

Coursework 1

Plastics in Civil Engineering

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Submitted in part fulfilment for the requirements of the module ‘Materials Engineering’ (ACBA 5005) for the completion of a HND In Civil Engineering at UWTSD.

1.1 Introduction

Plastics are utilised in a variety of applications within the construction industry and as a result this industry has become the second greatest consumer of plastics after the packaging industry (Bpf, 2020). The construction industry consumes on average 23% of all plastic produced (Wrap, 2020) and within the UK the construction the sector produces around 50,000 tonnes of waste each year with 40% of this waste (20,000 tonnes) ending up in landfill (ConstructionMagUK, 2020).

Plastics are highly sought after in the construction industry due to their versatility, durability (including corrosion/rot resistance), strength-weight ratio, low maintenance, cost and are easily transported. Plastics are used in construction for cables, coverings, cables, panels, sheets etc. and are easily formable via extruding, bending, or moulding them depending on needs and requirements. Plastics can also be formed into emulsions by dissolving and/or dispersing them (Plastic in construction, 2020).

Although some of these plastics can be recycled a vast majority of them cannot and these plastics take around 1000 years to decompose (Tapan, 2020). During this period of decomposition there are a variety of environmental concerns due to the addition of chemical additives that make plastics resistant to fire and adhesives, therefore they cause leaching out from landfill as well as microplastics from breaking down being washed into rivers and streams damaging flora and fauna. The construction industry is striving to come up with ways to better utilise this material within the industry and these are explored in detail below.

2.1 Plastics and their properties

As aforementioned above plastics within construction can be used in a variety of forms and applications from windows and door profiles, water-proofing, roofing, soffits, guttering, drainage, irrigation pipes, insulation, sewer pipes and ducts, decorative laminates etc. Among these there are three main types of plastics Thermoplastics, Thermosetting Plastics and Elastomeric Plastics.

Table 1 below shows a very general classification of plastic polymers and a small number of materials that are produced from each of them.

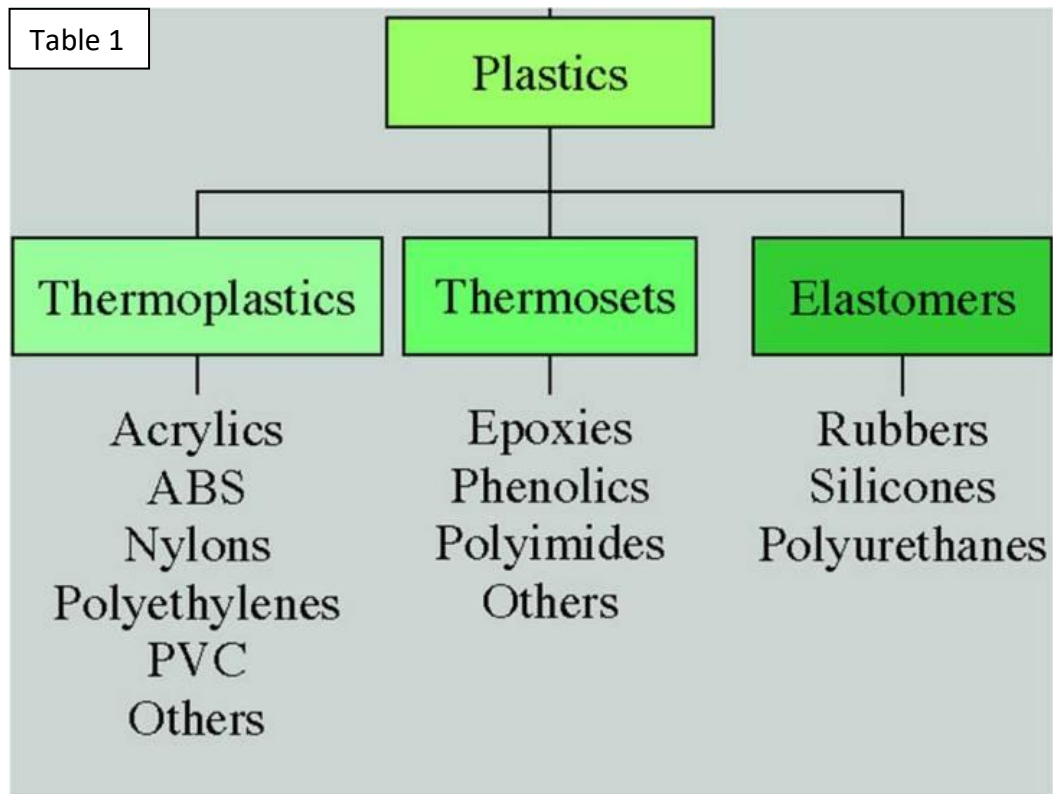


Table 1 – Classification of Plastic Polymers (<http://frontdesk.co.in/construction-materials/plastics/>)

2.2. Thermoplastics

Thermoplastics as defined by Baeurle, Hotta and Gusev (2006) are plastic polymers that when temperature becomes elevated can be softened and reformed and solidifies when cooled. These plastics can be recast and melted almost indefinitely, however when subject to freezing temperatures can become brittle and susceptible to fracturing (Thermoplastics :: PlasticsEurope, 2020) Due to its composition these thermoplastics are theoretically ‘mechanically recyclable’ as the long polymers are held together by moderately weak bonds (How Plastics Are Made, 2020). Most thermoplastics are produced via chain polymerization.

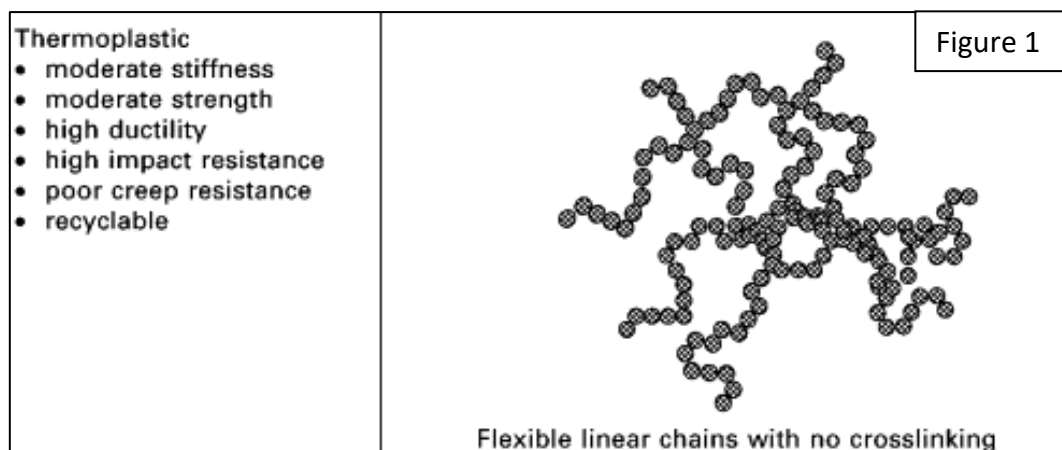


Figure 1 – Properties and molecular structure of thermoplastics. (Mouritz, 2012)

Figure 1 a shows the molecular structure and properties of thermoplastics (Mouritz, 2012) they are defined by having the following properties; moderate stiffness, moderate strength, high ductility, high impact resistance, poor creep resistance and are recyclable. Poor creep resistance (brittleness) can be decreased by adding plasticizers, a common example of using these plasticizers is within PVC plastic (polyvinyl chloride) which is hard and brittle to help it become ‘softer’ and more ‘pliable’.

Common thermoplastics are polyolefins (polythene, polypropylene, polybutylene), acrylics, polycarbonates, polyamides (Nylons), vinyl’s (PVC, PVCU etc).

The list below indicates the uses of thermoplastics within the construction industry:

- Construction of pipes, rebars and lightweight structures
- Storage Tanks
- Window/door panels, bathtubs, sinks, shower stalls
- Aircraft manufacturers use thermoplastic composite materials due it being a tough and durable structural material (Thermoplastic Composites in Construction - Types, Properties, Uses, 2020)
- Thermal insulation i.e. temporary shelters
- Floors and tiles

2.3 Thermosetting Plastics

Thermosetting plastics also commonly known as ‘thermosets’ differ from thermoplastics in a number of ways. Thermosets are typically made from larger polymer chains (Woodford,2019) that when manufactured form strong bonds between the molecules meaning that once heated form a hard and dense structure (Romeorim.com,2020) These thermosets once cured are unbreakable compared to that of thermoplastics that can be remoulded or reformed due to weak bonds between the molecules.

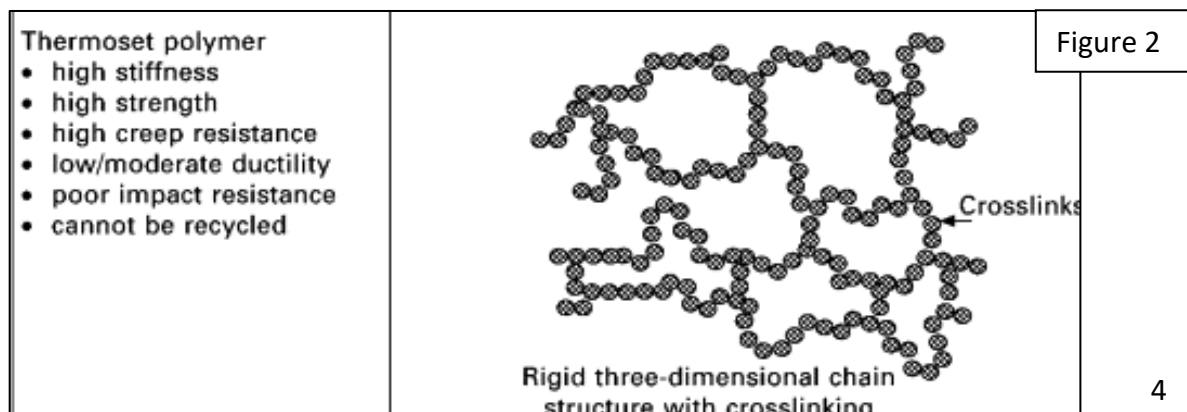


Figure 2 – Properties and molecular structure of thermosetting plastics (Thermosets). (Mouritz, 2012)

Figure 2 above shows the general properties and molecular structure of thermoset polymers with strong rigid three-dimensional chain structure with cross-linking indicating a tough and resistant structure that occurs after polymerisation. It has high strength, high stiffness, high creep resistance (resistant to frost), low ductility, poor impact resistance and cannot be recycled.

These thermosets have a variety of advantages; low density, low life-cycle costs, outstanding thermal and electrical insulation as well as a reduced oxidation and degradation and given the right conditions can have a long service life (Song and Gupta, 2012).

Common thermosetting plastics include that of polyurethanes used in mattresses, cushions, and insulation within the construction industry for buildings (Woodford, 2019) example is polytetrafluoroethylene (PTFE) used for non-stick coatings on pans and pots. Epoxies such as adhesive glues, coating for electrical devices such as light switches as well as helicopter blades (How Plastics Are Made, 2020). Another thermoset that can be used in electrical appliances, circuit boards and switches is that of 'Phenol Formaldehyde' and when these are exposed to burning/heat they will not collapse like thermoplastics, they will in fact remain solid and slowly disintegrate, blacken and give off a bad smell ('phenol' or 'urea' i.e. smelly). The most used applications within construction of thermosets include adhesives, sealants, thermal insulation, piping, roofing, bridge structures and civil structures repair (Song and Gupta, 2012).

2.4 Elastomeric Plastics

Elastomeric plastics also commonly known as 'elastomers' are special polymers that have high elasticity. These elastomers can be stretched to several times their nominal length and will return to their original shape after stress is released (Rodriguez, Mathias, Kroschwitz and Carraher, 1988). Figure 3 shows the properties and molecular structure of elastomeric plastics.

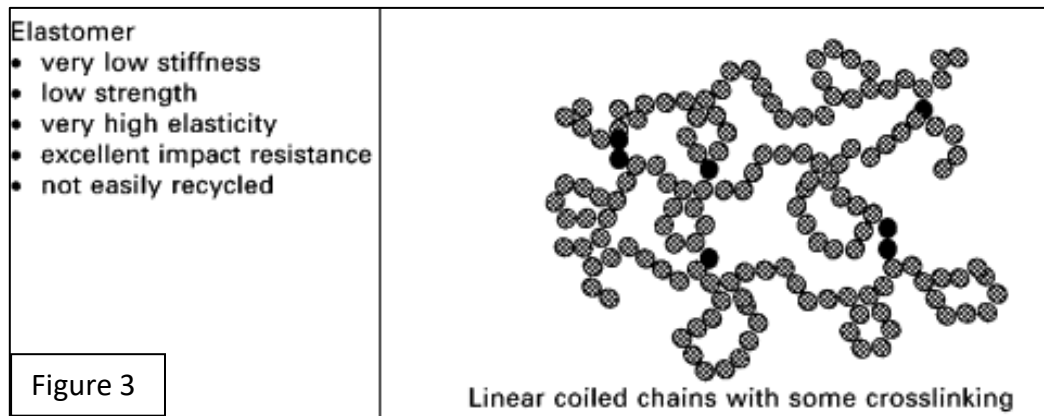


Figure 3 – Properties and molecular structure of elastomeric plastics (Elastomers). (Mouritz, 2012)

Elastomers are linear coiled chains with some crosslinking but have low density ((Rodriguez, Mathias, Kroschwitz and Carraher, 1988). They have very low stiffnesses, low strength, high elasticity as mentioned previously, excellent impact resistance however are not easily recycled. TPE's (Thermoplastic Elastomers) however can be readily recycled (Fazli and Rodrigue, 2020). White and De (2001) define thermoplastics as having very weak intermolecular forces with a relatively high failure strain, but a low 'Young's Modulus'.

A few examples of elastomers are rubber, neoprene, EPDM (Ethylene Propylene) and butyl rubber. The civil engineers benefit from elastomers by utilising them in bearings, expansion joints, sealing joints, bridge deck waterproofing and anti-seismic devices (Fragnet, 2013).

3.1 Plastic Road Construction

MacRebur has become a pioneer for using plastic waste materials within the design and application of road construction within the UK. This technology received a £1.6 million trial in January 2019 from the Department for Transport (DofT) to trial their product (www.dng24.co.uk, 2020) This method of resurfacing incorporates the introduction of 'plastic pellets'.

As of November 2020 MacRebur has three products that consist of 100% waste plastic MR6, MR8 and MR10 all of which have benefits depending on the purpose. Table 1 indicates the areas in which these products are most suited.

Table 1

MacRebur Product	Details
MR6	MR6 is a complex arrangement of polymers designed for the extension and enhancement of bituminous binder for asphalt used in road surfaces. Ideally suited to surfacing intersections, roundabouts and slow moving, heavy vehicle areas, where deformation resistance is critical.
MR8	MR8 is a blend of polymers designed for the extension of bituminous binder for asphalt used in road surfaces. Ideally suited to surfacing car parks, driveways and local roads, where sustainability and economics are the primary drivers.
MR10	MR10 contains a block co-polymer designed for the extension and enhancement of bituminous binder for asphalt used in road surfaces. Ideally suited to surfacing general trunk roads where stiffness and crack resistance is critical.

MacRebur (macrebur.com, 2020) products are used as binder enhancers so that there is a reduction of bitumen usage within the asphalt mixture, not only does it reduce the amount of plastic that reaches landfill but replaces the oil based bitumen meaning that 1 tonne of bitumen that is replaced means 1 tonnes of carbon emissions that are also saved (bbc.co.uk, 2020).

MacRebur's product consists of a select mixture of polymers that have been specifically designed and tested and so that they are comparable to that of 'normal' bitumen-based asphalts. MacRebur states that they are designed so that they improve the overall strength and durability of asphalts, are deformation/fracture/moisture damage resistant and do not leach or contain microplastics (macrebur.com, 2020).

Cumbria council was the first within the UK to utilise these new asphalt enhancement products from the DofT grant and since this time other local authorities have jumped on board with this new technology in areas such as Gloucester, Birmingham, Buckinghamshire, Kent, Bedford, Reading, Suffolk etc. (Landi and Bosley, 2020)

In September 2017 MacRebur carried out surfacing on the A7 in Carlisle for Cumbria CC, they wanted to find and deliver a longer lasting, more durable and suited surface course due to the traffic volumes carried between Carlisle and the M6 Motorway. The project included the resurfacing 625 tonnes of binder AC20 HDM (High Density Macadam) and 600 tonnes of 35/14 HRA (Hot Rolled Asphalt) with pre coated chippings, MacRebur offered the client a range of bitumen replacement products that matched those of a PMB (polymer modified bitumen), they opted to supply their MR6 product that would improve overall tensile strength and rutting within the asphalt. As a result the client was able to replace 6% of traditional 50pen binder in both of the HRA and AC mixes allowing for a more environmentally friendly installation whilst delivering the same performance (macrebur.com, 2020). The final product can be seen in figures 5 and 6.



Figure 5 & 6 – Photos of the A7 in Carlisle of newly laid asphalt that incorporates MacReburs MR6 product.

Other companies are now jumping on board with the use of recycled plastic for roads either as a replacement, aggregate/bitumen extender and/or modifier (White and Reid, 2019) India are using 7% less bitumen usage by dry-mixing and shredding recycled plastic into their asphalt mixes (Indiatimes, 2020). Australia since 2018 have also been trialling three different recycled plastic products in Adelaide (adelaidenow, 2020), Melbourne (Victoria Bag Ban, 2020) and Sydney (Topsfield, 2020).

KWS, Wavin and Total have come together to work on Plastic Road construction in Rotterdam, Netherlands, they have successfully produced and implemented a plan to produce plastic segments of road from recycled plastic for road construction. In 2018 PlasticRoadEu and their partners produced a bike path of 30 meters (PlasticRoad, 2020). Figure 7 (PlasticRoad, 2020) shows an idealised example of how the plastic road will be installed, It features prefabricated sections that have hollow sections

beneath the surface that can be used for utilities, water storage/drainage, pipes etc. through this method if a section becomes damaged or reaches the end of its life cycle it can simply be replaced as a section rather than ‘planing out’ the whole road.

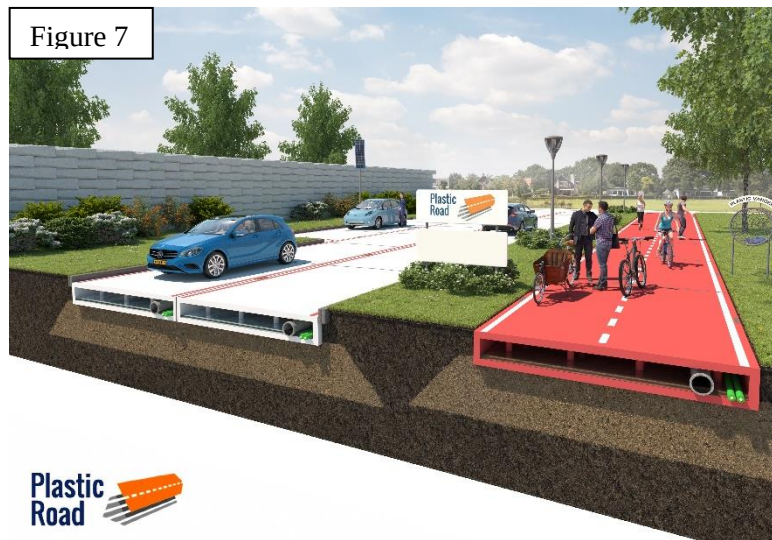


Figure 7 – Idealised PlasticRoadEu design and implementation (PlasticRoad. 2020).

4.1 Materials practicality, functionality, and future potential

Plastic waste as a product for road constructions is a relatively new concept, with companies around the world including the UK, Netherlands, India, America, and Australia leading in road constructions using non-recyclable plastics. Companies such as MacRebur & PlasticRoadEU have seen some relative success within the industry although there is still some questions of the overall practicality and future potential of these new products both positive and negative.

MacRebur have seen positive results using around 5-10% (Sasidharan, Eskandari Torbaghan, & Burrow, 2019) by weight of plastic that becomes incorporated as part of the bituminous mix instead of oils will help increase the overall strength, durability and structure of the road (macrebur.com).

NPT Council (Workplace), contacted MacRebur in 2017 to get an understanding of the product for use on their network. NPT queried regarding early life skid resistance and the potential to incorporate it within micro-asphalts, David Wykes (MacRebur) informed NPT that there is no noticeable change of early skid life resistance, he also stated that there is significant difficulty incorporating their products within micro-asphalts due to the inability to break down the pellets leading to clumps of plastic left within the final product. Therefore, meaning that this product is currently limited to only bituminous products. If MacRebur were to continue with developing the product they may be able to

introduce these plastics into thermoplastic screeds for potholes, as microasphalt systems and surface dressing treatments alike.

PlasticRoadEu's product is advancing in the Netherlands where they are installing on bike paths. The road has a hollow space built in to allow ease of wiring and pipes for utilities (PlasticRoad. 2020) maintenance of these products is definitely an issue, in theory the pipes would be difficult to isolate and carrying out repairs would mean cutting out large sections of plastic that would compromise the structure and therefore the whole 'section' of this part of the road. If it were to be replaced rather than using isolated patching it would cause traffic management issues, time delays and costs to the client. Ideally the bike-path/road should have little to no utilities running through it in order to maximise its lifespan.

The main advantage of plastic roads is that they can be built from waste that would typically end up in landfill and pollute the environment through leaching (Cho, 2020). Another positive is roads can be engineered with the plastic to meet specific requirements i.e. products such as MR6, MR8 and MR10 for weather/wear/rutt resistance etc. The client will benefit from plastic waste as a cheaper alternative to petroleum which is becoming ever scarcer. Due to plastic-bitumen roads utilising a variety of plastic types, segregation of these plastics is not needed and therefore a quick alternative for using these non-recyclable plastics (Cho, 2020) Plastic roads will also typically have better flexibility than normal Asphaltic Concrete roads where the addition of fibres is used to increase strength and rut resistance and need for repair, plastic products can be used to produce similar results.

There are also a number of disadvantages to these products, the first of which being contractors that use these products such as those supplied from MacRebur may not have the ability to run their product through their plant so advancements may have to be made to ensure that all plastic products can be incorporated effectively into mixes. When plastics melt it compromises the overall asphalt and leads to premature failures causing skid resistance/structural issues. