
			Minimum	0.8	1.1	1.5	2.2	2.5	3.5	4.0	6.3	8.0
Tensile Modulus[1]	ASTM D 1623	MPa	Nominal	49	55	75	95	130	175	205	250	320
			Minimum	37	45	57	85	105	135	160	210	260
Shear Strength	ASTM C 273	MPa	Nominal	0.4	0.56	0.76	1.15	1.6	2.2	2.6	3.5	4.5
			Minimum	0.3	0.46	0.63	0.95	1.4	1.9	2.2	3.2	3.9
Shear Modulus	ASTM C 273	MPa	Nominal	12	15	20	27	35	50	60	73	97
			Minimum	9	12	16	23	28	40	50	65	81
Shear Strain	ASTM C 273	%	Nominal	9	12	20	30	40	40	40	45	45
Density	ISO 845	kg/m³	Nominal	38	48	60	80	100	130	160	200	250

All values measured at +23°C

1. Properties measured perpendicular to the plane

Nominal value is an average value of a mechanical property at a nominal density

Minimum value is a minimum guaranteed mechanical property a material has independently of density

Divinycell H is type approved by:

Diab

Figure 4.1: Typical data sheet lay-out of Diab data sheet, updated version are available at diabgroup.com

Definition of Nominal and minimum values

Nominal value is the specified value for the material. That means that the properties of the material will have a mean value close to the nominal value. The mean value is based on all measured values on full size blocks. The material delivered to a customer is normally only a fraction of the totally produced material. This may result in that the actual value on the property of the delivered material has a mean value lower or higher than the declared value. Minimum values are calculated as the nominal value minus (-) two standard deviations.

The minimum value is based on all measured values of all batches. The delivered materials have a 97,6% probability of being above the minimum value, thus having 2,4% probability of being outside the minimum value.

Minimum values is a minimum guaranteed mechanical property a material has independently of density.

From the requirements of structural properties for a core material it obvious that the most important static tests for a core material will be compression and tensile tests perpendicular to the plane and shear tests parallel to the plane.

Testing is done in a testing machine, suited to the range of force and displacement involved, having two parallel plates, one fixed and the other movable. Load is measured with a force sensor and displacement from the machine movement or with an external extensometer. While load measurement is very straight forward, displacement is more complicated and the choice of method influences the test result.

4.1.1 Compression testing

Table 4.1 on page 29 summarize requirements for test specimen configuration and method for displacement measurement.

Compressive strength is calculated at maximum load or at 10% deflection, whichever occurs first. All standards will give comparable result, independent of specimen configuration.

Compression modulus is calculated from the linear part of the load-displacement curve in the elastic region. Displacement, or strain, can be measured in three ways; from the machine drive system (compression platen or crosshead movement), direct measurement on the plates or direct measurement on the specimen (extensometer).

The first method does correct for deflections in the machine loading system (machine compliance). The first and second does not correct for the cut open surface cells of the specimen, which are weaker than the closed cells. Both increase the displacement, thus decreasing the modulus. Only direct measurement on the specimen with an extensometer results in a correct modulus. In addition the relation between specimen area and height affects the modulus, up or down.

Compressive modulus for two materials can only be compared if measured with the same method and specimen configuration!

Test standard	Specimen					Displacement measurements
	Geometry	Area	Height	Length	Width	
DIN 53 421	Cubic	-	50 mm	50 mm	50 mm	Extensometer on specimen Resin filled surface may be used
ASTM D 1621-73	Square or circular	25-230 cm²	>25.4 mm Ø or width	-	-	Extensometer on specimen or cross head movement
ASTM D 1621-10	Square or circular	25-230 cm²	>25.4 mm Ø or width	-	-	Extensometer on platens or compression platen movement. Correct for machine compliance
SO 844:2009	Square or circular Right prism with 100 mm base is preferred	25-230 cm²	50 mm	-	-	Compression platen movement
Diab Standard ASTM D 1621-73	Square	25 cm²	30 mm	53 mm	53 mm	Extensometer on specimen

Table 4.1: Test standards, compression

As can be seen in the table Diab prefers AST D1621-73, "Standard Test Method for Compressive Properties Of Rigid Cellular Plastics", since the method is in compliance with and it measures the modulus in the material through the use of extensometer.

4.1.2 Tensile testing

Most sandwich constructions are loaded in tension perpendicular to the plane, which is through the thickness direction of the foam. This limits the numbers of test standards to be used, since the core thickness is typical 60-80 mm. In example the standard ISO 1926 requires a dog-bone shaped specimen with a length of 150 mm. This standard can only be used to for in the plane tests.

