GB

PANELTIM®

Pioneer in plastic sandwich panels

QUICK GUIDE TO PANELTIM®

Introduction to Paneltim® plastic panels

MORE THAN 20 YEARS
THE PIONEER IN PLASTIC SANDWICH PANELS

WWW.PANELTIM.COM

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1. INTRODUCTION

PANELTIM® PANELS PRODUCED BY SPECIALISTS, FOR SPECIALISTS

Paneltim is a Belgian family-owned company that has produced plastic sandwich panels since 1997.

Various techniques are used for the production of the plastic panels, namely: high-pressure injecting (1600, 1850, 3000 and 4000 metric tonne clamping force), mirror welding, cutting and CNC controlled milling.

In the construction sector, the panels are used to build plastic rectangular liquid tanks, filters for liquids, swimming pools, heat exchange units, air scrubbers, odour filters, and numerous other applications.

Polypropylene (PP) and polyethylene (HDPE) hollow panels are lighter and stronger than most other plastic panels. Generally speaking PP and HDPE are resistant to a number of chemicals. Panels made with PP and HDPE can be welded easily. This makes them perfectly suited for constructions that are required to be light, strong and clean.

Our daily challenge is to innovate, in order to optimise the quality of our panels and to seek new product possibilities in partnership with our customers.

Through our global network, we challenge and assist our customers across diverse sectors to explore strong and innovative applications for Paneltim® products.

PANELTIM® PRODUCT RANGE

The range of Paneltim® plastic panels (PP and HDPE) consists of two categories:

- **Paneltim® Multipower Panels** and
- **Paneltim® Lightweight Panels**.

Within these categories several variants are available. A special variant is the **Paneltim® Antislip** with a slip-resistant profile for better grip.

PANELTIM® PRIME PANELS FOR STRUCTURAL APPLICATIONS

Paneltim® panels are available in a wide range of options: made of new "prime", near-to-prime or recycled raw materials.

For construction of structural applications, Paneltim advises to using only prime panels.

Hence this Quick Guide to Paneltim® makes reference only to panels of prime quality. For more information on other qualities of panels, consult our website paneltim.com or general brochure.

1.1. PANELTIM® MULTIPOWER PANELS

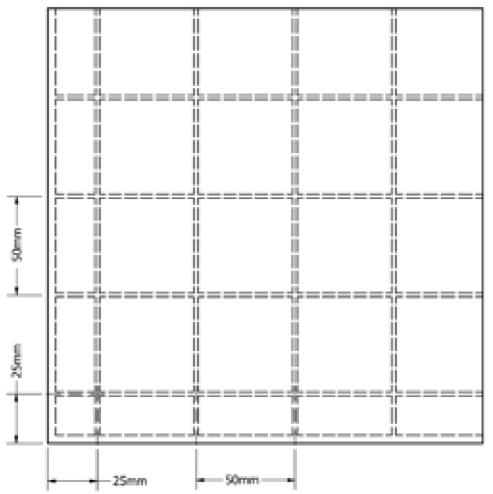
Paneltim® Multipower panels are the strongest and most robust within the range of Paneltim® plastic panels.

Paneltim® Multipower panels are available in PP and HDPE. They have a thickness of 50 mm and a panel size of 2,600 mm x 1,000 mm. Multipower panels have a square internal structure with cells of 50 mm x 50 mm (except for the first cell which is 25 mm x 50 mm to minimise material loss during welding).

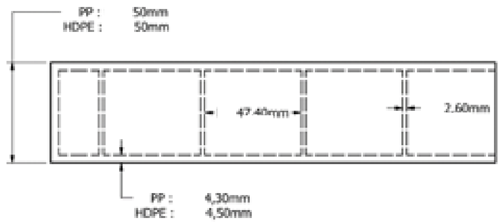
The exterior wall thickness of these panels is 4.3 mm in PP and 4.5 mm in HDPE (see table below for internal and exterior wall thicknesses).

Paneltim® Multipower panels are available in different colours, depending on the raw material used i.e. PP or HDPE.

Paneltim® Multipower panels.



Thickness	Cells in mm	Material	Length x width in mm	Exterior wall in mm
50 mm	50 x 50	PP	2,600 x 1,000	4.3
		PE		4.5



Dimensions Multipower panels.

1.2. PANELTIM® LIGHTWEIGHT PANELS

Paneltim® Lightweight panels are light, strong, and rigid, with excellent resistance to deflection under load.

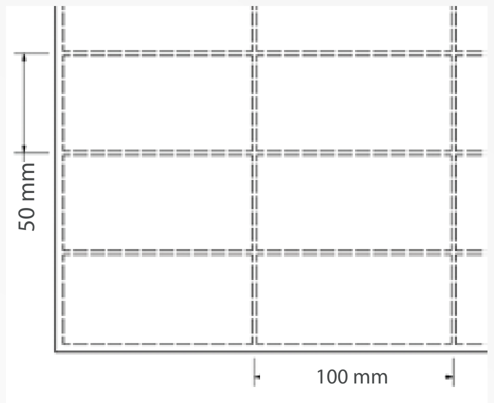
Lightweight panels are available in PP and HDPE. They are available in different depths: 20, 35, and 50 mm. Depending on the panel depth, Lightweight panels are available in sizes of 1,200 x 1,000 mm or 2,600 x 1,000 mm.

Lightweight Panels have a rectangular internal structure with cells of 50 mm x 100 mm.

The exterior wall thickness of these panels is 3.5 mm (see chart below for internal and exterior wall thicknesses).

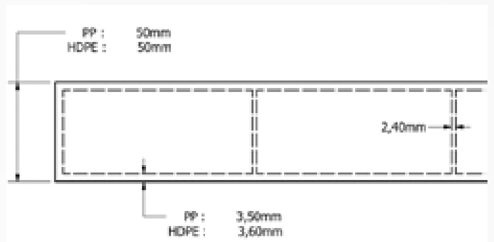
Paneltim® Lightweight panels are available in different colours, depending on the material used i.e. PP or HDPE.

Paneltim® Lightweight panels.



Thickness	Cells in mm	Material	Length x width in mm	Exterior wall in mm
20 mm	50 x 100	PP	1,200 x 1,000	3.5
		PE		3.5
35 mm		PP	1,200 x 1,000	3.5
		PE		3.5
50 mm		PP	1,200 x 1,000	3.5
		PE	2,600 x 1,000	3.5

Paneltim® Lightweight panels with dimensions 1,200 mm x 1,000 mm can have a double rib (cross) in the middle. By sawing in the middle of these two ribs, closed panels of 40 cm, 50 cm or 60 cm long or wide are easily produced.



Dimensions of the Lightweight panels.

1.3. PANELTIM® ANTISLIP PANELS

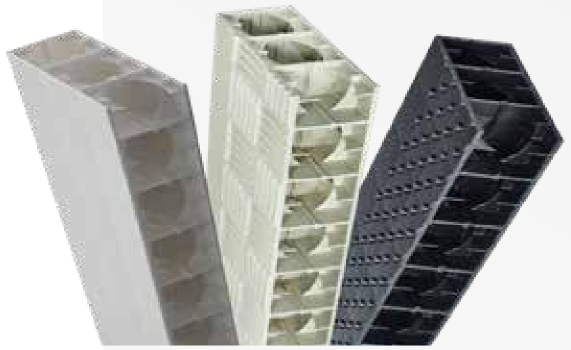
Paneltim® Antislip panels are designed for heavy loads and are ideal for various antiskid applications. These panels have a five bar, stud or orange peel structure on the surface.

Paneltim® Antislip panels are available in PP, with 50 mm depth and size 1,200 mm x 1,000 mm.

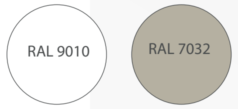
50 mm Antislip panels have an internal structure of 50 mm x 50 mm.

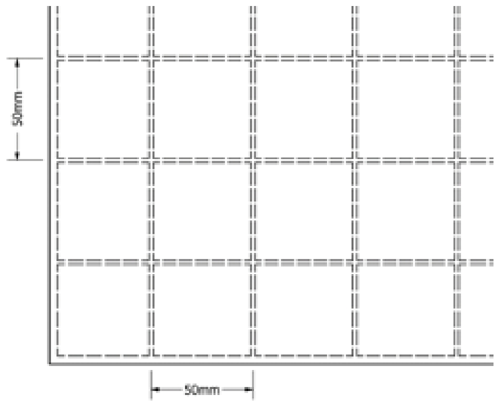
The exterior wall thickness of these panels is 3.3 mm (see table below).

Paneltim® Antislip panels are standard available in beige (RAL 7032). The orange peel structure is also available in white (RAL 9010).



Paneltim® Antislip panels.

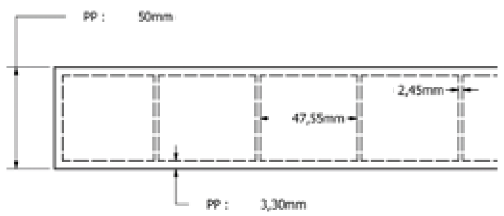




Thickness	Cell in mm	Material	Length x width in mm	Exterior wall in mm
50 mm	50 x 50	PP	1,200 x 1,000	3.3

Paneltim® Antislip panels with orange peel structure are equipped with a double rib (cross) in the middle. By sawing in the middle of these two ribs, closed panels of 40 cm, 50 cm or 60 cm long or wide are easily produced.

The surface of the first cell all around a Paneltim® Antislip panel with five bar or stud structure is smooth whereas the entire surface of the Paneltim® Antislip - Orange peel has the orange peel structure.



Dimensions antislip panels.

2. PANELTIM® MATERIALS

Paneltim® panels are injection moulded in high quality Polypropylene (PP) or High density Polyethylene (PE). These materials have been tested and evaluated according to European and international standards. The general standard for construction and materials is EN 1778 – "Characteristic values for welded thermoplastic constructions: Determination of allowable stresses and moduli for design of thermoplastic equipment".

RECYCLING CODES

Most plastics have a recycling number for easy identification. These numbers are shown on most products as a recycling symbol. During the handling of end-of-life products, this symbol simplifies identification of the material. PP has recycling symbol 5, HDPE has symbol 2.

Symbol	Abbrev.	Name	Usage
1	PET	Polyethylene tereftalate	Polyester fibres, film, soft drink bottles
2	HDPE	High density polyethylene	Bottles, bags, dust bins, tubes, imitation wood, Paneltim® panels
3	PVC	Polyvinylchloride	Window-frames, tubes, bottles (for chemicals and glue)
4	LDPE	Low density polyethylene	Bags, buckets, soap dispensers, tubes
5	PP	Polypropylene	Bumpers, interior panels for cars, industrial fibres, Paneltim® panels
6	PS	Polystyrene	Toys, flowerpots, videocassettes, ash trays, suitcases, polystyrene foam
7	O	Other plastics such as PMMA (plexi, persplex), polycarbonate, polyamide (nylon), ABS, fibre reinforced plastics	

100% RECYCLABLE

ECOLOGY

Paneltim® PP and HDPE panels are 100% **recyclable**.

The panels are **free of toxic substances.**
They are conform the European directive 2011/65/EU.

This is a great advantage compared with other panels, that are often not fully recyclable or need more complex processing.

2.1. POLYPROPYLENE COPO PRIME

Polypropylene Copolymer (PP Copo) Prime is a material that is perfectly suitable for welding and easy to clean.

The polypropylene recycling number is 5.

Some basic properties of Polypropylene are shown in the table below.

Properties		Value	Units
Density		905	Kg / m^3
Thermal conductivity		0.23	W / (m K)
Heat capacity		1690	J / (Kg K)
Linear expansion coefficient		100 - 180	$\cdot 10^{-6}$ / K
Mechanical properties	**Temperature (°C)**	**Value**	**Units**
Elasticity modulus	23	1340	MPa
	40	840	
	60	630	
Poisson coefficient	---	0.39	---

1 calorie = 4.18 Joules

2.2. HIGH DENSITY POLYETHYLENE

High density polyethylene (HDPE) is a material perfectly suitable for welding and easy to clean.

The recycling number of high density Polyethylene is 2.

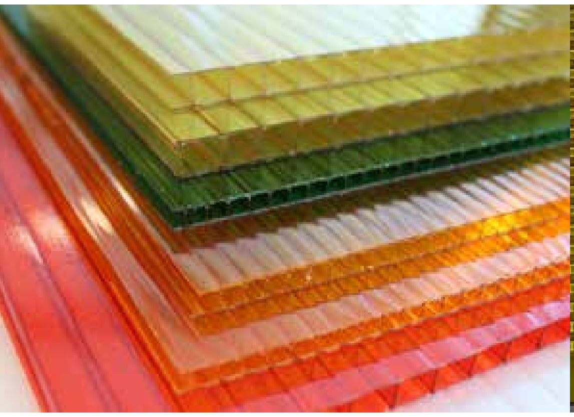
Some basic properties of Polyethylene are shown in the table below.

Properties		Value	Units
Density		954	Kg / m^3
Thermal conductivity		0.43	W / (m K)
Heat capacity		1680	J / (Kg K)
Linear expansion coefficient		100 - 200	$\cdot 10^{-6}$ / K
Mechanical properties	**Temperature (°C)**	**Value**	**Units**
Elasticity modulus	23	1020	MPa
	40	600	
	60	350	
Poisson coefficient	---	0.41	---

2.3. PP AND HDPE USAGE

POLYPROPYLENE

Polypropylene is used in different product areas and can be processed and machined with different techniques such as injection moulding, thermoforming, milling and drilling. Here are some examples.



POLYETHYLENE

Low density Polyethylene is often used for films or foam and in packaging or bottles. High density polyethylene is used in f.i. waste containers, piping and reservoirs. Some examples:

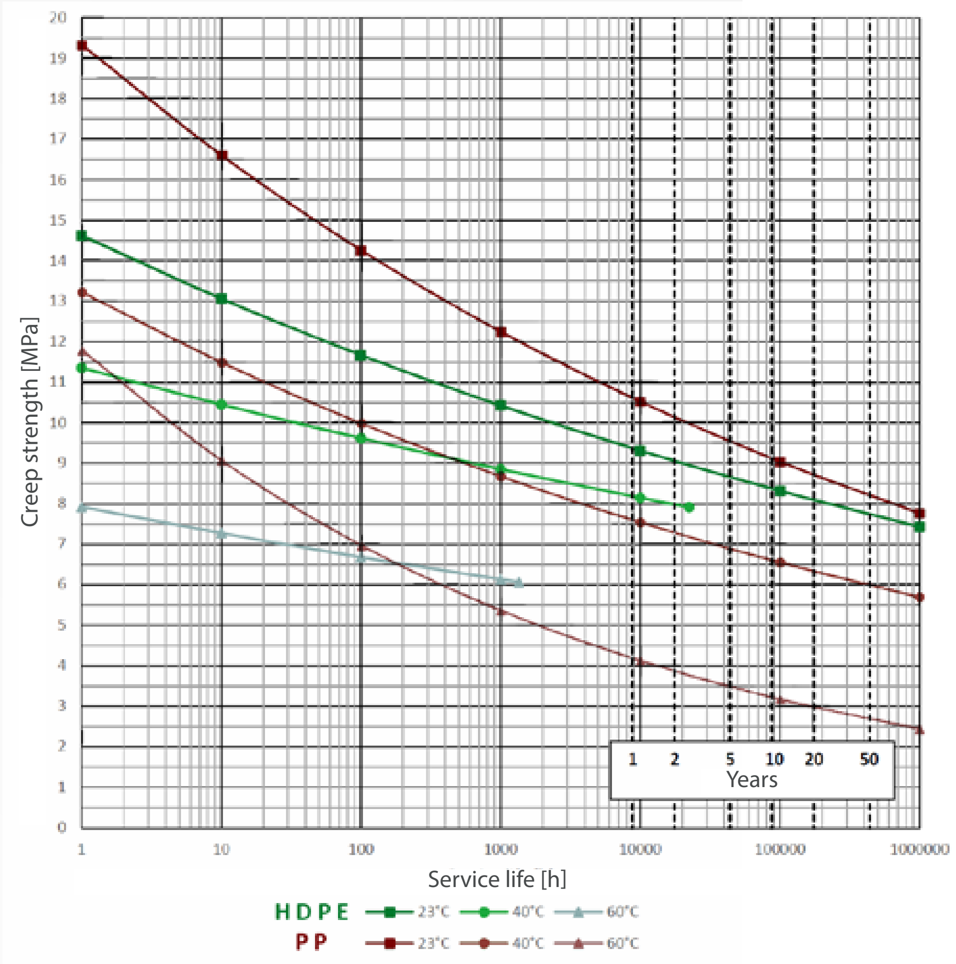
2.4. CHOICE OF MATERIAL

POLYPROPYLENE

In general (97% of the cases) polypropylene Paneltim® panels are used. PP is stronger and more rigid than polyethylene and has a higher elasticity modulus. Moreover, PP is less sensitive to creep and performs better at higher temperatures. This is illustrated in the creep curves shown below. Polypropylene is superior to polyethylene in resisting greater forces at higher temperatures without permanent deflection occurring.

