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**Abstract.** The concept of sustainability is creating big discussions, it can be defined in different ways. PVC is one of the most common, widely used, and earliest plastic developed to use commercially. International standards are in most countries used to control the production, qualities, and use of PVC. This material has a wide range of long-life applications such as, pipes, flooring, cables, window frames, children toys, a big variety of life saving medical devices, etc. PVC can be recycled multiple times. The professional designers, architects, specifiers and engineers must be well informed about low impact products, sustainable systems and technologies. The selection of those products will make a considerable impact to achieve sustainability. PVC sheet piles can be an alternative material to rock, wood, steel and concrete for the construction industry. They are production-, logistics-, and assembly friendly thanks to their lightweight construction. Simple and fast installation using standard and non-heavy equipment, which gives a significant CO2 reduction.

**Keywords:** Sustainability, Sustainable construction material, PVC, PVC sheet piles.

## 1 Introduction

The entire world has the responsibility to take care of our mother Earth and control the negative impact our civilization has done on the environment, not only creating plastic pollution but also keep on taking resources from the Earth and most are not effectively necessary.

Many species, including humans, might get problems in the future. The whole world already achieved the point that our societies overloaded the Earth capacity to support us. Humans are getting vulnerable with their greed to have more and more without any control, without any limits. Thinking only about “OUR” success, compromising the future of our societies, of our future generations to achieve also their own needs.

Today the most discussed subjects in our societies is the sustainability concept, but what is sustainability? What is the difference between being sustainable and being green? What kind of sustainable solutions exist to change our world, our way of living?

On construction sites nothing is changing the usage of traditional materials, which are still in vogue. Steel, concrete, wood and rock are the best examples. Although, on the market already exists products to substitute them in many cases.

Today, from recycled plastic trash it is possible to manufacture new, strong and beautiful products. One example of these materials are the PVC Sheet piles.

Around 20-25 years ago plastic sheet piles were manufactured from polyvinyl chloride and later from fibre reinforced polymers. This material has been applied a lot in the Netherlands and USA, for soil retaining, watercourse protection and marine applications.

Along these years many studies have been showing the strengths and the weakness of these PVC products. There are also many concerns about the performance in structural applications. Comparing with a steel sheet pile the bending moment of the plastic is less, also the maximum length of the plastic is limited. A plastic sheet pile cannot be welded. Nevertheless, PVC has many advantages over the traditional construction materials and many types of applications for this material. This product doesn't need maintenance and at the end of their lifetime they can be recycled and transformed in new materials again.

## **2 Sustainability**

The concept of sustainability is not easy to define, there are people who defines as an "environmental benefit" when compared with traditional practices which are not using green products, so called "natural" materials for the construction industry. This concept can create big discussions until it is completely defined.

For now, sustainability can be defined as the capacity to endure, the ability to sustain, a balanced environment between exploring the Earth resources and the human needs. The big growth of societies, specially the big consumption of the Earth natural resources and societies needs, developed a huge strain on the ecological and climate systems.

The construction industry consumes a very high percentage of materials and energy from natural resources. The professionals of this industry, architects and engineers, should be aware of these facts and search for green solutions for their projects. The same form as they plan houses, creating concepts about energy usage, soil usage, quality of air and light, they should create concepts for building materials as well, searching how materials are made, where they come from, do they need maintenance, how long they can "live" and after their useful life what will happen, where it will be disposed.

Sustainability is already focused on recycling, optimizing production and using recycled resources almost to their maximum potential, but this potential can be optimized when society start helping by little steps and one is put into action those changes.

### 3 PVC as a sustainable material

Polyvinyl chloride (PVC) was accidentally synthesized in 1872 by a German chemist Eugen Baumann. The polymer appeared as a white solid inside a flask of vinyl chloride that had been left exposed to sunlight. In the early 20th century the Russian chemist Ivan Ostromislensky and Fritz Klatte of the German chemical company Griesheim-Elektron both attempted to use PVC in commercial products, but difficulties in processing the rigid, sometimes brittle polymer was the result.

Waldo Semon and the B.F. Goodrich Company developed a method in 1926 to plasticize PVC by blending it with various additives. The result was a more flexible and more easily processed material that soon achieved widespread commercial use. PVC has already a history of more than 70 years of commercial usage with a huge variety of final products, since food packaging till blood bags (because of its minimal toxicity), as well as windows and doors profiles till water pipelines.

Two natural resources are used to produce this material, 57% of salt and 43% of oil. In their formation, Polymers are composed by oxygen, carbon and hydrogen which are susceptible to fire. However, PVC contains a very high level of chlorine (around 57%) by weight, which makes it fire retardant and therefore it is used in wires and electrical cables.

The risk of using this material is very small. His production, quality and usage must follow international standards.

Along the years, technology has developed new products which are durable and well performed for the needed constructions. Going back to the green natural materials (plants and bio-mass sources) doesn't make any sense for the simple reasons that they are not durable and will cause more impact on the environment as the new technology materials.

The same way chlorine and caustic are in the PVC formation, there are many products on the market which are using both components. For example, to produce basic organic chemicals and acids used in polymeric materials, solvents, pigments and inks, pharmaceuticals, cleaning and disinfection agents, water treatment, chlorine is very important, also caustic is a very important chemical to produce aluminum, water treatments, paper and textiles.

Substantial progress has been occurred on the PVC industry on the last few years. The new PVC has no longer legacy additives, they have been replaced by alternatives and the industry keeps on working to improve better and better solutions.

Another big progress on the PVC industry is the recycling challenge. PVC can be reprocessed into new products which are comparable to the original products. Plastic material can easily be recycled and stays fixed in their formation because its structure does not dissolve and biodegrade or corrode. Durability and relatively maintenance-free materials are the big advantage in supporting the human needs and a virtue in sustainability terms.

Many of the PVC manufactures already started a take-out program to replace the old PVC materials. With this replacement a huge portion of the emissions associated with new PVC manufacture are removed. With the non-polymer materials, aluminum, wood and iron, they will not achieve the quality results from the PVC. In order to be

recycled, those non-polymer materials, have associated a large energy and emissions in their reprocessing structure.

Recycled waste will possibly contain cadmium. In the European Union, a higher cadmium content in rigid construction materials is allowed when originates from recycling (Regulation 494/2011 of 20 May 2011 of Annex XVII of REACH).

The EU authorities together with the PVC industry certifies that recycling activities will continue sustainable, developing requirements and regulations to support the PVC recyclers.

Every material creates issues, to our health, to the environment, some with more hazards, other with less. All human activities make impact on the environment, the professional designers should choose the most perform material for their projects which make less impact.

According to Vinyl framework, in 2017 the European countries have reached 639.648 tons of PVC waste recycling.

#### **4 PVC sheet piles**

PVC sheet piles is a construction material made of approximately 90% recycled plastics, which comes from construction demolition, like PVC windows and doors, etc.

The combination of different recycled raw materials and manufacturing techniques (co-extrusion), ensures that PVC sheet piles shows significant specifications, like UV- and chemical corrosion resistance.

The high-quality PVC surface layer ensures a high wear resistance and low environmental impact. Thanks to their flexibility and long service life without maintenance or additional corrosion protection, PVC sheet piles are ideal for river, sea and environmental protected area projects. And, after their long service life, PVC sheet piles can be recycled again.

Tests were made, according to the European Union's specifications and regulations, to measure their toxic values on the environmental water around the installed PVC sheet piles, showing no increase of relevant values were to consider.

PVC sheet piles are more production-, logistics-, and assembly friendly thanks to their lightweight construction. Simple and fast installation using standard and non-heavy equipment, which gives a significant CO<sub>2</sub> reduction for the ozone layer. In other words, man need less transport movement as when using steel sheet piles or rock.

It is possible to transport a full truck load with at least 90 pieces of PVC sheet piles, even than the truck total weight is not been reached, that means, due to the lighter weight, the truck with a full load of this plastic material will consume less diesel than a truck which is loaded with only 1/3 of the loading area with steel sheet piles.

Aesthetically, PVC sheet piles also follows the latest fashion styles by supplying natural colours, for example brown, green, sand, light and dark grey, so that the

material feels one within the surrounding nature and people has less problems looking at a sheet pile wall.

Steel sheet piles can also be painted in natural colours, but this must be done every 2nd year. Preparing the steel sheet piles before painting and using paint also creates an attack on our environment. Electricity is needed to grind the sheet pile surface and the old paint dust and particles mixes with the ground top layer or when the sheet pile wall is constructed in water on the water surface. This creates poisoning of everything what is living in the area of the sheet pile wall.

However, PVC sheet piles have some limitations on strength and length, comparing with steel. Anyway this material can be a substitute for many materials on certain applications. This material is ideal to work in rivers or at sea as well as environmental protected areas, due to its flexibility and long service life without maintenance.

The combination of different kind of raw materials, which are provided by recycled resources, together with the co-extrusion manufacturing techniques, ensures to the material features like UV-resistance and resistance against corrosive chemicals. A high-quality PVC surface layer ensures their wear resistance and a low environmental impact.

## **5 PVC sheet piles applications**

### **5.1 Coastal and Fluvial**

- Bank protection
- Coastal defences
- Embankment consolidation
- Protective and hydraulic engineering works
- Construction of retention basins
- River bed consolidation
- Erosion control bulkheads
- Embankment partitioning
- Building of irrigation channels

### **5.2 Prevention of hydrogeological instability**

- Soil conservation works
- Flooding barriers
- Erosion control protection
- River bed protection
- Securing embankments
- Hydraulic barriers against infiltration

### **5.3 Environmental reclamation**

- Reclamation of polluted sites
- Enclosure of polluted areas
- Containment of underground polluted water
- Reclamation of ground and foundations

### **5.4 Construction in urban areas**

- Creation of support walls
- Building and securing natural and artificial reservoirs
- Constructing docks and landing stages
- Securing excavations and landslides
- Containment enclosures and walls
- Creation of green areas
- Artificial lakes on golf courses

## **6 PVC sheet piles cost and efficiency advantages**

Using PVC sheet piles also have significant cost and efficiency advantages comparing to traditional solutions like steel or natural construction materials (stones, rock or wood).

- Cost efficient in comparison to traditional solutions
- Logistics - and assembly - friendly due to lightweight construction
- Simple and fast installation using standard tooling and machinery
- Lower carbon levels during production and transportation
- Exceptional lifetime
- No maintenance
- Ecological
- Non-toxic material to environment
- Impact resistant
- Excellent mechanical performance (Resistant to mechanical damage, including scratches, cracks and abrasions)
- Pollution resistant
- UV resistant
- Corrosion resistant
- Safety on site
- Excellent environmental and aesthetic impact

## 7 Conclusion

All human activities create environmental impacts, in particularly, the construction industry consumes a very high percentage on materials and energy from the natural resources. Professional designers, architects, specifiers and engineers must be well informed about low impact products, sustainable systems and technologies. The selection of those products will make a considerable impact to achieve sustainability.

It is already proved, tested and documented that PVC is a sustainable product, it belongs to the circular economy and reduce the CO<sub>2</sub> emissions. PVC sheet piles can be an alternative for many concrete, steel, rock and wood constructions.

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