Tensile strength is calculated at maximum load, which normally occurs when the specimens breaks. Displacement, or strain, is measured by direct measurement on the specimen with an extensometer. Tensile modulus is calculated from the steepest part of the load-displacement curve in the elastic region (this is not included in the standard).

As for compressive strain, displacement is allowed to be measured from the machine movement, but this will increase displacement, thus decreasing the modulus as described above.

The preferred Diab standard is ASTM D1623-09, "Standard Test Method for Tensile and Tensile Adhesion Properties of Rigid Cellular Plastics". The specimens are cylindrical dog- bones with 60 mm diameter and 40 mm waist. The specimens are bonded to steel/aluminium grip assembly blocks.

For testing of sandwich panels it is recommended to use ASTM C 297-04, "Standard Test Method for Flatwise Tensile Strength of Sandwich Constructions".

4.1.3 Shear testing

Shear properties can be determined either through block shear testing or sandwich beam bending. It is recommended to use block shear testing.

Block shear testing is based on bonding rectangular blocks of core material to two steel fixtures which are displaced relative to each other to apply a shear deformation to the core material.

Commonly used standards include ASTM C273, "Standard Test Method for Shear Properties of Sandwich Core Materials" and ISO 1922, "Rigid cellular plastics - Determination of shear strength". The primary difference is that ASTM C273 aligns the loading axis with the diagonal of the test sample whereas in ISO 1922 the loading axis is aligned along the vertical central line of the specimen. Table 2 summarize requirements for test specimen configuration and method for displacement measurement.

Shear strength is calculated at maximum load. Both standards will give comparable result, independent of specimen configuration. ASTM C273 also notes that core materials with high elongation, i.e. that yield more than 2%, should use the 2% offset method for the yield strength calculation.

Shear modulus is calculated from the linear part of the load–displacement curve in the elastic region. As for compressive and tensile strain, displacement is allowed to be measured from the machine movement, but this will increase displacement, thus decreasing the modulus as described above.

None of the standards requires or describes how shear strain shall be reported.

Test standard	Specimen			Loading plate	Displacement measurement	Speed of testing	Loading
	Thickness	Length	Width				
ASTMC 273-03	Equal to sandwich thickness	12x thickness	>50 mm	Steel, thickness prop. to thickness	Deflectometer or extensometer	Failure within 3-6 minutes	Tension or compression
ISO 1922-2012	25 mm	250 mm	50 mm	Steel, 16 mm thickness	Machine movement	1mm/min	Tension
Diab Standard ASTMC 273-07	25 mm	300 mm	50-75 mm	Steel, thickness>20 mm	Extensometer	2 mm/min (failure after 3-4 min)	Tension

Table 4.2: Test standards , shear

The preferred Diab standard is ASTM C273. The loading plates are thicker than required in the standards to avoid bending deformation in the plate. This is a problem especially on high density grades. The shear strain is defined as the strain developed at a point where the stress has decreased to 90 percentage of the ultimate peak load or at fracture, whichever occurs first.

For testing of sandwich panels it is recommended to use ASTM C 393-11 "Core Shear Properties of Sandwich Constructions by Beam Flexure". This test method is however limited to obtaining the core shear strength and the stiffness of the sandwich beam. The standard says in NOTE 1– "Core shear strength and shear modulus are best determined in accordance with Test Method C273 provided bare core material is available".

The facings must be sufficiently thick and/or the support span sufficiently short such that transverse shear forces are produced at applied forces low enough so that the allowable facing stress will not be exceeded.

Example of specimen configurations for a four point bending test:

Ex. 1 Core thickness 30 mm with 2.5 mm laminate thickness:
Length = 600 mm, width = 60 mm, outer span length = 500 mm, inner span length 200 mm

Ex. 2 Core thickness 60 mm with 5 mm laminate thickness:
Length = 600 mm, width = 60 mm, outer span length = 500 mm, inner span length 200 mm

4.1.4 Definition Density [kg/m³]

Density is not describing a materials mechanical performance, however in structural design it is rated as a very important property of the material and thus shown on the first page of the data sheet.

Nominal value is the specified value for the material. That means that the density of the material will have a mean value close to the nominal value. The mean value is based on all measured values on full size blocks. The material delivered to a customer is normally only a fraction of the totally produced material. This may result in that the actual value on the density of the delivered material has a mean value lower or higher than the nominal value.

Minimum density of the block is the specified value to meet the requirement for minimum mechanical properties. Maximum density of the block is the specified value to assure that weight of the material is within specification.

4.2 Technical characteristics

The most common design criteria on structural core material's are its mechanical performance, however in many cases it is a combination of a core materials structural strength and other characteristics that are of interest i.e. insulation-, sound dampening-, dielectric properties etc. In this section core materials technical characteristics are described in general terms. These characteristics are only measured and described, for Diab cores, where it is applicable and of interest.

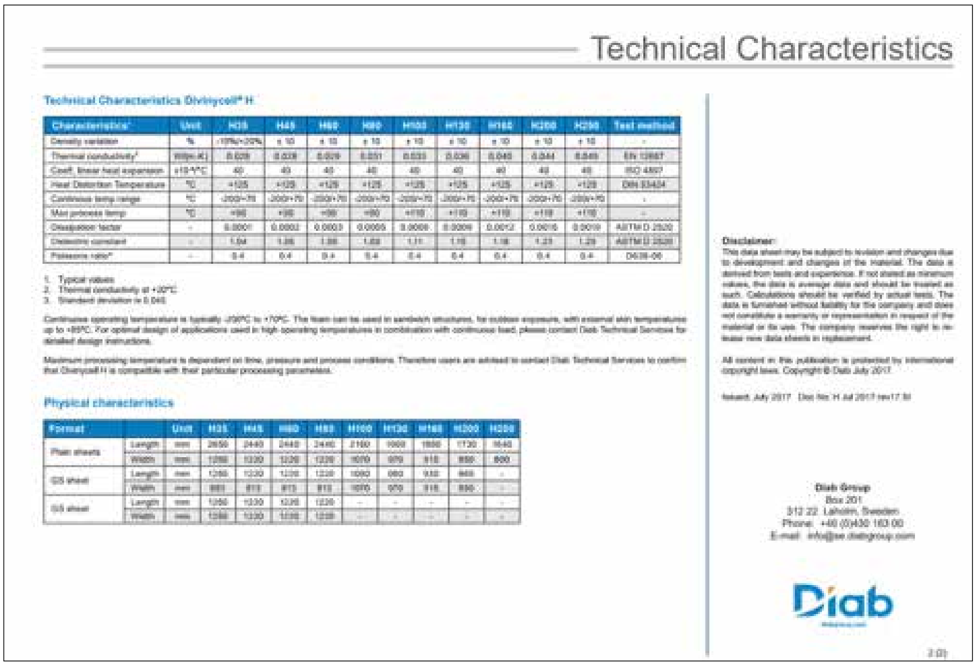


Figure 4.2: Typical data sheet lay-out of Diab data sheet second page, updated version are available at www.Diabgroup.com

4.2.1 Thermal Conductivity [W/m];

Thermal conductivity is the property of a material's ability to conduct heat. In other words; thermal conductivity is the material property that states the value of thermal insulation capacity for a given material. Heat transfer across materials of high thermal conductivity occurs at a higher rate than across materials of low thermal conductivity; consequently materials with low thermal conductivity are often used as thermal insulation.

Thermal conductivity is however not a constant, but a property that is affected by temperature, density, time and moisture content. In almost all insulation material it is the air or the gas inside the material that gives it its insulating capacity.

In SI units, thermal conductivity is measured in watts per meter kelvin (W/m·K).

4.2.2 Heat distortion temperature

The heat deflection temperature or heat distortion temperature (HDT) is the temperature at which a polymer or plastic sample deforms under a specified load. Diab uses DIN 53424 to determine HDT.

4.2.3 Continuous operating temperature

Continuous operating temperature is not defined to a standard it is instead based on empiric knowledge and a combination of tests. The performance of the core is also dependent on loading, time etc. which makes it very difficult to state a value; therefor any given value is for guidance only. An operating temperature is stated on several of Diab data sheets, where it is stated;

"The core can be used in sandwich structures, for outdoor exposure, with external skin temperatures up to a stated operating temperature on the data sheet. For optimal design of applications used in high operating temperatures in combination with continuous load, please contact Diab Technical Services for detailed design instructions."

4.2.4 Max process temperature

Maximum process temperature is not defined to a standard it is instead based on empirical knowledge and a combination of tests. Performance of the core is also dependent on many other process conditions, such as pressure, resin compatibility, time etc. which makes it very difficult to state a value. This means that the stated value is for guidance only. However a maximum process temperature is stated on several of Diab data sheets, but shall be considered as a rough guidance only, on the data sheet it is stated;

"Maximum processing temperature is dependent on time, pressure and process conditions. Therefore users are advised to contact Diab Technical Services to confirm that Divinycell Matrix is compatible with their particular processing parameters."

4.2.5 Dielectric properties

The dielectric constant (or relative permittivity) of a material affects how electromagnetic signals (radio waves, radar waves, etc.) move through the material. A low value of dielectric constant means that e.g. radar signals travels through the material with only small losses.

When we talk about the dielectric constant in common usage we mean the "relative dielectric constant". It is the ratio of capacitance for the material compared to capacitance for vacuum as the dielectric. Since the relative dielectric constant is a ratio it has no unit.

The dielectric constant for Divinycell is approximately 1.1 compared to 1.0 for vacuum and 80 for water. With its low water absorption and water vapor permeability, the dielectric constant of Divinycell will be un-affected over time compared to material with open cell structure and medium to high water absorption and water vapor permeability that will rapidly degrade the dielectric properties.

The dielectric constant is not constant over the frequency range. It is therefore necessary either to measure the dielectric constant at the frequency at which the material will be used or, if the material is to be used over a frequency range, to measure it at several frequencies suitably placed for the application of interest

Diab measures dielectric constant by the use of the ASTM D2550 standard.

The dissipation factor is a measure of the energy loss in the dielectric. The energy loss shall generally be small in order to reduce the heating of the material.

4.2.6 Poisson's ratio

When a material is stretched in one direction, it usually tends to contract in the other two directions perpendicular to the direction of stretching. This phenomenon is called the Poisson effect. The Poisson ratio is the ratio of the fraction of contraction divided by the perpendicular fraction of expansion.

The Poisson's ratio of a stable, isotropic, linear elastic material cannot be less than −1.0 nor greater than 0.5 due to the requirement that Young's modulus, the shear modulus and bulk modulus have positive values. Most materials have Poisson's ratio values ranging between 0.0 and 0.5. Most steels and rigid polymers exhibit values of about 0.3.

Published values of Poisson's ratio for Divinycell are measured values. Calculations of Poisson's ratio from Young's modulus and shear data will give a higher Poisson's ratio due to the un-isotropic cell structure in many foams.

Mechanical properties and technical characteristics are available on www.Diabgroup.com

FST Characteristics

Fire, smoke and Toxicity, FST is a huge area to cover since there is a vast variety of demands in different industries and in different regions of the world. Sandwich core materials are and can be used in many different applications with a variety of FST demands.

Fire, smoke and Toxicity, FST is a huge area to cover since there is a vast variety of demands in different industries and in different regions of the world. Sandwich core materials are and can be used in many different applications with a variety of FST demands.

There are many aspects to in during different fire scenarios and there are many methods to measure how a material behaves when subjected to a flame or heat:

- Flame Spread
- Dripping
- Smoke opacity
- Heat Release (Energy emittance)
- Toxic fumes
- Oxygen index Etc

Core material is usually used as a sandwich material, but with skins on both sides of the core, which can be chosen to improve the materials behavior under fire. But the amount of available skins and resins makes it impossible to try all combinations out.

Several of Diab products are used in applications where FST properties are of importance and some of these results are officially stated on Diab data sheets. Diab has chosen to test core material without skin to the standards which are most commonly asked for:

- German railway standard DIN 5510,
- French railway standard
- NF16-101 Aircraft FAR 25.

The test methods used in the mentioned standards above can be very similar to methods used in other standards as well.

Data on which FST certificates Diabs different core materials meets, please check for latest updates on diabgroup.com

For more information, please visit diabgroup.com

Glossary

The following terms are commonly used within Diab. Although many of these terms have various meanings and some have extended definitions, this glossary may be used as a quick reference to gain a basic understanding of a composite or sandwich panel-related-term.

A

Accelerator	Accelerates cure of a resin.
Additives	The term used for a large number of specialist chemicals which are added to resins/compounds to impart specific properties, for example, flame retardancy, and UV resistance.
Adhesive	"Substance applied on mating surfaces to bond them together by surface attachment. An adhesive can be in liquid, film or paste form.
Aramid	Short for "aromatic polyamide," aramid fibers are a class of high strength synthetic fibers. Kevlar is a common aramid fiber and is trademarked by DuPont.
ASTM	The "American Society for Testing and Materials" (ASTM) is an international standards organization which compiles standards and test methods for materials, products, and systems.
Autoclave Molding	Often used for advanced composite aerospace parts, autoclave molds are heated pressure vessels used for curing. Due to the uniform high pressure, temperature, and long curing times, extremely high quality parts are created with few voids.

B

Balsa Core	See: End Grain Balsa.
Bendable	In the meaning that the core is treated in such way that it is possible to bend.
Blister, blistering	Undesirable raised areas in a moulded part caused by local internal pressure, due usually to rapped air, volatile reaction by-products or water entering by osmosis.
BMC	"Bulk Molding Compound" (BMC), is a mixture of chopped strand fiber and resin, mixed into a "bulk" compound prepreg, which is used in injection or compression molding.

C

Carbon Fiber	An extremely lightweight textile material, when combined with a resin (most often epoxy), will produce an extremely rigid composite reinforcement. Due to the lightweight and strength features, carbon fiber is in high demand from aerospace, military, and recreational applications.
Catalyst (also called hardener)	A chemical compound (usually an organic peroxide) which initiates polymerisation of a resin.
Chopped Strand Fiber	"Chopped Strand Fiber" or simply, "Chopped Fiber," is structural fiber that is cut into small lengths. Chopped fiber combined with a resin, is most often injected or sprayed into a mold.
Chopped strand mat	See Chopped Strand Fiber, the difference is that fibers in this case is put together in a "mat" form.
Closed Molding	In closed molding and in infusion the same type of finishing codes can be used. In comparison to open molding that utilizes only one mold, closed molding utilizes two molds, a top and bottom mold. By utilizing a pressure difference (vacuum) laminates and core are impregnated. The transportation of resin is usually facilitated by distribution channels in the core or by flow mats or similar. Parts manufactured from this process will have a smooth surface on both the sides of the panel if it uses rigid molds. An alternative is to use a vacuum bag as a top mold, so called infusion, which uses very similar flow principals and is a variant of closed molding. There is a variety of closed molded processes, vacuum resin infusion molding (VRIM), RTM, etc. Usually the same type of core finishes can be used in different closed molding processes.
CNC	Computer Numerical Controls (CNC), are used in precision machinery, controlled by a predetermined computer program.

Coefficient of thermal expansion	A material's fractional change in length corresponding to for a given unit change in temperature.
Composite	Term used for material consisting of two or more materials, most often a resin with fiber reinforcement.
Compression Molding	Method of forming composites by using a shaped mold which applies pressure and often heat.
Compression strength	The crushing load at failure of a material, divided by cross-sectional area of the specimen.
Continuous Fiber	Term used for reinforced structural fiber that is "continuous" and not broken or chopped.
Core bedding	When the core is put down in mold on top of wet or cured laminate it usually is called core bedding. To facilitate a very good bonding between laminate and core, the core bedding technique can be used. It is very similar to vacuum bagging. Usually a light weight putty is put on the cured laminate with a spatula then the core is put on top, the next step is to cover It all with a plastic bag and then to pull vacuum. This presses the core firmly down against the laminate and at the same time air entrapments are pulled out.
Core Material	General term for the center material in any sandwich structure, used to increase strength, stiffness, and insulation. Common core materials include foam, balsa, and honeycomb.
Corrosion resistance	The ability of a material to withstand contact with ambient natural factors without degradation or change in properties. For composites, corrosion can cause crazing.
Creep	Term used to describe the weakening of materials over time, when under load, the deflection of the material may slowly change.
Cross Linking	Cross linking is covalent bond linking of polymer chains to one another. Un cross linked polymers (generally thermoplastics) can have bonds break with heat, and reform. Where as cross linked polymers (generally thermosets), cannot reform, and are set permanently once cured.
Cure	The process of hardening of a thermosetting resin (by cross-linking of the molecular structure), under the influence of heat.
Cured	Term used to describe resin when it has turned into a solid state.
Curing agents	Chemical compounds used to cure thermosetting resins.
Curing time	The time taken for a resin to cure to its full extent.

D

Delamination	The separation of the bond between the skin and core material in a sandwich panel. Can also be applied to the separation of plies or fibers in a laminant.
Die	Mold with a constant cross section, used in pultrusion, extrusion, and other composite manufacturing methods.
Dielectric Strength	Electrical field strength of an insulating material. Measurements and definition can be found under ASTM test procedure D149.
Divilette	A light weight putty usually used to bond core against a laminate (core bedding), or to bond core materials together during customers manufacturing.
Divinycell	Brand name core by Diab, the material referred to as Divinycell is a rigid polymer foam commonly used in composite sandwich panels.
Double Cut	The core material is cut, grid scored from both sides of the core.

E

E-glass	Most commonly used structural reinforcement fiber, commonly known as "fiberglass." E-glass is widely used due to its low cost, high production, lightweight, high strength, and insulative properties.
End Grain Balsa	Structural core with high shear strength. End grain balsa sheets are blocks of balsa wood, taken from a balsa tree, and aligned and adhered together to form a lightweight structural core.
Epoxy	Epoxy is a resin used in prepregs or as a liquid resin in closed molding or hand lamination. Epoxy exists in many different versions, which means that extra caution can be needed before usage regarding its compatibility against used core material.
EPS Foam	Expanded Polystyrene (EPS) foam is common insulative foam used in sandwich structures. The density can vary, and rigid EPS foam is the most common foam used in structural insulated panels (SIPs).
Extrusion	Method of forming plastics by means of forcing molten resin through a shaped die, producing a constant-area cross section.

F

Face Sheets	Face sheets is a term used to describe the skin or surface material of sandwich structures.
Fatigue Strength	Fatigue strength is the maximum cyclic stress a structure can withstand before failure.
Fiber Placement	Method of strategically placing and orientating reinforcing fiber in a composite application to maximize structural properties.
Fiberglass	Fiberglass is a general term for structural fiber used in reinforced composite applications. It can also be a general term for a finished fiber reinforced product.
Filament	A single textile element of small diameter and very long length considered as continuous.
Filament Winding	Method of manufacturing composite products by winding resin impregnated structural fibers around a shaped mandrel or containment vessel. This is done using computerized CNC controls.
Filler	Fillers are inert materials added to composite resin to add volume, thus lowering the resin density. Fillers are also used to increase certain performance characteristics such as fire or crack resistance. Examples are calcium carbonate and aluminum trihydrate.
Finish designation	Diab term, specific "naming" of different groups of finishes.
Flexural strength	The strength of a material in bending expressed as the stress if a bent test sample at the instant of failure.
Flow	Flow is a term describing the viscosity of a resin, and its ability to "flow" of move through fiber reinforcement during wet-out.
Flow mat	Facilitates resin flow in manufacturing, it is in some cases used as a replacement or supplement to grooved and perforated materials. Usually avoided since it adds weight and cost to the application.
Flow media	
Flow mesh	See Flow mat.
Foam Core	By trapping air in a cellular polymer structure, foam is created. Foam is an effective core material for sandwich panels as a great deal of volume and structure can be added for very little weight. A wide range of foam cores are commercially available derived from a wide range of polymers.
FRP	Acronym for "Fiber Reinforced Plastic," is a common term used to describe composite products.

G

Gel	The state of a resin, which has set to a jelly-like consistency.
Gel Coat	Gel coat is the top surface applied to a mold providing a superior surface finish to the final composite product.
GFRP	Acronym for "Glass Fiber Reinforced Plastic."
Glass fibre	Reinforcing fibre made by drawing molten glass through bushings. The predominant reinforcement for polymer composites, it is known for its good strength, processability and low cost.
Grade	Every product family contains different grades, for example: Divinycell H60 is a grade within the product family "H".
Grid Scored	In Diab terminology it is typically GS or GSW materials which are cut almost all the way through, to make the sheets bendable or suitable for core bedding.
Grooved	Grooved materials are machined only on the surface of the material to facilitate resin and airflow in infusion or other closed molding processes.
GRP	Acronym for "Glass Reinforced Plastic."

H

Hand Lay-Up	Wetting out laminates manually with a roller in a mold. By the use of roller a part can be rolled until enough laminate thickness I achieved. In steps -apply resin in mold then put a mat of fiber on top, then use a roller to apply resin. Next step is to use a roller without adding resin, but instead compress the laminate and press out air entrapments in laminate. This is repeated until intended thickness is achieved.
Hardener	See Catalyst (also called hardener).
Honeycomb core	A resin or reinforcement made from two or more different polymers orreinforcement materials.
Hybrid	Reinforcing fibre made by drawing molten glass through bushings. The predominant reinforcement for polymer composites, it is known for its good strength, processability and low cost.
Hydraulic Press	Is a method of manufacturing sandwich panels by placing adhesive between the skin and core, and applying pressure using hydraulic machinery, thus creating an air tight bond.

I

I-Beam	An I-beam is an efficient method of creating a structural beam while using a minimal amount of material. An I-beam profile accomplishes similar structural results as sandwich panels.
Impact Strength	Impact strength is the ability of a material or sandwich panel to resist fracture during shock or impact.
Impregnation	Saturation of reinforcement with liquid resin.
In-mould coating (IMC)	A process used with SMC (and recently developed also for thermoplastics) in which a liquid/melt coating layer is applied to the exterior of a moulding while still in the mould, as part of the moulding cycle.
Infusion	In closed molding and in infusion the same type of finishing codes can be used. Infusion utilizes one stiff mold, and in contradiction to closed molding a flexible vacuum bag is used as top mold. By utilizing a pressure difference (vacuum) laminates and core are impregnated. The transportation of resin is usually facilitated by distribution channels in the core or by flow mats or similar. The most common technique is to seal off the part intended to infuse with a plastic bag, pull vacuum with a tube in one end of the part, and insert resin with a tube in the other part. When the resin has filled the part the resin hopefully cures shortly after that. Usually the same type of core finishes can be used in closed molding processes.
Inhibitor	Inhibitors are chemicals added to thermoset resins to slow down the chemical reaction causing the resin to cure.
Injection Molding	Method of manufacturing plastics (most commonly thermoplastics) by injecting molten resin into a heated mold under high pressure.
Interface	The contact area between reinforcement and resin.
Isotropic	Is a description of composite material having equal structural properties in the three coordinate directions of X-Direction, Y-Direction, and Z-Direction.

J

Joint	Term used to describe the connection of sandwich panels.

K

Kevlar	Trademarked material manufactured by DuPont. Kevlar is an aramid fabric, combining light weight and high strength. Kevlar is noticeable by its unique yellow color, and was first made popular for use in bullet-proof vests.

L

Laminate	Term used to describe the application of resin to fiber reinforced fabric, can also be used to describe the process of adhering skin to a core material.

M

Mandrel	Positive internal shape used in manufacturing hollow composite products.
Matrix	Term used to describe the structure of resin molecules.
MEKP	Acronym for Methyl Ethyl Ketone Peroxide, a common catalyst used in resins.
Modulus of Elasticity	See: Young's Modulus.
Mold	Shape, most often made of steel, used to maintain the shape of the desired composite product.
Mold Release	Chemical used in composite manufacturing to prevent the laminant from
Monomer	A compound containing a reactive double bond, capable of polymerising.

N

Nomex	Trademarked fire-resistant material by DuPont. Nomex paper is used in making a honeycomb core material.
Non-Woven Fabric	See: Stitched Fabric.

O

One-off Another commonly used description for this is strip planking. In this manufacturing technique the product is built up as a frame work, similar to a skeleton, and then the frame work is covered with planks. When using Divinycell the sheets are usually sawn to planks, which then are nailed to the framework. After sanding and grinding the part is laminated as usual and after curing and sanding the part is turned around and the frame work is taken away and inside lamination is done

P

Parting Line A parting line is a small raised mark or line on a molded composite part where a small amount of resin was allowed to seep into the crevice where the two mold sections meet.

Peel Ply A lightweight synthetic fabric applied to the surface of a composite during lamination or molding. Peel ply keeps the areas of secondary bonding clean and facilitates an easier grinding of the same.

Perforated

Phenolic Resin "Fire-resistant" resin used in many different industries beyond composites.

Pigment Chemicals added to resin to create coloring of the composite.

Ply Term used to describe a single layer of fiber reinforced fabric.

Poisson's Ratio Is the ratio to describe the tendency of material to contract in one direction when stretched from other directions. Poisson's ratio is the transverse strain divided by the axial strain.

Polyester Resin Common thermoset resin used in composite applications.

Polymer Is a commonly used term to describe plastic. Polymers are structural molecular units connected by covalent bonds.

Polyurethane Resin Thermosetting resin that has increased impact properties, but shorter pot life.

Porosity Numerous air pockets or voids in a moulded product.

Post Cure Is a method for strengthening composite laminates, after the resin is technically cured, by applying heat for an extended amount of time thus imparting increased cross-linking of the resin.

Pot Life Pot Life is a term used to describe the period of time a thermosetting resin will stay in useable gel form before curing.

Pre-form Term used to describe a unit or stack of fiber reinforcements prior to adding resin or molding.

Premix A moulding compound prepared prior to, and apart from, the moulding operation, containing all components necessary for moulding

Prepreg A prepreg is a laminate, fibers and resin, where the resin is pre mixed and ready to react, but the reaction will not start until the prepreg is exposed to an elevated temperature. Prepregs are vacuum bagged and then subjected to an increased temperature to cure the laminates. Fiber reinforcement that is impregnated with a resin matrix prior to being used; prepreg material is cured by adding heat and pressure.

Print-through Imprints on the surface caused by irregularities in the core, fibers or resin.
Example: Grooves can cause print-throughs.

Pultrusion Method of manufacturing composites, by "pulling" raw fiber wetted with resin, through a heated die. Pultrusion is used to efficiently produce large amounts of a continuous profile.

R

Reactive resins Liquid resins which can be cured by catalysts and hardeners to form solid materials.

Reinforcement Term used to describe the fibrous structural material that, when added with resin, can provide a strong solid laminant.

Release agent A substance which prevents a moulding from sticking to the mould surface; it may be a chemical compound or a solid material such as a cellulose or plastics film.

Resin Chemical matrix to bond and hold structural fiber in place. Most resins are either thermosetting resins, or thermoplastic resins.

Resin transfer moulding (RTM) RTM is a method of forming a composite laminate by injecting resin into a closed mold, or by "pulling" resin through a mold using a vacuum.

Roving Roving produced by winding a large and determined number of filaments direct from a bushing. Term for structural fiber in raw unit form, much like a thread of yarn. Generally available in multiple strands of filaments.

S

S-glass	S-glass is a fiberglass reinforcement similar to E-glass, but with a slightly different chemistry providing lighter and stronger properties.
Sandwich Panel	Structural panel consisting of a lightweight core, with skin material on either side. Sandwich panels are used to add structure, stiffness, and insulation to applications without adding considerable weight.
Sandwich structure	Composite composed of lightweight core material to which two relatively thin, dense, high strength, functional or decorative skins are adhered.
Scrim	Thin glass fiber cloth or mat, which purpose mainly is to keep the blocks in GS materials in place during handling.
Shear Strength	In sandwich panels, this term is often applied to the core properties and the core shear modulus, G. The higher the core shear modulus, the better the resistance to bending of the sandwich panel. Core shear modulus is measured through ASTM tests, such as 273.
Sheet moulding compound (SMC)	A flat pre-preg material, comprising thickened resin, glass fibre and fillers, covered on both sides with polyethylene or nylon film, ready for press-moulding.
Sizing	Chemicals added to reinforcing fiber to help create a more uniform and complete bond with the resin matrix.
Skin	Surface material used on a sandwich panel; skins provide the tension and compression strength, as well as providing impact resistance. Skins are often made of OSB for structural insulated panels, and FRP for composite sandwich panels.
Spray lay-up	It is a process where a chopper gun is an essential part of the process, in short -a fiber rowing is chopped up in shorter strands and it is simultaneously saturated with resin. After adequate amount of resin is sprayed up the laminate is compressed with a steel roller.
Stitched Fabric	Unidirectional fiber reinforcement which is layered and orientated on top of one another and stitched together to form a fabric. The fibers are orientated at off-axis angles, most commonly + or – 90 degrees, and + or – 45 degrees. This provides increased strength to the end FRP product.
Strand	An assembly of parallel filaments simultaneously produced and lightly bonded.
Strip planking	See One-off

T

Tensile Strength	The stress required to pull a material or structure from opposite directions to the point of failure.
Thermoforming	By increasing the temperature in a core material close to its plastic temperature it becomes possible to reform the material to fit certain geometries.
Thermoplastic	Is a polymer resin that is in a solid state at room temperature, but turns liquid with heat, allowing for forming and molding. Thermoplastics are generally able to be remolded or reformed, allowing them to be easily recyclable.
Thermoset	Is a polymer resin that begins in a liquid state, and is cured with the addition of heat, radiation, or a through a chemical reaction. Thermosetting resins are more often stronger then thermoplastic, but due to the chemical structure, the molecules cannot be reformed or remolded, and are often difficult to recycle.

U

Uni-Directional	Is a term used to describe structural fiber reinforcement that runs along only a single axis of direction.

V, W

Vacuum Bag Molding	Is a method of laminating composites and sandwich structures by placing the preform composite in a sealed plastic bag; then applying a vacuum thus removing all air prior to dispensing resin into the sealed mold.
Vacuum bagging	This is used to minimize the amount of air there is in a laminate. The part is covered with a plastic bag and then vacuum is pulled. Excessive resin and unwanted air is removed while compressing the part to get a good laminate/ bonding.
Vacuum bonding	In this context it is a process used to bond core sheets together.
VARTM or VRTM	Acronym for "Vacuum Assisted Resin Transfer Molding," see "Vacuum Bag Molding.
Veil	IVeil is a cloth material laid on the surface of a composite lamanant prior to cure. Veils can provide increased surface finish to composite products, or be printed with logos or designs. They are often used to assist in the prevention of fiber blooming, caused primarily by UV.
Wet-out	Term used to describe the resin impregnation on a composite laminant.
Vinylester Resin	Commonly used thermosetting resin in composites manufacturing. Used due to low costs, excellent corrosion-resistant properties, and good structural properties.
Viscosity	Term used to describe the fluidity of a liquid resin, and its ability to flow, or not flow, with ease.
Void	Term used to describe gaps or air pockets within a cured laminate. Voids are considered flaws, and can diminish desired properties of a composite.
Woven Fabric	Structural fiber reinforcement is woven together, orientating fibers off- axis to one another. Woven fabric has increased interlaminar strength properties as the structural fiber is intertwined with one another.

Y

Young's Modulus	Young's modulus is the measure of stiffness of a material or structure. Also known as modulus of elasticity, E. This is generally referred to as the ratio of stress to strain in the cross section of the material.

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