POLYETHYLENE

In some cases, however, Paneltim® panels in polyethylene are used, e.g. when the working temperature is very low. Also, whenever existing products in polyethylene need to be joined or combined with Paneltim® panels, then polyethylene panels will be preferred.



Creep curves of PP and PE at different temperatures.

Hot air welding

Butt welding

Extrusion welding

3.

PANELTIM® KEY BENEFITS

HIGH BENDING RESISTANCE

Owing to their internal structure, Paneltim® panels have an excellent bending resistance in any direction. This is a major advantage compared with extruded panels. Paneltim® Multipower panels in PP are amongst the strongest plastic panels available on the market today.

RIGID AND LIGHT

Owing to their thin wall construction, the panels are very light. Products made of solid plastics or alternative materials will need a much higher mass to provide the same rigidity.

HEAT INSULATING

Because the panels contain static air, they have a good resistance to heat. Choosing Paneltim® instead of conventional construction materials may therefore result in better thermal performance.

HYGIENE & CHEMICAL RESISTANCE

PP and PE panels are resistant to chemicals, repel dirt, and are easy to clean. The closed cell structure prevents dirt penetration.

EASY PROCESSING

Paneltim® panels are 100% recyclable and do not contain toxic substances.
They are easy to process with conventional machining and can be made to measure easily and accurately.
Excellent end results can be achieved using different welding techniques or mechanical joints, with easy and fast on-site assembly.

3.1. HIGH BENDING RESISTANCE IN ANY DIRECTION

BENDING RESISTANCE OF PANELTIM® PANELS

PANELTIM® MULTIPOWER PANEL

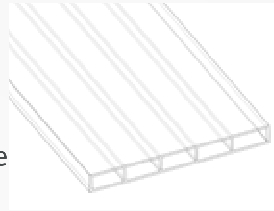
The 50 mm Paneltim® Multipower panel performs well on bending resistance;
5,000 N (approx. 10 kg) is needed for a deflection of 10 mm on a panel of 1m x 1m simply supported (hinged) on 2 sides; other sides free with a uniform momentaneous load.

PANELTIM® LIGHTWEIGHT PANEL

The 50 mm Paneltim® Lightweight panels also perform well;
4,000 N is needed for a deflection of 10 mm on a panel of 1m x 1m simply supported (hinged) on 2 sides; other sides free with a uniform momentaneous load.

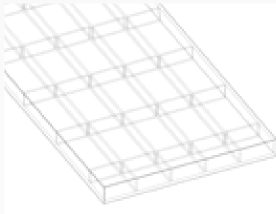
EXTRUDED PLASTIC PANELS VERSUS PANELTIM® PANELS

EXTRUDED PLASTIC PANELS HAVE A STRONG AND A WEAK DIRECTION



These panels are weaker in one direction, because there is no structural element perpendicular to the extrusion direction of the panel.

PANELTIM® PANELS ARE STRONG IN 2 DIRECTIONS



Paneltim® Lightweight panels have an internal cell structure of 50 mm x 100 mm.
Therefore the strength of the panel is partly dependent on the orientation.

Paneltim® Multipower panels have an internal cell structure zof 50 mm x 50 mm.
Therefore these panels are equally strong in both directions.

Paneltim® Lightweight, Multipower and Antislip panels

3.2. HIGH RIGIDITY WITH REDUCED WEIGHT

DIFFERENCE BETWEEN RIGIDITY AND STRENGTH

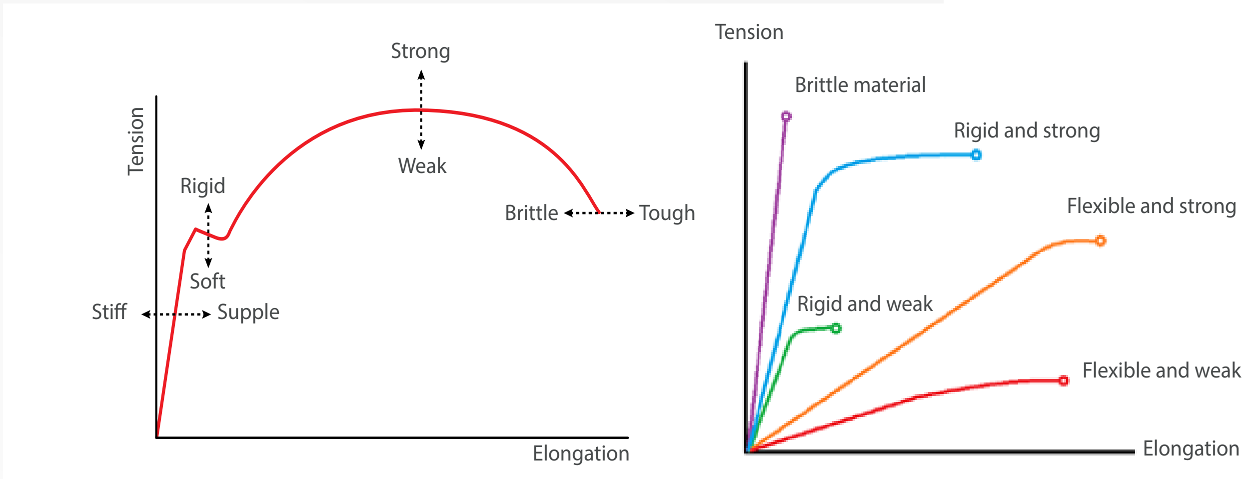
The term strength is often incorrectly used. It is important not to mistake rigidity for strength.

- **Strength** of a construction relates to the yield resistance (breakage or permanent deflection under permanent load).
- The **rigidity** of a construction relates to the bending resistance (elastic deflections, variable loads).

Practical examples:

A bisquit and a steel beam are both rigid, but not equally strong.
Nylon and steel are both strong, but not equally rigid.

The easiest way to explain the difference is to look at the tension curves of the material. A general theoretical curve is shown in the diagram on the left with different sections of the curve representing the different properties of the material. On the right, some simplified examples are shown of tension curves for theoretical materials with different properties.



Theoretical tension diagrams.

Tension curves generally show a straight first section in the beginning of the curve. The slope of this section is a measure of the **rigidity** of the material. If the curve's slope is steep, the material will not deflect much under loading and is therefore rigid.

If the curve is less steep, then the material will be more flexible.

After the first straight section, a curvature can be observed in the next section; this is where the material will deflect considerably and finally break. The higher this curvature and breaking point (small circle), the **stronger** the material.

On the other hand, a brittle material will not show a curvature in the diagram, but will break earlier. Brittle materials can be extremely rigid and strong.

EXAMPLES OF STRENGTH AND RIGIDITY PER CATEGORY

BRITTLE diamonds, glass, ceramics,...



STIFF AND STRONG steel, platinum, titanium,...



STIFF AND WEAK chalk, graphite, biscuits



FLEXIBLE AND STRONG polymers, leaf springs, bows,...

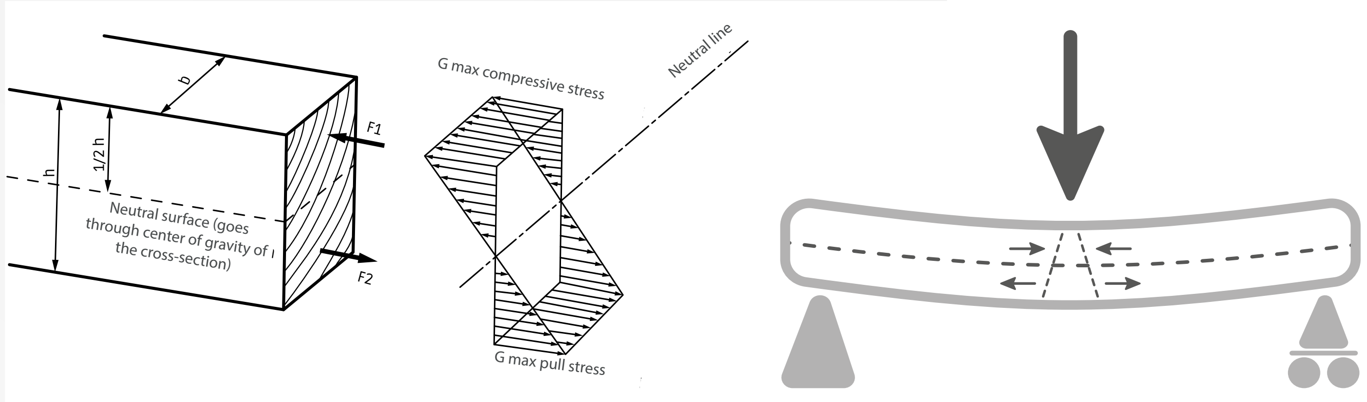


FLEXIBLE AND WEAK rubber, elastomers, films,...



HIGH RIGIDITY OF PANELTIM® PANELS

Because of their thin wall construction and rectangular internal cell structure, Paneltim® panels are more rigid and strong compared with other materials.
When any object is subjected to a bending load, the internal stress is higher at the outer extremities of the object than in the middle (see below).



Schematic representation of internal bending torque.

STEEL I-BEAM PRINCIPLE

The material at the outer extremities will absorb a higher force than the material at the centre of an object. As a result, the material at the centre can be omitted to reduce weight, while the bending resistance will reduce only slightly. This is the steel I beam principle, which allows weight to be reduced and material saved in construction.


Practical examples of weight reduction at equal rigidity.

PANELTIM® PANELS: RIGID AND REDUCED WEIGHT

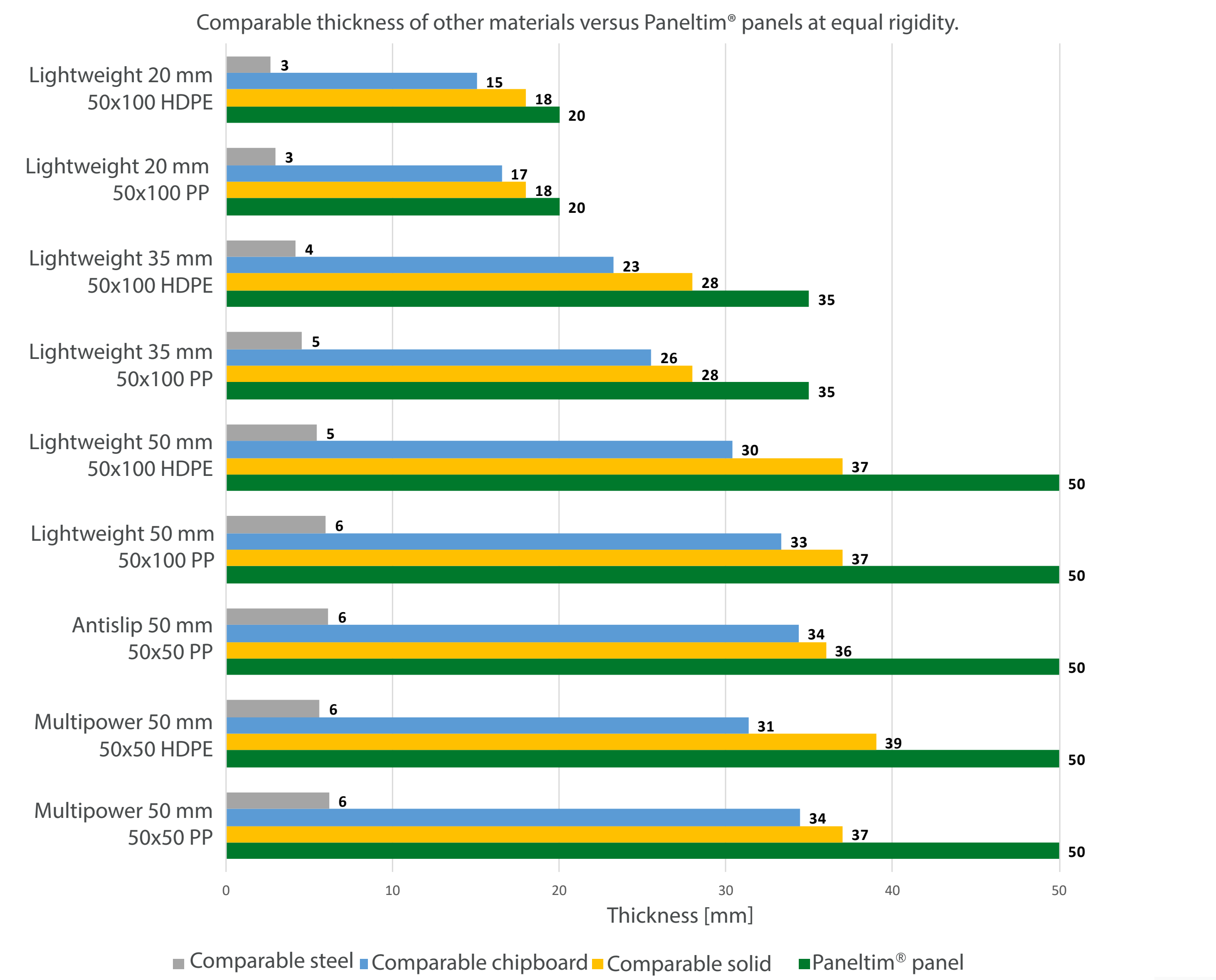
Paneltim® plastic panels are based on the same principle as the steel I-beams. Therefore Paneltim® panels are light and strong.

To obtain the same strength properties in **solid plastic panels**, a much greater volume and therefore a much higher weight is needed.

RIGIDITY OF PANELTIM® PANELS COMPARED WITH OTHER MATERIALS

How do Paneltim® plastic panels compare with other structural materials of comparable rigidity? The following chart compares different Paneltim® panels with steel, chipboard and solid plastic sheets. The length of the bar in each case shows the thickness of the material that has comparable rigidity to the Paneltim® panel.

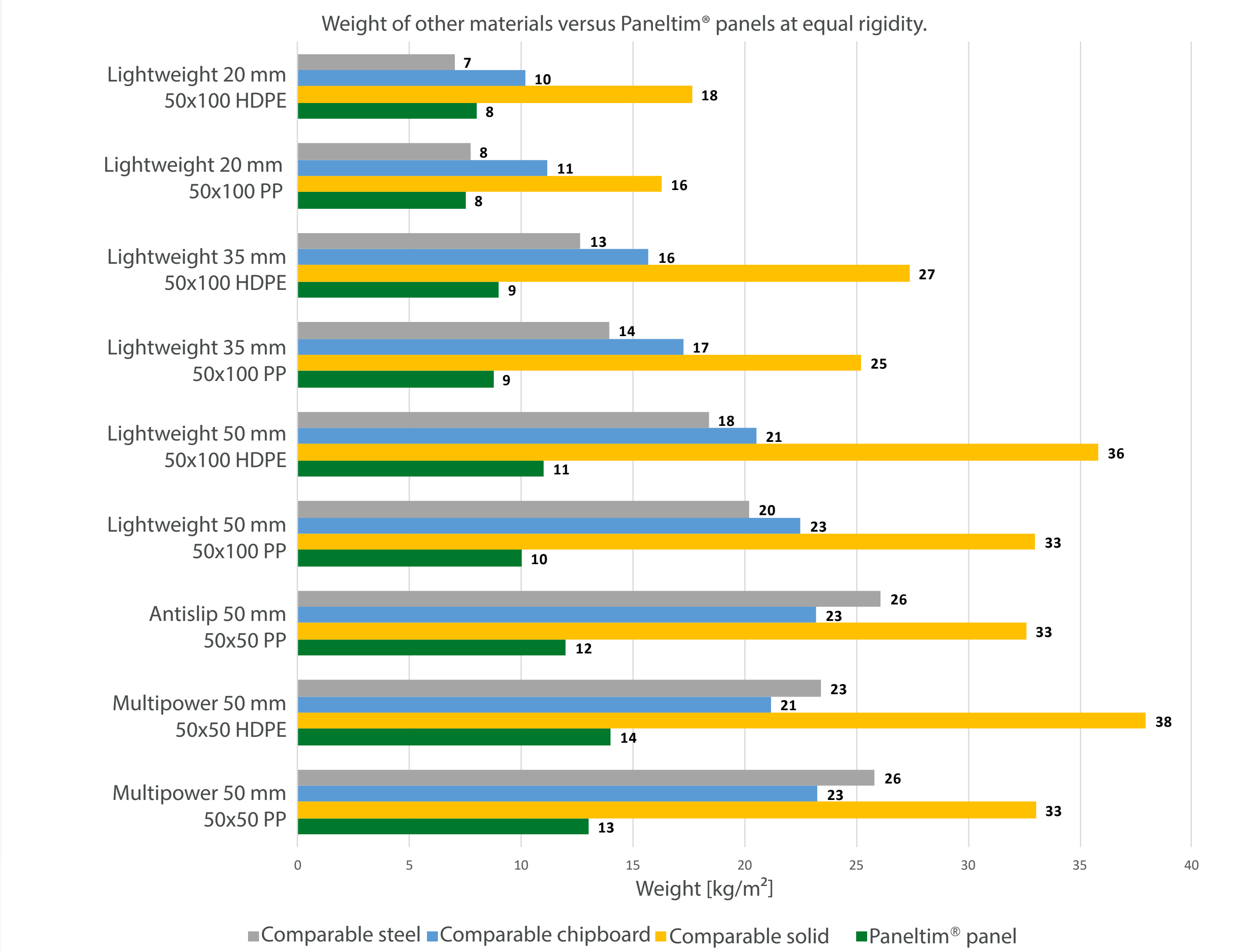
Note: The chart below does not consider long time effects such as creep, dynamic loading, temperature, etc.



Biological waste water treatment tank - Plastic Technology Lithuania

WEIGHT OF PANELTIM® PANELS COMPARED WITH OTHER MATERIALS

Weight is invariably an important consideration in construction. The chart below compares the self-weight per square metre of different Paneltim® panels with that of other structural materials, such as steel, chipboard and solid plastic sheets. In each case, the structural material depicted in the comparison has a thickness and rigidity that corresponds to the Paneltim® panel. The chart below therefore shows the weight per square metre of different structural materials in relation to Paneltim® panels of comparable rigidity.



OTHER MATERIALS MAY BE THINNER AT EQUAL RIGIDITY, BUT BECAUSE OF THE INTERNAL CELL STRUCTURE OF PANELTIM® PLASTIC PANELS, THEY ARE THICKER, YET MUCH LIGHTER.

Practical examples:

A 37 mm thick construction in solid HDPE can be replaced by a 50 mm Paneltim® Lightweight panel to obtain a weight reduction of 70%, keeping the same rigidity.

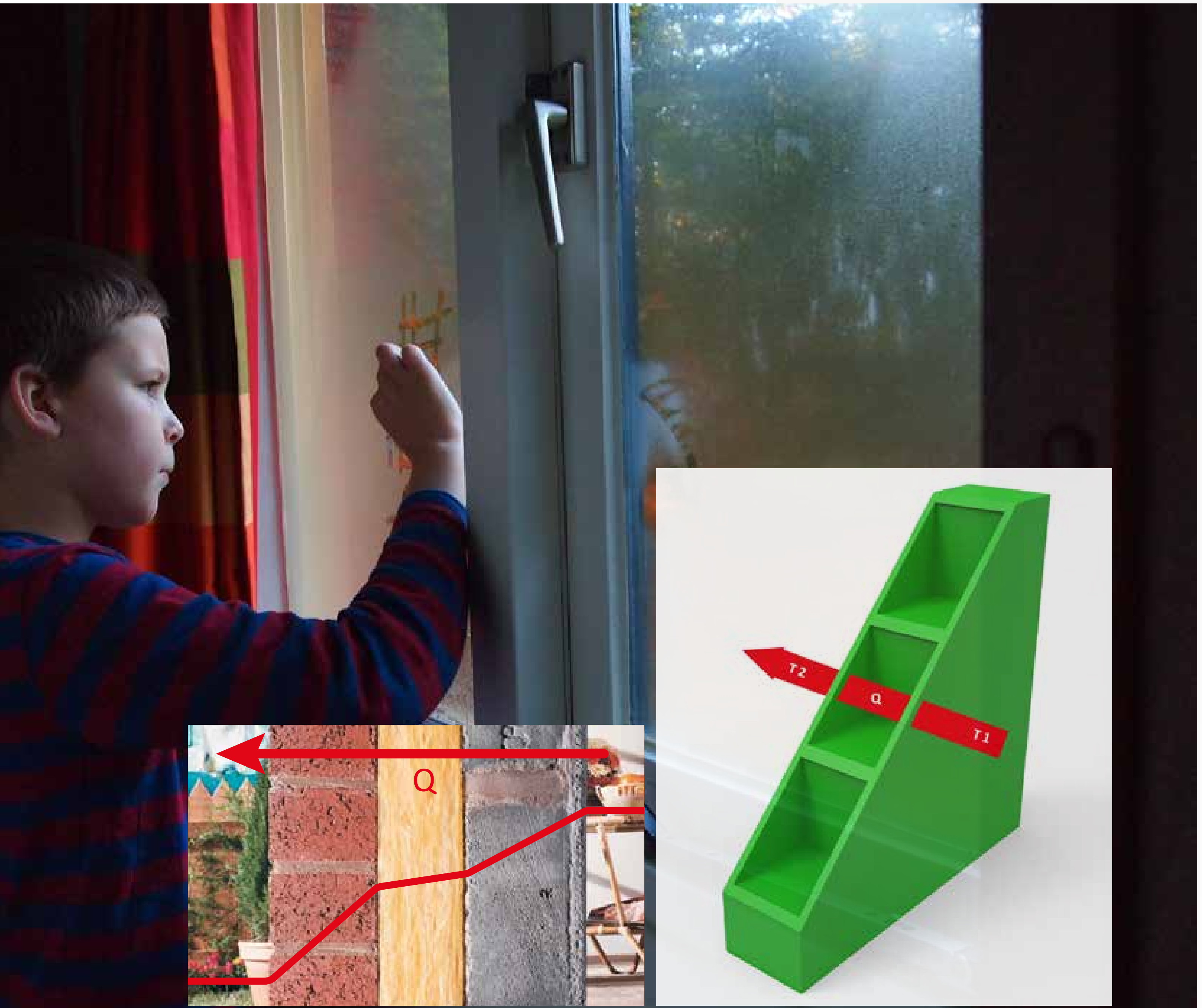
A 6 mm thick steel floor can be replaced by an equally strong floor of 50 mm Paneltim® Antislip panels, reducing the weight by 54%.

A wall of 37 mm solid PP can be replaced by a 50 mm Paneltim® Multipower panel, keeping the same rigidity while reducing the weight 2.5 times.

3.3. THERMAL PROPERTIES

Filled with air on the inside, Paneltim® panels perform well when it comes to thermal insulation in comparison with similar products. Air has a high thermal resistance. This insulation effect can be compared to the principles of a cavity wall or double glazing.

Note that under normal conditions, air inside the panels will be static, but when a temperature difference arises between the sides of the panel, then the air will start circulating internally within the cell and consequently thermal resistance will decrease.



Cavity wall and schematic representation of double glazing effect in a Paneltim® panel.

In case of a temperature difference between the two sides of the panel, a certain thermal flow (Q) will pass through the panel from the warm to the cold side . The thermal flow will pass a plastic layer first, then a layer of air and finally a plastic layer again.

The resistance absorbed by this thermal flow is the sum of the specific resistances of the materials.

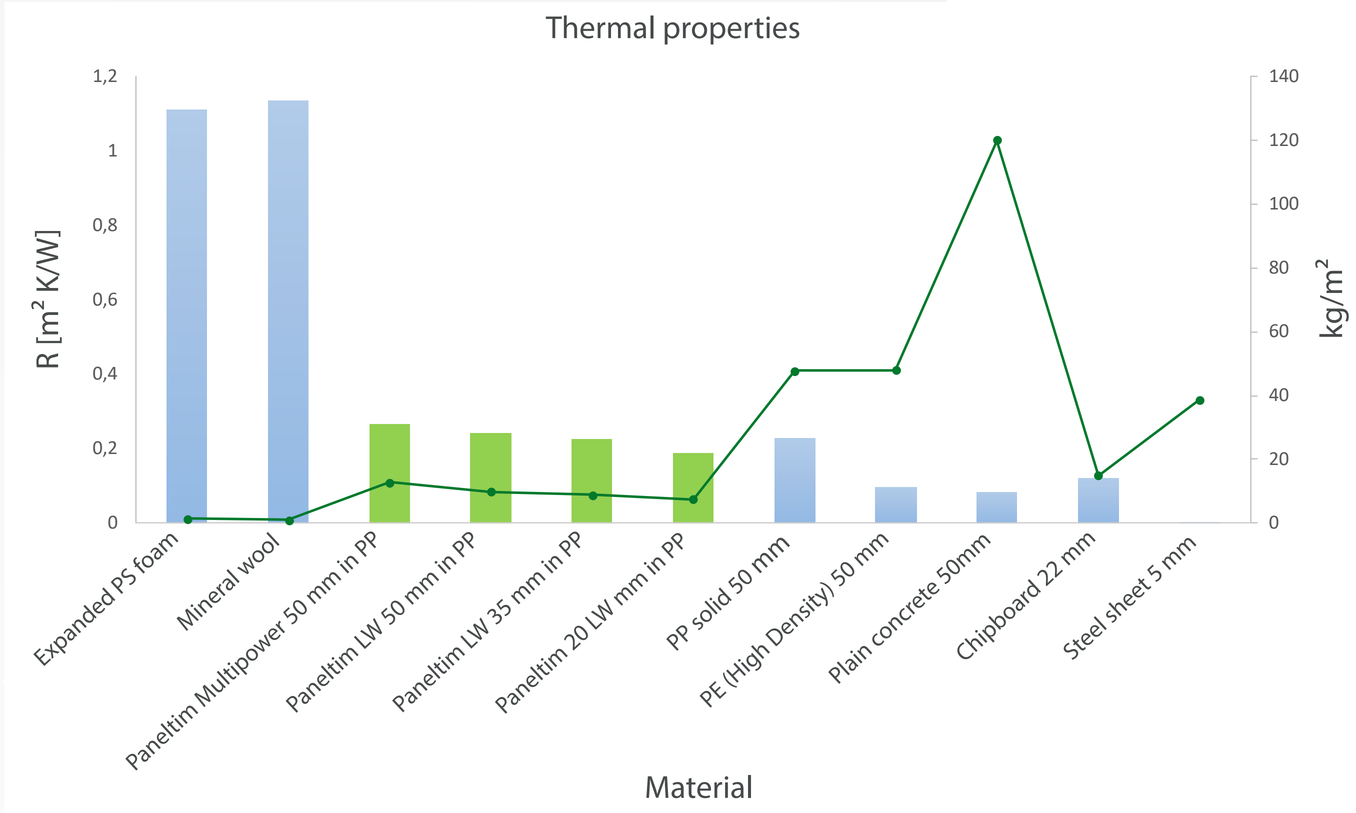
$R_{tot} = R_{PP} + R_{air} + R_{PP} = 2 \cdot R_{PP} + R_{air}$

In the following chart some materials are shown with their thermal resistance R.

It is clear that the Paneltim® panels insulate much better than concrete, chipboard or steel.

Specific insulating materials such as mineral wool do have better resistance, but they absorb liquids and therefore are not suitable for situations where humidity can affect the insulating properties of the material.

Therfore Paneltim® panels are well-suited in cases where a combination of good insulation, mechanical strength and resistance to humidity are needed.



Different materials and their thermal resistance.

Practical examples:

When the inner walls of a building are constructed with **Paneltim® Lightweight panels** of 20 mm, instead of chipboard of 22 mm, then the thermal resistance will be more than 50% higher. The weight of the construction will also decrease by 50%.

When the inner walls of a building are constructed with **Paneltim® Multipower panels** of 50 mm, instead of solid PP panels of 50 mm, then the thermal resistance will be almost 20% higher, while the weight will be almost 4 times less!

Paneltim advises using Paneltim® Multipower panels for structural constructions.

3.4. HYGIENIC AND CHEMICALLY RESISTANT

HYGIENIC

Paneltim® prime panels are made of pure polypropylene or polyethylene and are coloured throughout, i.e. the colour cannot peel off. This means the panels are well suited for hygienic areas, food preparation areas, etc - indeed, wherever hygiene is an important consideration. The enclosed cell structure of the panels offers complete protection against ingress of dirt and water.

The surface of the panels is fast-drying, non-absorbent and water repellent - a significant benefit wherever high standards of hygiene are required.

CHEMICALLY RESISTANT

Paneltim® panels made of prime PP and HDPE are resistant to most current chemicals.

GENERALLY SPEAKING ANY USE OF PANELTIM® PANELS IN COMBINATION WITH AGGRESSIVE MEDIA SHOULD ALWAYS BE APPROACHED WITH UTMOST CAUTION. IT IS IMPORTANT NOT TO MAKE ASSUMPTIONS IN THAT RESPECT. THEREFORE, FOR ALL CHEMICAL APPLICATIONS KINDLY CONTACT PANELTIM FOR FURTHER INFORMATION.

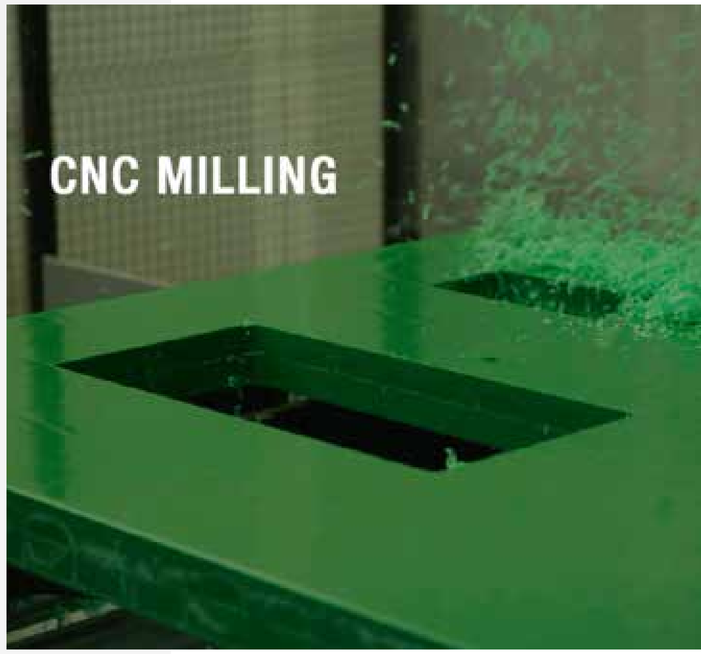
Platform around tanks - CPO France

4. PROCESSING OF PANELS

Paneltim® panels offer endless possibilities. In this section of the brochure, you will find a short summary of how to process the panels.

For more detailed information contact Paneltim.

The information provided is based on Paneltim's experience of best practice and cannot be generalised. Always test your own settings, depending on the specific equipment used.



4.1. MACHINING

Paneltim® plastic panels can be machined with regular and known techniques: sawing, milling and drilling. It is important not to generalise, and always test, finetune and validate settings on your own specific equipment.

4.2. WELDING

Paneltim® plastic panels are easy to install and mount using plastic welding. The extensive machining and welding possibilities of Paneltim® panels give excellent opportunities for easy on-site mounting, installation and customisation. This makes Paneltim® plastic panels a perfect choice for installations in confined spaces.

INSTALLATIONS IN CONFINED SPACES

Installation of a reservoir or other construction in a limited space can be carried out on site by a technician. This is a major advantage compared with the installation of conventional reservoirs. Waterproof mounting and welding, making connections to existing pipe entries, etc - all can be carried out on site. The photograph below shows a typical example of installation of a reservoir in a confined space.

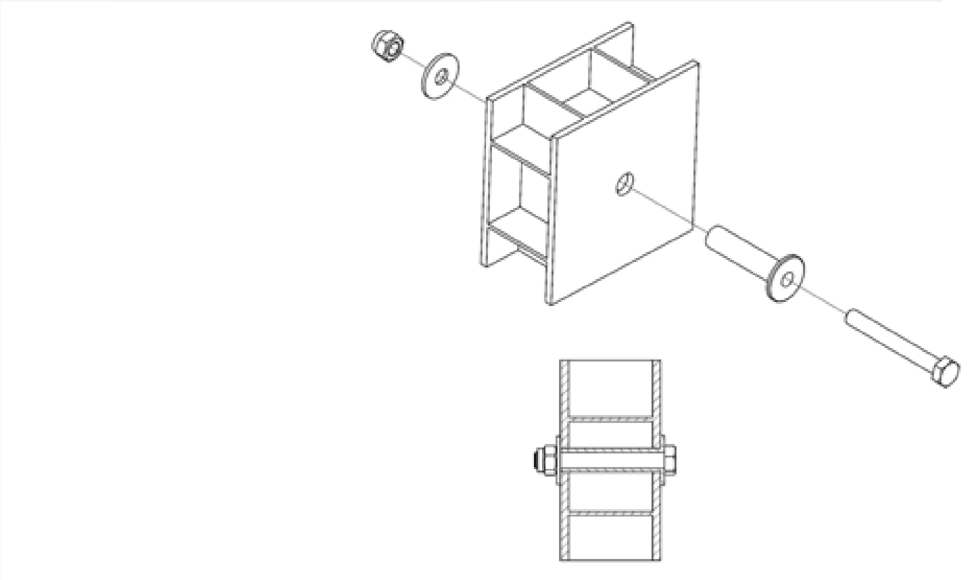
Water tank build in the Tauerntunnel - Aqua Umwelttechnik Austria

4.3. MECHANICAL JOINTS

Joining Paneltim® plastic panels mechanically using bolts requires the use of a bush to prevent compression by the bolt heads. Such compression could cause cracks in the panels or deflections in the vicinity of the bolts.

The exploded view below shows such a bush-and-bolt approach.

When connecting panels to a supporting construction or with incoming and outgoing pipework, always take into account the difference in thermal expansion between the materials.



Bush and bolt.

Fixing by plastic welding

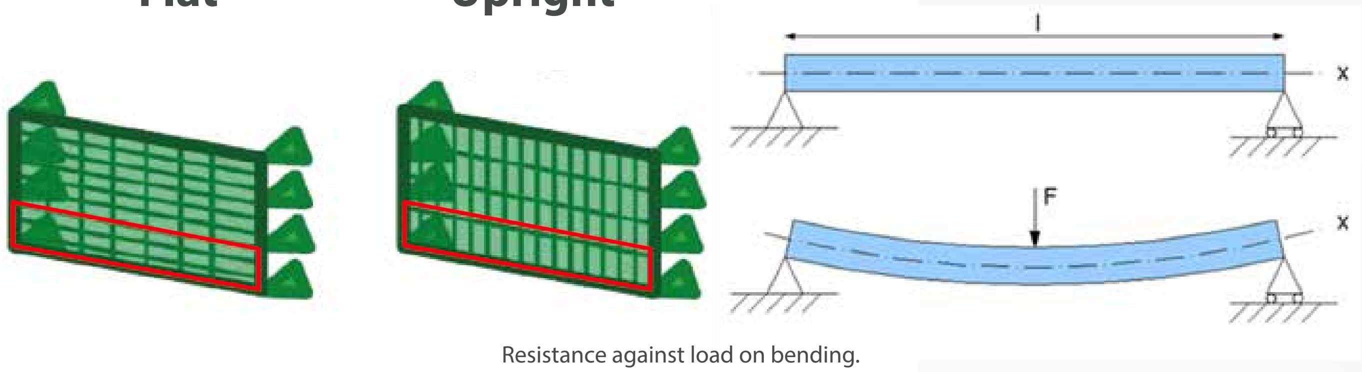
4.4. ORIENTATION OF THE PANELS

Paneltim® Multipower panels have a square internal cell structure of 50 mm x 50 mm. In view of their symmetrical structure, these panels will be equally strong independent of the orientation of the cells.

However, when using Paneltim® Lightweight panels, it makes a difference whether the cells are upright or flat in a construction because their internal cell structure is rectangular (50 mm x 100 mm). In this case, the panels should be oriented with the longer ribs in the direction of the highest load, in order to give maximum support.
For example:
• in case of a flat support with a car driving over
-> long ribs in the driving direction
• in case of a liquid storage tank
-> long ribs vertically, because hydrostatic pressure increases exponentially towards the bottom.

HOWEVER SEE COMMENT BELOW:
Always use 50 mm x 50 mm Paneltim® Multipower panels for containment of liquid.

Flat **Upright**



Resistance against load on bending.

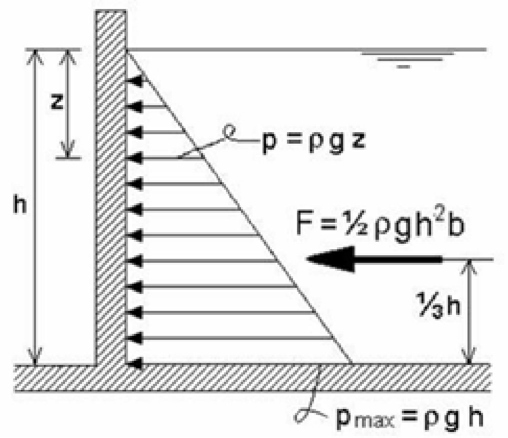
CELL POSITION FOR TANK CONSTRUCTION

FOR THE CONSTRUCTION OF LIQUID STORAGE TANKS
PANELTIM ALWAYS ADVISES USE OF
PANELTIM® MULTIPOWER PANELS
WITH AN INTERNAL CELL STRUCTURE OF 50 MM X 50 MM.

Paneltim® Lightweight panels with a 50 mm x 100 mm cell structure are not recommended for liquid storage tanks - 50 mm x 50 mm panels are advised for such applications.

The pressure of the water on the side walls is non-uniform. The pressure gradually increases towards the bottom in relation to the water column above (see schematic representation). The highest pressure is absorbed by the welding between the bottom of the tank and the walls.

Multipower 50 mm x 50 mm panels are advised for liquid storage applications.

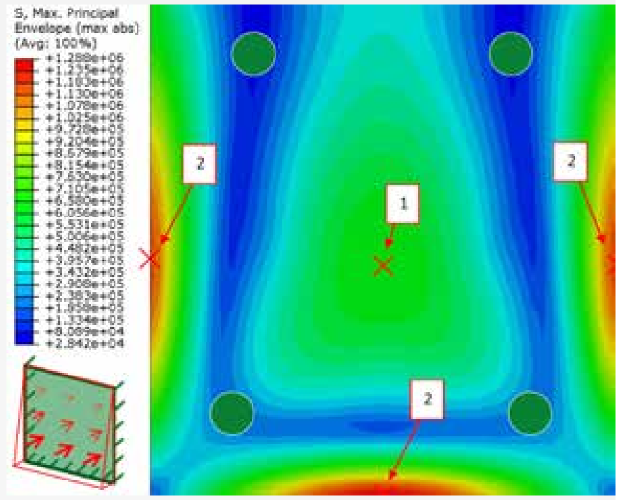


Schematic representation
of the increasing water presssure.

4.5. POSITIONING OF HOLES

In case of liquid storage tanks, pressure forces of the liquid are absorbed by the walls of the tank. These forces are higher in the welding area between the walls (points 2). Furthermore - again in the case of a filled tank - high stresses occur in the middle of the tank wall, at a height of 40% to 50% of the total height of the tank (point 1).

As a general rule, the green points in the illustration below indicate the most suitable positions for positioning holes. For this particular load case, best results are achieved when holes are positioned in the lower corners of the tank.



Internal tension in the wall of a tank & ideal hole positioning.

Hole in a large rainwater retention tank - Jenso in Australia

Paneltim® panels are injection moulded in high quality Polypropylene (PP) or Polyethylene (HDPE).

5.
IMPORTANT CONSIDERATIONS

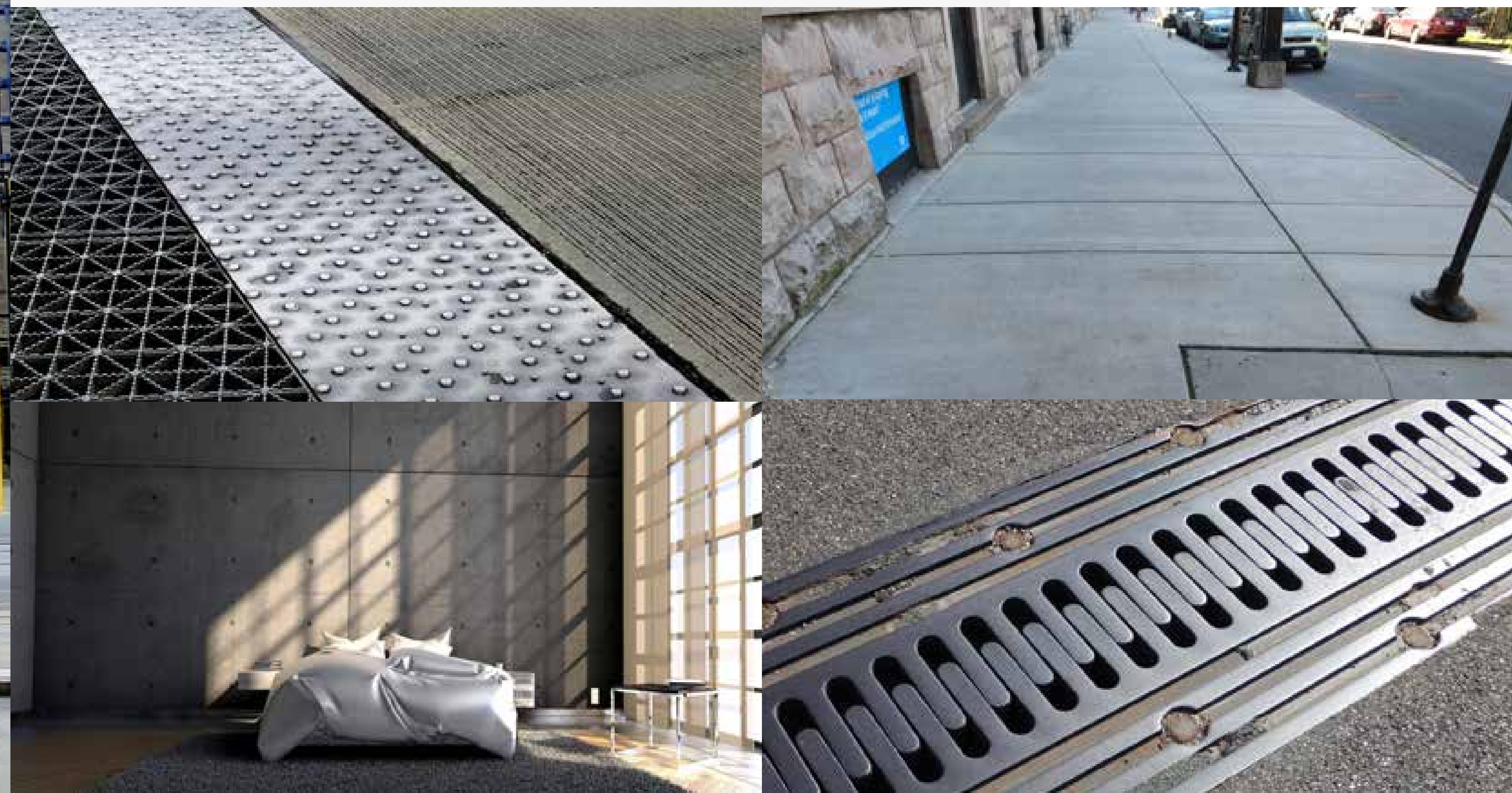
5.1. THERMAL EXPANSION

Materials have a tendency to expand and contract when subjected to changes in temperature.

This phenomenon is especially relevant in bridges, highways and buildings. That is why a certain clearance in joints between building elements is necessary to allow the materials to expand freely. E.g. in road construction, flexible rubber joints are necessary to allow road sections to expand without causing internal stresses and deformation.

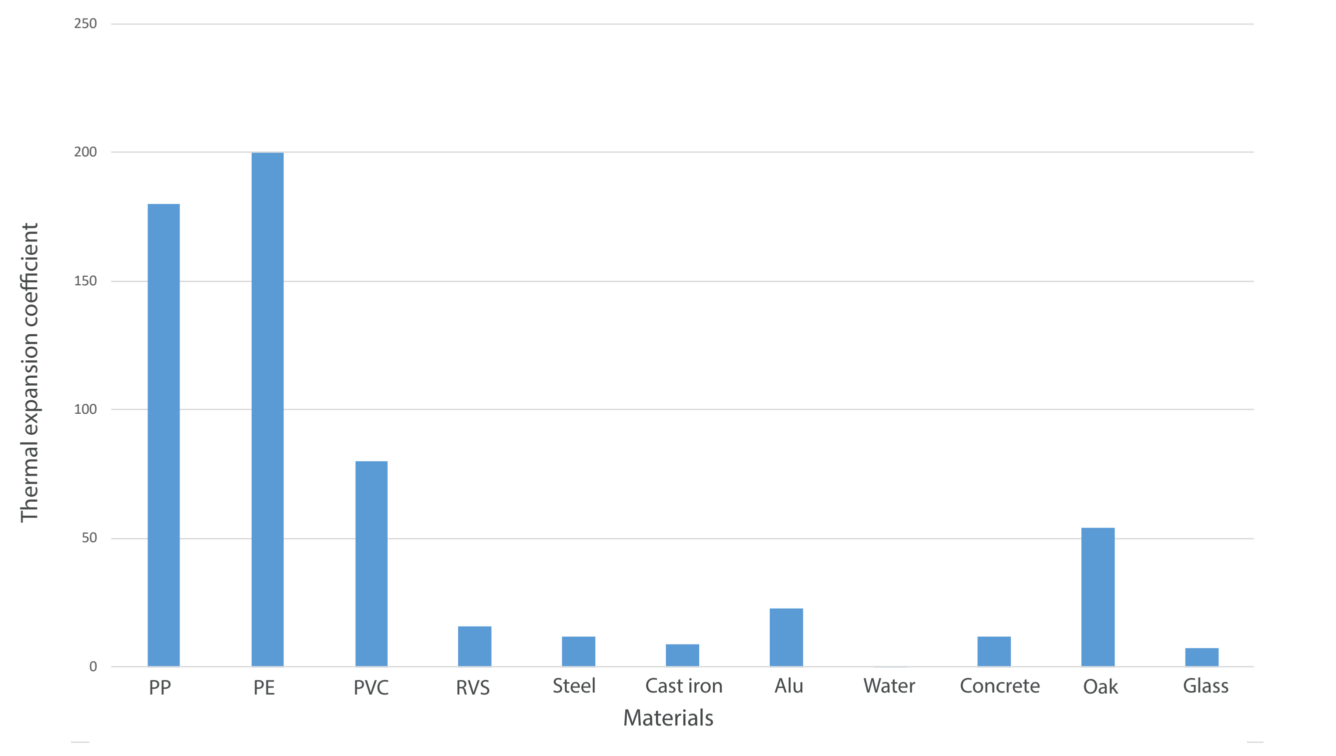
Also, when building concrete structures, if a sizable section of concrete is not provided with properly spaced joints to accommodate temperature change, then the concrete will start cracking in a regular pattern under temperature variations.

And so also with Paneltim® panels, thermal expansion and the associated stresses need to be considered and designed for.



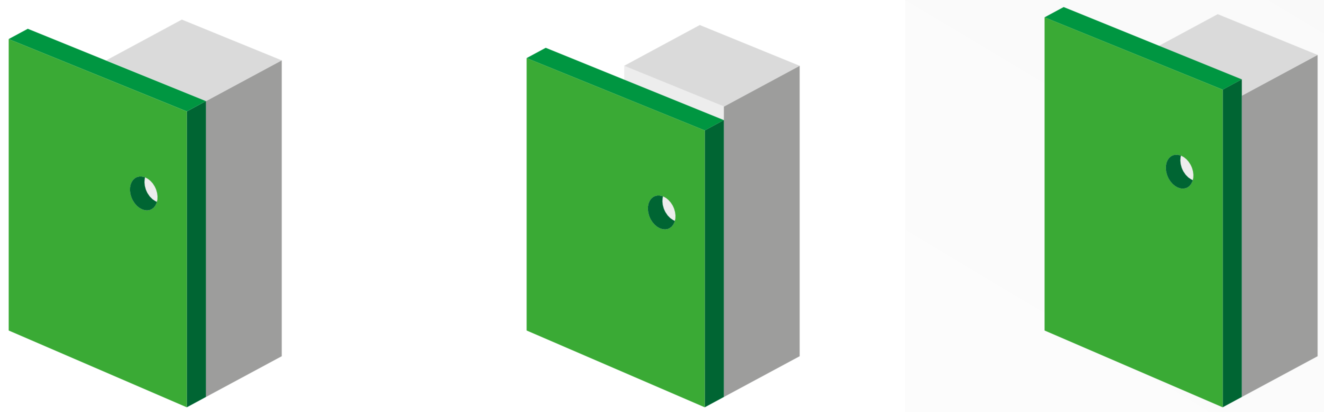
Solutions to avoid deformation and failure caused by thermal expansion and contraction.

All materials, including concrete steel and also plastic panels, have a thermal expansion coefficient. This coefficient of expansion is a material property. It describes the level of expansion and contraction under temperature variations and is different for different materials. The figure below shows the thermal expansion coefficient of different materials.



Thermal expansion coefficient of the different materials.

Thermal expansion will cause the dimensions of a product to change under temperature changes. When, for instance, a Paneltim® plastic panel is fixed to a supporting steel structure, both will behave differently under the temperature change, i.e. expansion will be different for the different materials.



Room temperature

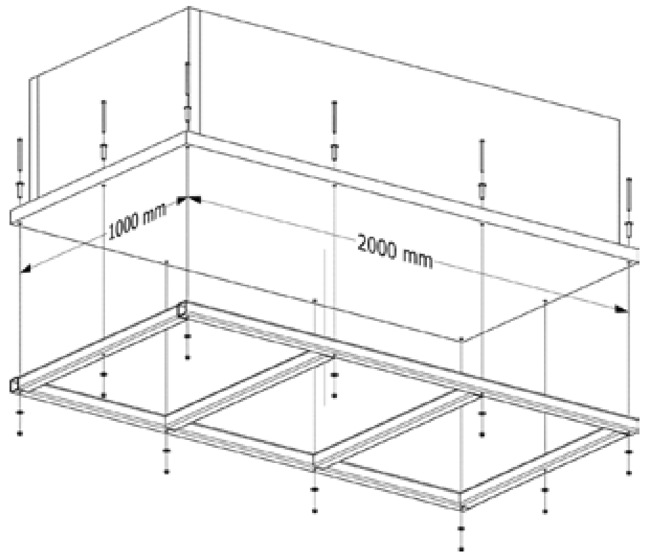
Lower temperature

Higher temperature

Schematic representation of the thermal expansion coefficient.

Practical example:

A reservoir made of Paneltim® panels is mounted on a steel supporting structure. The difference between the thermal expansion coefficients is $168 \cdot 10^{-6}\ K^{-1}$. Under normal circumstances, the temperature in the building is 18°C, but during the operation of the installation, the reservoir is filled with a liquid at 45°C. The temperature difference is 27°C. The construction is mounted with M8 bolts and bushes as shown in the figure below.



The difference in thermal expansion can be calculated with the following formula:
$\Delta x/l = \Delta\alpha \cdot \Delta T = 168 \cdot 10^{-6}\ K^{-1} \cdot 27° = 0.004536\ m/m = 4.536\ mm/m$

This means that on the shorter side of the reservoir there will be a difference of 4.5 mm between frame and reservoir. On the longer side the difference will be 9 mm. This will produce extra strain on the bolted joints. Therefore if the joints would not be appropriately dimensioned to allow for expansion/contraction differences, permanent deformation and damage could occur.

Practical example:

A Paneltim® panel is fixed to a steel supporting structure. The linear expansion coefficient of steel is $12 \cdot 10^{-6}\ K^{-1}$ and of polypropylene is $180 \cdot 10^{-6}\ K^{-1}$. The difference between the thermal expansion coefficients is $168 \cdot 10^{-6}\ K^{-1}$. The construction is installed in a building where temperature in winter reaches -10 °C and in summer +38°C, so the difference in temperature is 48°C. The calculation for the difference in expansion will be:
$\Delta x/l = \Delta\alpha \cdot \Delta T = 168 \cdot 10^{-6}\ K^{-1} \cdot 48° = 0.008064\ m/m = 8.064\ mm/m$.

This means that the panel will expand 8.064 mm more per metre than the steel structure. If there would be a bolted joint every metre, these holes would move approx. 8 mm relative to the steel construction. A clearance of 8 mm should therefore be added in the design.

Practical example:

For the **construction of a metal frame around a Paneltim® Lightweight panel** a reinforcement of metal U-profiles around the outside is used. This metal profile is fixed to the panel using bolted connections. However, anticipating different expansion of the metal profile versus the plastic, a sufficient degree of tolerance should be allowed at the metal profile corners. So rather than using round holes to bolt the panel to the metal profile, slotted holes should be used instead, allowing the panel to move freely in the profile under different expansion/contraction effects.

HEAT ABSORPTION

Plastic panels absorb heat by radiation. That is why constructions exposed to the sun heat up quickly. This must be taken into account in design and material choice.

Panels with a darker colour are more heat-absorbing than panels with a lighter colour. Hence panels in darker colours will reach higher temperatures, causing more expansion and internal strain. Once the maximum tolerated level of stress is reached, the panel would lose its durability.

Therefore, for panels exposed to direct sunlight light colours would be the best choice.

5.2. CREEP IN PANELTIM® PANELS

WHAT IS CREEP?

Creep is the permanent deformation of a material under long-term mechanical stresses, i.e. under tensile or pressure loading, or under torque loading.

Creep is undesirable and reduces the effective life of an application.

No creep: when the apple is picked,
then the twig will move back to its original position.

HOW DOES CREEP WORK?

When a material is subjected to mechanical stress it will deform. Under moderate stresses this deformation will be elastic, which means that the deformation is reversible: the deformation occurs according to Hooke's law, which means that the deformation is proportional to the applied force.

$\Delta L = E \times F$

ΔL is the elongation (or deformation), E is the elasticity modulus of the material (in other words, it is a material property), and F is the applied tensile force.
When the force is removed, the material will return to its original length, meaning the deformation is reversible. The elasticity modulus E is a material constant (a material property) - but only under condition of short term loading and under constant temperature.
Depending on the type of material and depending on the level as well as the time span of the applied force, the material will at some point no longer return to its original length, but will show permanent elongation (deformation); this is when creep is occurring. Furthermore when creep persists long enough rupture will occur.
If creep persists for a prolonged period, the object will break!

Creep in daily life.

Practical examples:

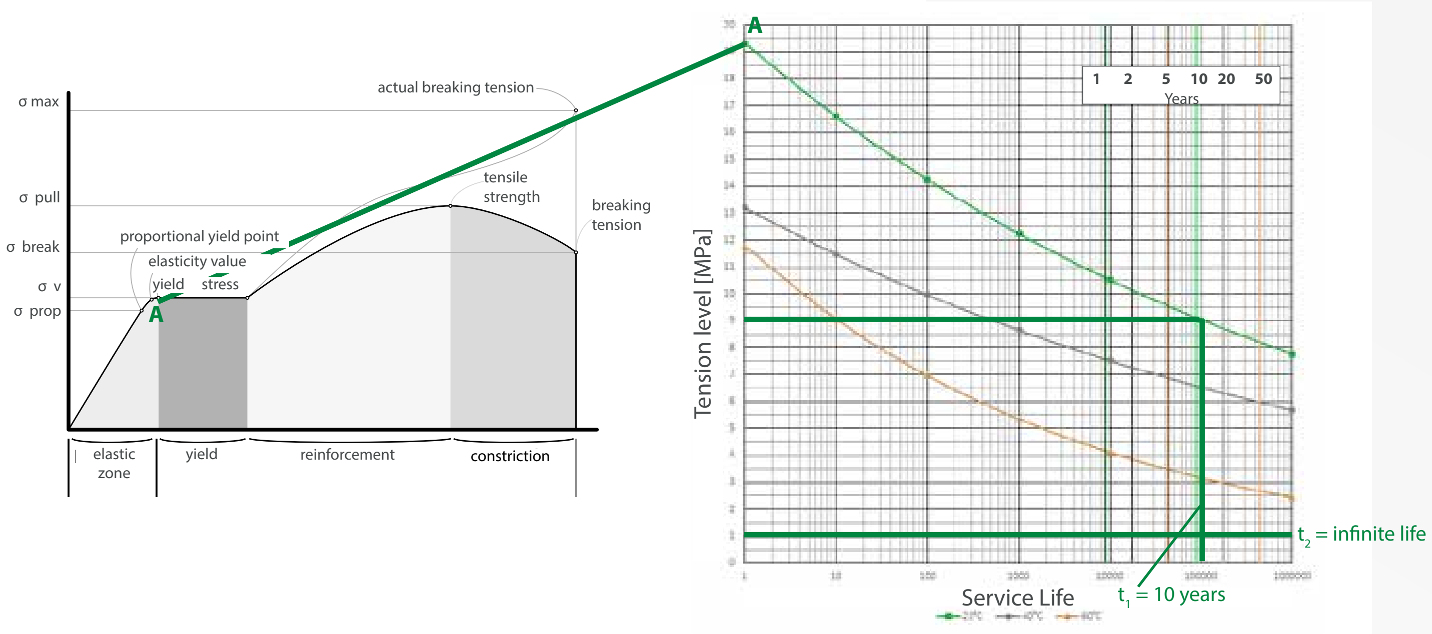
A shelf under permanent load will deform permanently after a while.

A clothes rail will start bending under loading and at some point will be bent permanently.

RELATION BETWEEN STRESS-STRAIN AND CREEP

Using data of tensile stress testing, stress and related elongation/deformation can be calculated. Representing this data graphically in a curve results in a so called stress-strain diagram (figure on the left).

Point A, which is the elastic limit or yield stress of the stress-strain diagram, corresponds with the beginning of the creep curve, at time 0. Over time this yield stress will decrease under permanent loading and as a result plastic behavior will start to occur at lower stress levels.



Stress-strain diagram & creep curve.

Practical example:

A line load of 73 kg applied to a panel of 1 m^2 corresponds to a load of 9.10 MPa (Mega Pascal) on the material. At 23°C we see on the creep curve that there will not be a permanent deformation. Indeed the maximal allowable stress at time 1 is approx. 19 MPa (A).

However, if a constant load of 9.10 MPa would be applied on the material, the situation would change over time. By following the green line going to the right until reaching the creep curve, clearly at some point permanent deformation will occur. It will take 10 years for the material to start showing permanent deformation, when applying a permanent force of 9.10 MPa. Hence after 10 years, the yield value has "moved down".

Furthermore, the chart shows that temperature is a defining factor in the calculation of service life time. The higher the temperature, the lower the allowed stress at the same service life time.

IMPORTANT NOTICE:

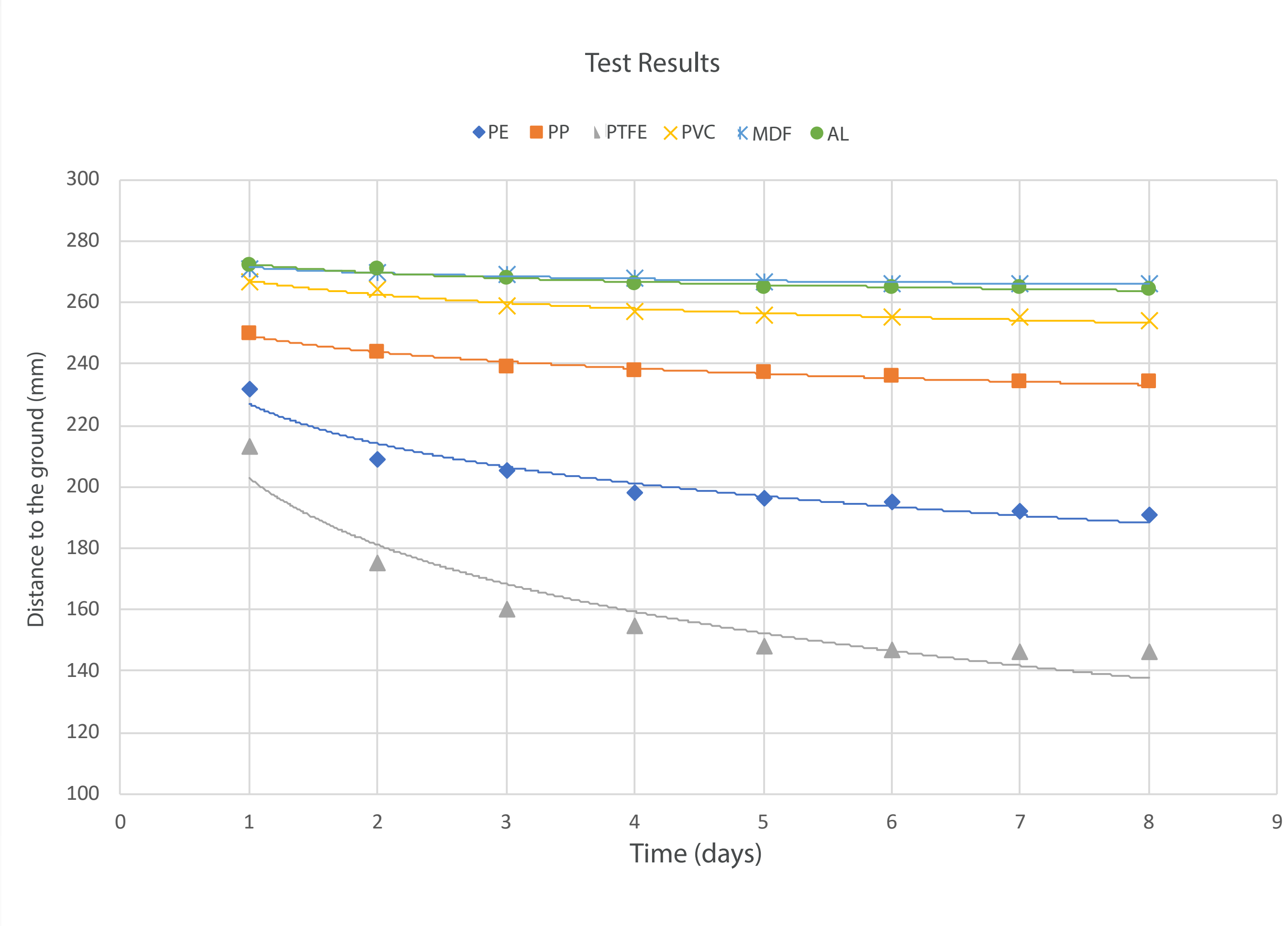
- **'Temperature' refers to the material, not the environmental temperature.**
- **A black panel can show deformation earlier than a white panel at the same temperature.**

DIFFERENCE IN CREEP BEHAVIOR

The images on the right show an experiment demonstrating the difference in creep in different materials.

Within a time span of 7 days, the distance to the ground is measured. As the days go by, the materials bend more and more. PP and HDPE are more affected by creep than aluminium and MDF. This experiment is carried out at constant environmental temperature.

Experimental setup demonstrating creep.



Comparing creep of PP and HDPE vs aluminum and MDF.

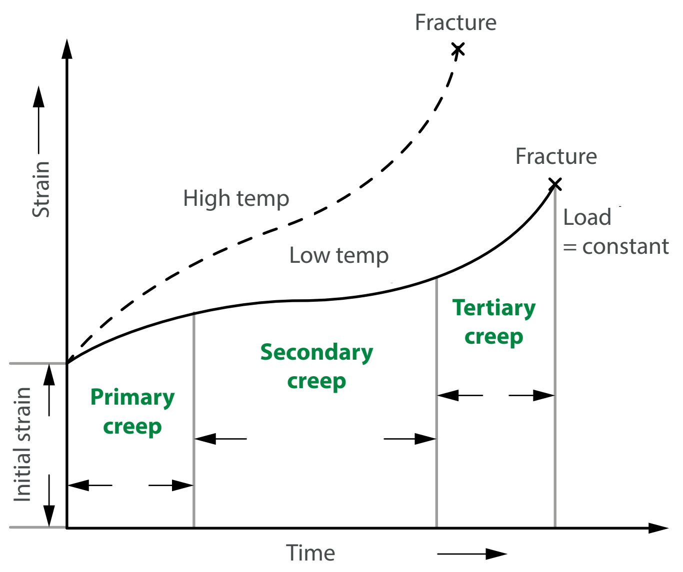
RUPTURE

The creep curve below (strain versus time) shows creep developing in three phases before final rupture.

Primary creep is the first phase in which creep speed slowly decreases. Apparently in this phase a certain strengthening of the material is occurring.

During **secondary creep** the creep speed is constant because of a certain balance between the material strengthening on the one hand and some softening of the material through "recovery" on the other hand. Usually this section of the curve is the longest.

During **tertiary creep** the creep process is accelerating, ultimately leading to rupture of the material. This rupture usually occurs at the intergranular level of the material.



Typical creep curve.

Practical example:

When a tank is subjected to mechanical stress over a prolonged period of time, the tank will pass through the above-mentioned three phases:

- In the first phase, the tank will expand under the mechanical load.
  = Primary creep

- After a while, the tank will move into the second phase where little to no expansion will take place.
  = Secondary creep

- When transitioning into the third and last phase, the tank will start expanding again at a faster pace, until rupture occurs.
  = Tertiary creep

The time period over which the tank passes through the different phases depends on the materials used as well as the actual load exerted on the tank; but after a defined period of time, the tank will fail.

6. PERFORMANCE CALCULATIONS

This section of the brochure covers a number of particular Paneltim® application scenarios with supporting calculations. Important conclusions are summarised at the end of each scenario.

6.1. PANEL SUPPORTED ON TWO SIDES AND UNDER UNIFORM LOAD

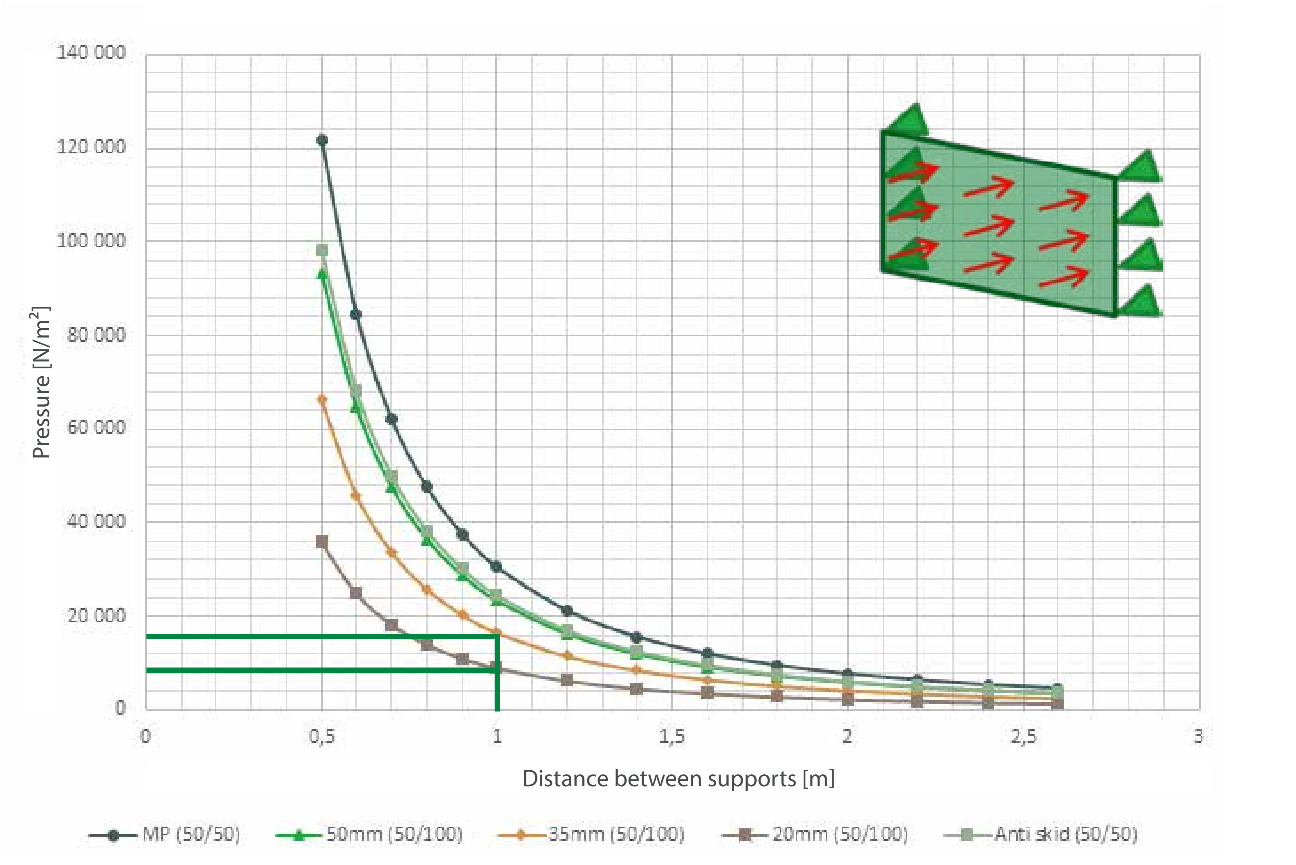
SCENARIO

A jeep of approx. 1,800 kg is standing on a Paneltim® panel with one wheel, and the panel is supported on both sides. The length (l) of the panel is 1 m and the width (b) is 1 m.
Because the jeep has four wheels, the load on the panel is 1,800 kg/4 = 450 kg. This means that the pressure on the panel is 450 kg/m² or approx. 4,500 N/m².

Load case: Jeep with one wheel on a 1 m x 1 m panel.

METHOD 1: USING PERFORMANCE GRAPHS TO FIND THE ALLOWABLE PRESSURE

In this exercise we use the performance graph of the corresponding load case: panel supported on both sides and subjected to a uniform load = pressure.



Performance graph "panel support on both sides & uniform load".

For Paneltim® Lightweight panels with an internal structure of 50 mm x 100 mm and supported on both sides with the supports 1 metre apart:

- for the 20 mm thick panel the maximum allowed pressure is about 8,000 N/m², i.e. sufficient compared with 4,500 N/m².
- for the 35 mm thick panel the maximum allowed pressure is about 18,000 N/m², i.e. sufficient compared with 4,500 N/m².

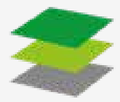
ATTENTION!
It is important to note that in the performance graphs documented in the PTS (and also the performance graph illustrated above), no safety factors, no creep factors, no temperature correction factors and no welding factors are taken into account. So the results obtained from these performance graphs are only valid for momentaneous (instant) loading and under standard 23°C conditions!

METHOD 2: CALCULATING THE ALLOWABLE PRESSURE USING FORMULAS

A more accurate method to choose panels for the described load case (jeep with one wheel on the panel, supported on both sides) is to use the calculations described in the PTS and again verify afterwards if the occurring pressure (4,500 N/m²) does not exceed the allowable pressure.

To achieve this, we need to follow a number of steps. These steps are also shown in the Quick Chart, which is included with this Quick Guide. This Quick Chart can be used for calculating different applications and configurations. The different steps are represented graphically with symbols.

1. MATERIAL CHOICE



Material

Depending on the application a choice needs to be made between PP or HDPE panels. Generally at normal temperatures and under normal chemical resistance requirements PP is advised. However, the example of the jeep will be worked out with both materials, in order to show the differences.

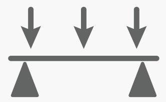
2. SAFETY FACTORS AND MATERIAL PARAMETERS

Life Time

We want the jeep to be able to stay on the panel for 10 hours.

Temperature

The temperature of the panels we work with is 23°C.
ATTENTION: The temperature of the material, not the environmental temperature. Careful with absorption in case of black panels!
Depending on the temperature and depending on the material a material-temperature factor A1 needs to be applied. In this case A1 is 1.0.



Load type

Depending on the type of load, it is necessary to work with a safety factor S.
As the jeep is not moving (static load), factor S equals 1.3.
If the jeep would be moving (dynamic load), factor S would be 2.0.

3. SELECTION OF THE PANEL

The selection of the panel is depending on the required bending strength.

FOR HEAVY DUTY CONSTRUCTIONS SUCH AS LIQUID TANKS, CORRIDORS OR FOOTBRIDGES, PANELTIM ALWAYS ADVISES PANELTIM® MULTIPOWER PANELS OR PANELTIM® ANTISLIP PANELS.

Because the purpose of this exercise is to compare results of this calculation method to the results of the performance graph method we will evaluate the Paneltim® Lightweight panels of 20 mm, 35 mm and 50 mm in the calculation method, and compare then to the results of the performance graph method.

4. CALCULATION OF THE ACTUAL OCCURRING STRESS

The formula for the maximum allowable stress in the case of a panel supported on two sides with uniform pressure is presented on the right and can also be found in the PTS . In this formula tp represents the total thickness of the panel.

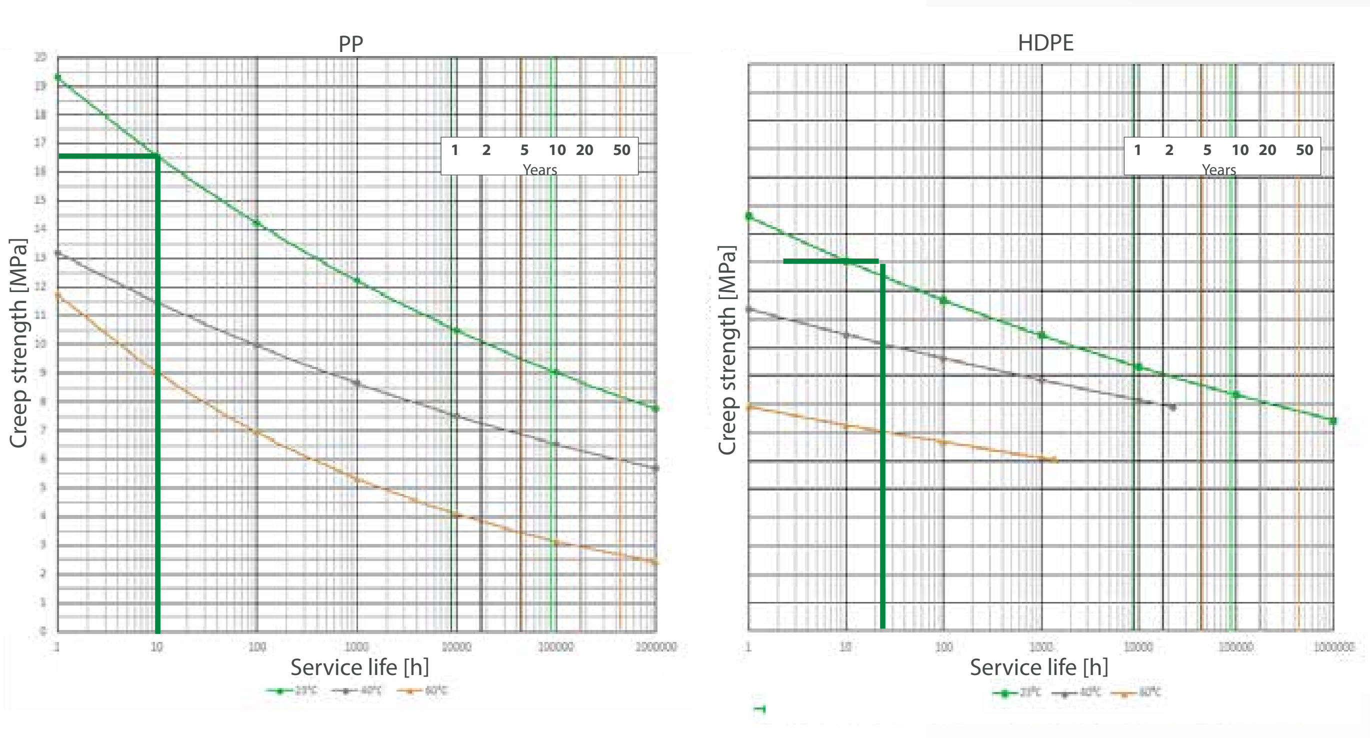
$$\sigma b = \frac{3Pl^2 . tp}{4. t_{eq}^{\;3}}$$

In the case of the 50 mm x 100 Paneltim® Lightweight panels with a thickness of 20 mm, 35 mm or 50 mm thickness, this tp is therefore resp. 20 mm, 35 mm or 50 mm.
t_{eq} on the other hand represents the equivalent thickness of the panels (as if the panel would be a solid sheet). This equivalent thickness is different for 50 mm x 100 mm Paneltim® Lightweight panels versus 50 mm x 50 mm Paneltim® Multipower panels and is also different for 20 mm vs 35 mm vs 50 mm panels. The equivalent thickness (teq) for the different types of panels can be found on the Quick Chart.
When filling in all the other values in the formula on the right, the below table shows the occurring stress in the three Paneltim® Lightweight panels under the described load case (jeep with one wheel on the panel).

Paneltim® Lightweight panel	Occuring stress
50 mm	3.33 MPa
35 mm	5.38 MPa
20 mm	11.57 MPa

5. DETERMINATION OF THE DESIGN RESISTANCE

Now we have to evaluate if this occurring stress in the panel does not exceed the design resistance, i.e. the maximum allowed stress in the material.
From the creep strength curve - which is shown here below, but can also be found in the PTS - we can establish that - under the defined conditions - the maximum allowed creep stress for the material PP would be 16.5 MPa (indeed knowing that defined conditions above are that the panel temperature is 23°C and that we want the jeep to be able to stand on the panel with one wheel for 10 hours).
Note that for PE, using the same approach, we can establish that the maximum allowable creep stress in the material would be 13 MPa.



Creep curve of PP and PE with measured values.

However, bear in mind that the allowed creep stress (K) for both PP and PE under the given conditions needs to be reduced further with a material factor (A1) and with a safety factor.

$$\sigma_{al} = \frac{K}{A_1 \; . S}$$

Refer to the formula on the right, which illustrates how to calculate the design resistance using the allowed creep stress in combination with material factor and additional safety factor.

Note that these additional safeties are introduced into the formula in order to make sure that we stay away far enough from the “risky” area where creep would start occurring.

The table below shows the results of the calculations and provides the design resistance for PP and PE under the given conditions (23°C and 10 hours).

Material	Design resistance
PP	12.7 MPa
PE	10.0 MPa

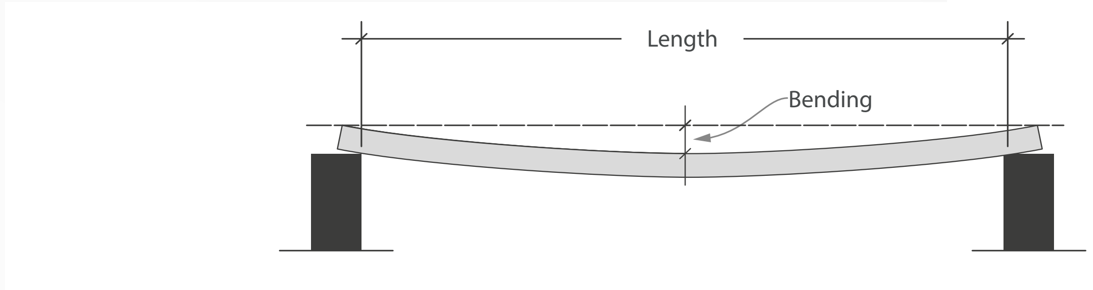
Material	Paneltim® Lightweight	Occurring stress	Design resistance	Successful?
PP	20 mm	11.57 MPa	12.7 MPa	YES
	35 mm	5.38 MPa		YES
	50 mm	3.33 MPa		YES
HDPE	20 mm	11.57 MPa	10.0 MPa	NO
	35 mm	5.38 MPa		YES
	50 mm	3.33 MPa		YES

6. CALCULATION OF PANEL DEFLECTION

As a final check to validate whether a panel is suitable for the application (in other words, which panel will be able to hold the one wheel of the jeep for 10 hours) we will need to check the deflection (bending) of the panel.

$$f = \frac{5}{384} . \frac{P.b.l^4}{E.\frac{b.t_{eq}^{\;3}}{12}}$$

The formula on the right to calculate the occurring deflection f can again be found in both Quick Chart and PTS.
The maximum deflection of the panel cannot be more than half of the panel’s equivalent thickness.
Note: for certain applications an even lower maximum deflection may have to be imposed!



Panel deflection f.

The result of the calculations with the formula can be found in the table below, i.e. the actual deflection of each panel type under the load of one wheel of the jeep after 10 hours.

Material	Paneltim® Lightweight	Bending (f)	Half of equivalent thickness (teq/2)	Successful?
PP	20 mm	90 mm	9 mm	NO
	35 mm	24 mm	14 mm	NO
	50 mm	10 mm	18.5 mm	YES
PE	35 mm	31 mm	9 mm	NO
	50 mm	13.6 mm	18.5 mm	YES

From the above table it becomes clear that for the Paneltim® Lightweight panels of 20 mm and 35 mm the deflection or bending will be far too high under the load of the wheel of the jeep.

50 mm Paneltim® Lightweight panels with internal structure 50 mm x 100 mm in PP or HDPE will be a good choice, they will certainly hold the one wheel of the jeep for 10 hours.

Conclusions:

It appears that the selection made using the performance graph in method 1 does not correspond with a more detailed calculation, as done in method 2. The reason being that - as indicated before - **performance graphs do not take into account service life and safety factors**.

Had we chosen a service life of 1 year for the material, then for PP at 23°C the creep strength would be 10.5 MPa, which would translate to a design resistance of 6.15 MPa (instead of 12.7 MPa). This means that in terms of actually occurring stress the PP 20 mm panel would no longer fulfill the requirement. For HDPE the design resistance would change from 10 MPa to 5.5 MPa.

Having said that, within a year the design resistance of a panel would be half of the original value. So obviously it is extremely important to **take into account service life in the application**. The longer the desired service life, the lower the design resistance, which would translate to the need for thicker panels.

Furthermore looking at the **effect of temperature** on a PP panel: at a service life of 10 hours and a 40°C temperature, the design resistance would decrease from 12.7 MPa to 8.8 MPa. At 60°C this would decrease even further to 6.9 MPa.

In other words a temperature increase from 20°C to 60°C would reduce the design resistance 1.8 times. It is very important to take this into account if service life needs to be maintained in the design.

Also - as discussed earlier - **the colour of the panels** plays a major role. Because of absorption darker panels will reach much higher temperatures than initially expected. This will further reduce the design resistance. Ignoring this may lead to constructions failing before the end of their expected service life.

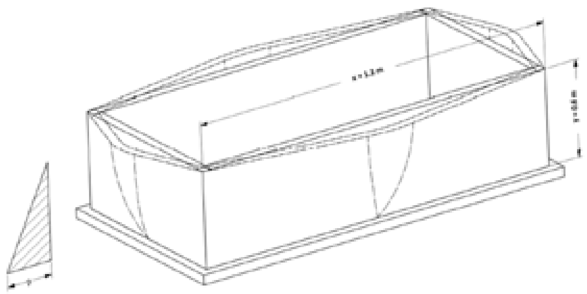
For HDPE temperature is an even more important factor. At 40°C the design resistance for HDPE would decrease from 10 MPa to 8 MPa. At 60°C it would decrease further to 5.5 MPa. So at 60°C the design resistance would be almost half of that at 23°C. At 60°C and with a service life above 1000 hours HDPE would not be suitable anymore.

6.2. TANK CONTAINING LIQUID

A rectangular tank without reinforcement has a length (x) of 1.2 m and a height (y) of 0.6 m.

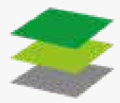
Can the tank be built with HDPE Paneltim® Lightweight panels with a thickness of 35 mm and an internal structure of 50 mm x 100 mm?

As in the case of the jeep (6.1), the Quick Chart will be used to reach a conclusion. In this case however, some additional considerations need to be taken into account: a welding factor to account for the fact that there are welding joints in the construction; and a reduction factor to account for the type of liquid inside the tank.



Liquid storage tank.

1. MATERIAL CHOICE



Material

For the purpose of this example, HDPE will be assumed as the selected material.
Later it will be demonstrated why perhaps this would not be the best material choice.

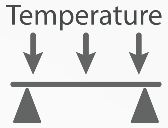
2. SAFETY FACTORS AND MATERIAL PARAMETERS

Life Time

The tank needs to have a 10 year service life.

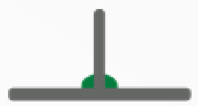
Temperature

The temperature of the panels used is 23°C.
Careful with absorption in case of black panels!
At that temperature the material temperature factor is 1.0.



Load type

Depending on the type of load, a safety factor S needs to be taken into account.
In this case S is 1.3.
We will consider the tank always full, which is considered a static load.



Welding type

Welding factor fL: In most cases stress will be highest close to the weld.
A welding factor will therefore need to be applied. In order to be on the safe side it is recommended to always use a welding factor of 0.6, although more detailed info on welding factors can be found in the Quick Chart and in the PTS.

Liquid type

The liquid in the tank is untreated water with a density of 1,000 kg/m³.

3. SELECTION OF THE PANEL

For this exercise a Paneltim® Lightweight panel with internal cell structure 50 mm x 100 mm and thickness 35 mm will be used for the calculation. **For liquid storage tanks this would normally never be used.**

4. CALCULATION OF THE ACTUAL OCCURRING STRESS

Stresses occurring in the side walls of the tank will be calculated for the worst case scenario of the tank filled to the top. Only the most critical side wall will be checked. In this case this is the longest side wall of the tank. The required formulas are depending on the length/height ratio of this longest side wall. In this example the ratio is 2.

$$\sigma = \frac{\beta 1 \,.\, P \,.\, y^2}{teq^2} . SCF$$

Hydrostatic pressure at the bottom of the tank can be calculated with the formula:
P = ρ . g . h = 1,000 [kg/m^3] . 9.81 [m/s^2] . 0.6 m = 5,886 Pa

The highest occurring stress in the tank wall can then be calculated from the formulas in the Paneltim Technical Standard: 2.15 MPa.

5. DETERMINATION OF THE DESIGN RESISTANCE

To verify if the occurring stress in the tank wall does not exceed the maximum design resistance, first check the creep curves. For HDPE panels and for a service life of 10 years, the creep strength equals 8.37 MPa.

Next, after taking into account the necessary safety factors, the design resistance can be calculated to be 3.86 MPa. In this case the design resistance is higher than the highest actually occurring stress in the tank, so the panels will meet the design resistance requirements.

Material	Paneltim® Lightweight	Occurring stress	Design resistance	Successful?
PE	35 mm	2.15 MPa	3.86 MPa	YES

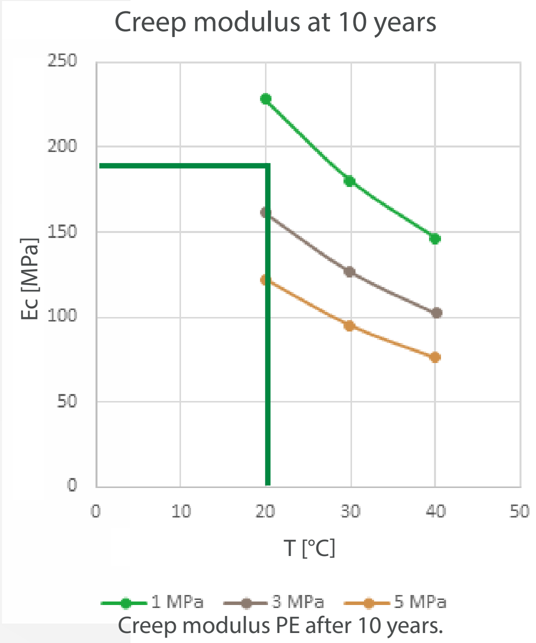
6. CALCULATION OF PANEL DEFLECTION

As we require a service life of 10 years in this exercise - contrarily to the previous example with the jeep - we cannot assume a constant E-modulus in this case. Instead, we will need to replace the E-modulus with the creep modulus.

The creep modulus can be found in the chart on the right (also to be found in the Quick Chart and in the PTS) for the specific conditions of the material, i.e. temperature of 23°C and maximum occurring stress of 2.15 MPa.

Under these conditions, the chart gives a creep modulus of 190 MPa.

Deflection of the side wall can now be calculated using the formulas in the Paneltim Technical Standard: 16.3 mm. This deflection is higher than half of the equivalent thickness (14.85 mm).



Creep modulus PE after 10 years.

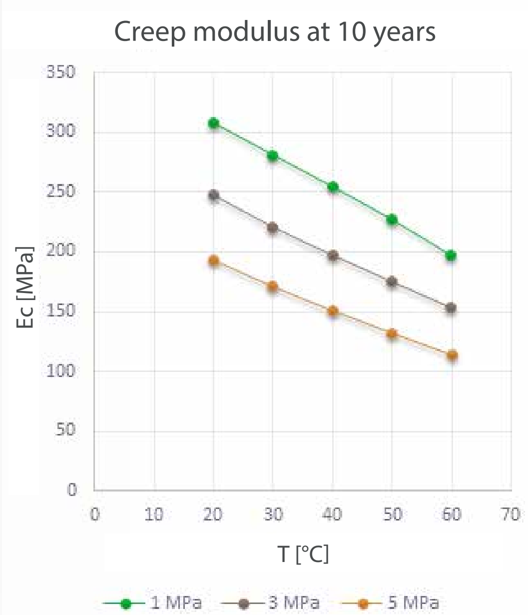
Therefore **Paneltim® Lightweight panels with a thickness of 35 mm will not meet the deflection requirements.** So another solution has to be found for building the requested construction.

Material	Paneltim® Lightweight	Bending	Half equivalent thickness	Successful?
PE	PE 35 mm	16.3 mm	14.85 mm	NO

Possible solution 1: use PP instead of PE

The creep modulus Ec of PP under said conditions would be 273 MPa, resulting in a lower deflection, i.e. 11.4 mm.

In other words: the deflection of a panel with the same internal structure, but made out of PP instead of HDPE - and used under those same conditions - would have a lower deflection: 11.4 mm instead of 16.3 mm.
11.4 mm would be lower than half of the equivalent thickness, meaning the solution would meet the requirements.



Creep modulus PP after 10 years.

Possible solution 2: use a PE Paneltim® Multipower panel

The maximum occurring stress in a 50 mm HDPE Paneltim® Multipower panel with internal cell structure 50 mm x 50 mm would be 1.5 MPa. This value would be lower than the design resistance of 5.79 MPa and would meet the requirements.

Deflection of this panel would only be 6.3 mm. Clearly the use of a stronger panel results in meeting the requirements.

Yet if we were to use a 50 mm PP Paneltim® Multipower panel with internal cell structure 50 mm x 50 mm (instead of PE), then the deflection would decrease further. Indeed, deflection would reduce to only 4 mm.

7. SERVICE LIFE

The table below shows the effect of panel thickness on service life, by comparing a number of different panels.

Material	Panel type	Deflection after 10 years	Deflection after 25 years
PE	Paneltim® Lightweight 35 mm	16.3	17.7
PP		11.4	13.1
PE	Paneltim® Multipower 50 mm	6.3	7.0
PP		4.0	4.4

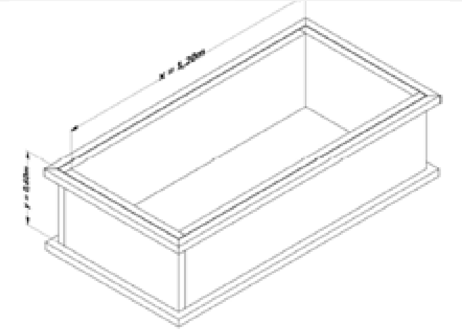
The data clearly shows that Paneltim® Lightweight panels are strongly affected by creep. Indeed, after 25 years of service life the deflection of a PP panel of 35 mm will come very close to the maximum allowed deflection of 14.85 mm.

FOR LIQUID STORAGE TANKS IT IS ALWAYS ADVISED TO USE PANELTIM® MULTIPOWER PANELS OF 50 MM WITH AN INTERNAL CELL STRUCTURE OF 50 MM X 50 MM IN PP. THIS WILL MINIMISE THE RISK OF PERMANENT DEFORMATION CAUSED BY INTERNAL STRESS AND PANEL DEFLECTION.

6.3. LIQUID STORAGE TANK WITH EDGE STRENGTHENING

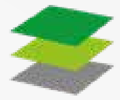
A rectangular tank with edge strengthening has a length (x) of 1.2 m and a height (y) of 0.6 m.

Can the tank be built with HDPE Paneltim® Lightweight panels with a thickness of 35 mm and an internal structure of 50 mm x 100 mm?



Liquid storage tank with edge strengthening.

1. MATERIAL CHOICE



Material

To allow comparison with the exercise in 6.2, HDPE will also be used in this example.

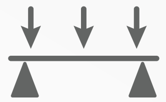
2. SAFETY FACTORS AND MATERIAL PARAMETERS

Life Time

The tank needs to have a 10 year service life.

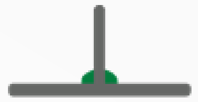
Temperature

Temperature of the panels is again assumed 23°C.
Careful with absorption in case of black panels!
So material temperature factor 1.0.



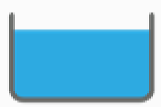
Load type

Safety factor S 1.3 because tank assumed always full, i.e. static load.



Welding type

Welding factor fL 0.6



Liquid type

Liquid in the tank again untreated water with a density of 1,000 kg/m³.

3. SELECTION OF THE PANEL

In order to compare with the previous example again a Paneltim® Lightweight panel of 35 mm and internal cell structure of 50 mm x 100 mm is selected.

4. CALCULATION OF THE ACTUAL OCCURRING STRESS

For tanks with edge reinforcements the formulas are different (refer to Paneltim Technical Standard for details). Maximum stress in the tank wall can be calculated as follows:

$$\sigma = \frac{\beta 2\ .\ P\ .\ y^2}{t_{eq}{}^2} . SCF = \frac{0{,}36\ .\ 5886\ Pa\ .\ (0{,}6\ m)^2}{(0{,}028\ m)^2}\ .\ 1{,}5647 = 1514432\ Pa = 1{,}51\ MPa$$

5. DETERMINATION OF THE DESIGN RESISTANCE

In the previous example the design resistance was already calculated to be 5.79 MPa. This is higher than the maximum occurring stress in the tank wall, so the panels meet the stress requirements.

6. CALCULATION OF PANEL DEFLECTION

This is were the previous example went wrong. In this example the graph of the creep modulus after 10 years shows 194 MPa for HDPE and a panel deflection of 4.3 mm. This is better than the required 14.85 mm.

Material	Paneltim® Lightweight	Occurring stress	Design resistance	Successful?
PE	35 mm	1.51 (MPa)	3.86 (MPa)	YES
		Deflection	**Half equivalent thickness**	**Successful?**
		4.3 mm	14.85 mm	YES

Conclusions:

Deflection is much lower than allowed. By adding edge strengthening deflection is improved from 16.3 mm to only 4.3 mm. This is almost 4 times less. Also the occurring stress is decreasing from 2.15 MPa to 1.51 MPa. For this example HDPE Paneltim® Lightweight panels of 35 mm with an internal structure of 50 mm x 100 mm were used in order to show the differences with the previous example.

PANELTIM® ALWAYS RECOMMENDS USING PANELTIM® MULTIPOWER PANELS IN PP FOR LIQUID STORAGE APPLICATIONS. REASON BEING THAT UNEXPECTED PEAK STRESSES MAY ARISE AT ALL TIMES IN THE AREA OF THE WELDING SEAMS. PANELTIM® MULTIPOWER PANELS IN PP WILL OFFER THE BEST SAFETY MARGIN AGAINST TANK DEFORMATION AND BREAKAGE.

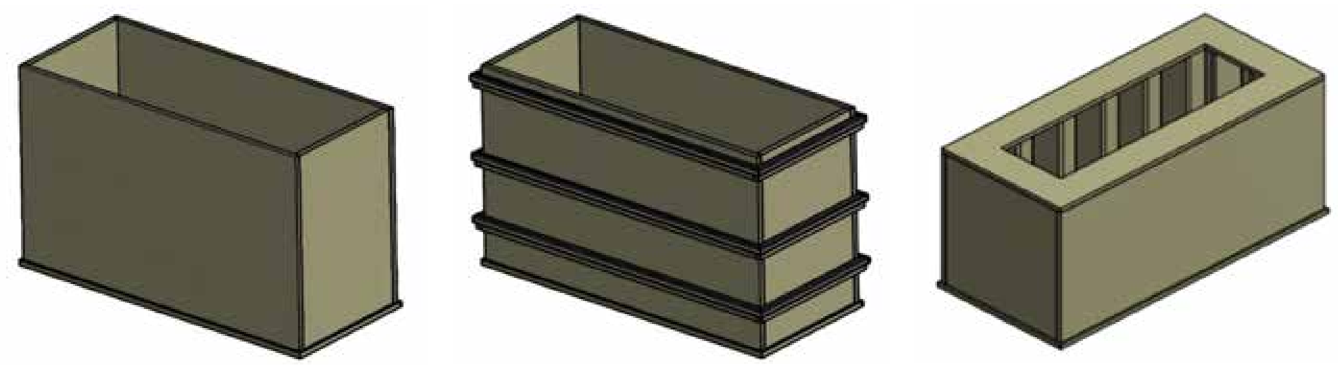
6.4. CALCULATION OF A LIQUID STORAGE TANK USING COMPUTER ANALYSIS

Not all applications can be calculated with formulas. Sometimes they are just too complex or sometimes it is simply faster and more accurate to use computer tools such as Finite Element Analysis (FEA).

In this section three models of a tank are analysed with FEA to demonstrate the power of this tool. FEA starts from a 3D model to which forces, boundary conditions and fixations are applied, in order to have the computer model correspond to reality as much as possible.

The model is subdivided into a grid of smaller elements. The density of this grid will be increased, wherever the user or computer expects to find higher stresses. The computer then calculates stress and deformation in each of these elements. The more and the smaller the elements, the more precise the calculation will be, but also the longer it will take and the more calculation power is needed.

Below the 3D models of the three tanks are shown:
The first tank does not have reinforcements and is simply made out of Paneltim® panels.
The tank in the middle has outer horizontal reinforcements out of steel on different heights.
The third tank has vertical internal reinforcements made of Paneltim®.



Tank 1: No reinforcements Tank 2: Border reinforcements Tank 3: Internal reinforcements

3D-models of the different tanks.

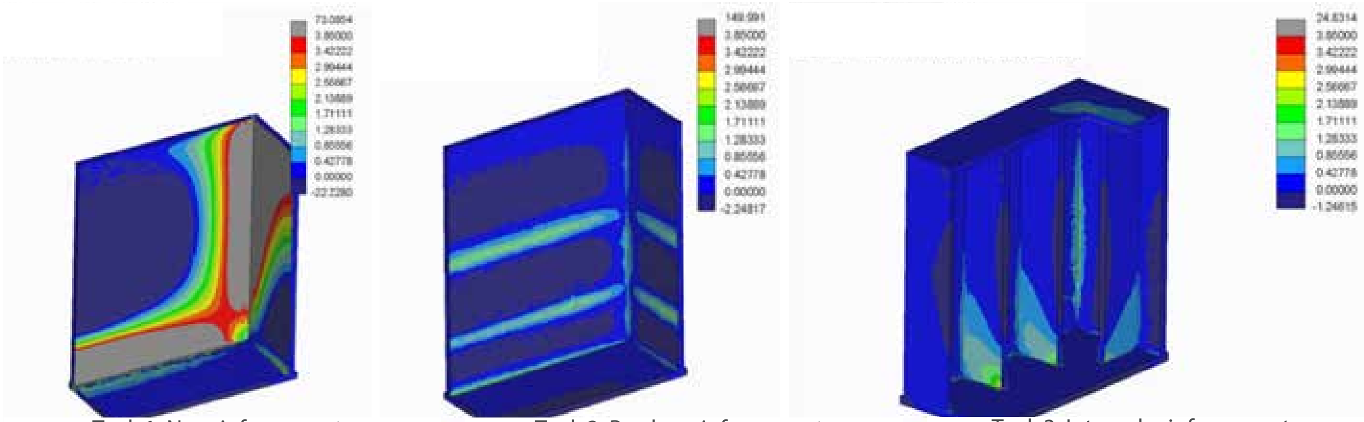
Using FE analysis on each of the three models, the effect of reinforcements can be evaluated quickly.
In below table the properties of the tanks are shown. The results are discussed further on.

	Tank 1	Tank 2	Tank 3
Dimensions (bxdxh) (mm)	3,000 x 1,200 x 1,900	3,000 x 1,200 x 1,900	3,000 x 1,300 x 1,500
Volume (m^3)	6.84	6.84	5.85
Maximum content (l)	6,300	6,300	4,680
Material tank	Paneltim® Multipower PP 50 mm	Paneltim® Multipower PP 50 mm	Paneltim® Multipower PP 50 mm
Material reinforcement	---	Steel profile 70 x 70 thickness 6.3 mm	Paneltim® Multipower PP 50 mm
Weight tank (kg)	267.70	267.70	232.90
Weight reinforcement (kg)	---	349.25	122.40
Total weight (kg)	267.70	616.95	355.30

The following table shows the deflection results.

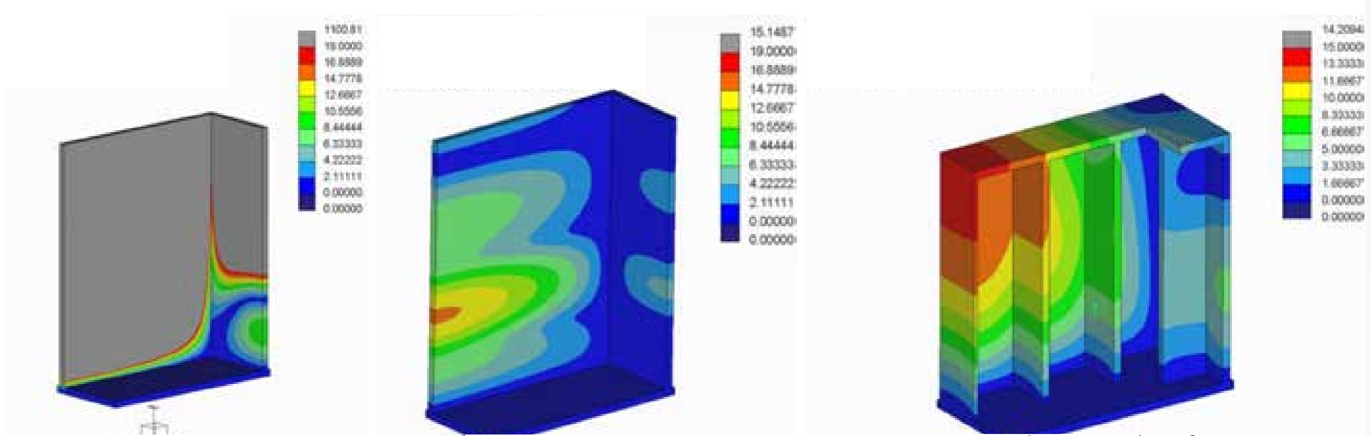
	Tank 1	Tank 2	Tank 3
Maximum deflection (mm)	(1,100.81)	15.15	14.21

The differences between the three tanks and the effects of the reinforcements are shown here below for the three tanks, by graphical representations of stresses and deflections for each of the tanks.



Tank 1: No reinforcements Tank 2: Border reinforcements Tank 3: Internal reinforcements

Graphical representations of internal stresses in the tanks.



Tank 1: No reinforcements Tank 2: Border reinforcements Tank 3: Internal reinforcements

Graphical representations of deflections occurring in the tanks.

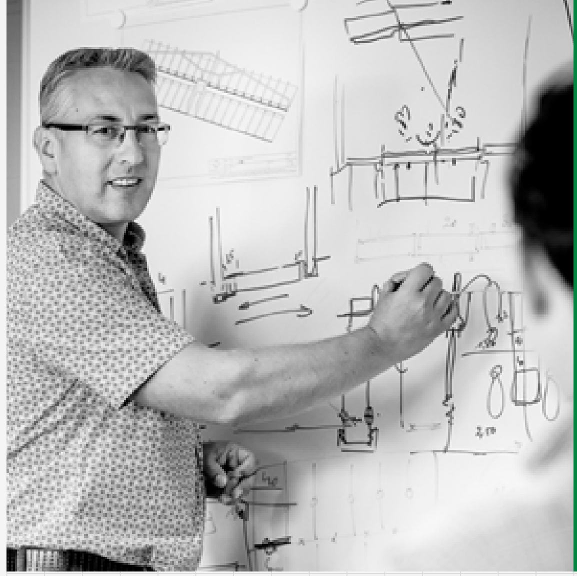
Conclusions:

The graph with internal stresses shows large areas of grey for the tank without reinforcements. These grey areas represent parts of the tank where the occurring stresses exceed the predefined allowed value.

Looking at the reinforced tanks however, there the occurring stresses are much lower and there are no grey areas visible. The highest stresses will occur close to reinforcements and in corners. Special attention will have to be given to these areas when designing joints or welding.

The graph with deflections shows a similar result.
For the tank without reinforcement, large grey areas are visible, so the deflection is far beyond the maximum allowed value. A value of, for example, more than 1 m means that the tank will not withstand the load.

Looking at the reinforced tanks deflection, it is considerably lower, and within maximum allowed limits. **This clearly shows the need for reinforcement.**



This Quick Guide to Paneltim® is a short summary of the Paneltim® Technical Standard (PTS). In the PTS, underlying formulas and technical data are documented in detail. For correct use of the Quick Guide and Quick Chart, a thorough knowledge and understanding of the Paneltim® Technical Standard is required.

Visit our website for
the most recent version of this 'Quick guide to Paneltim'
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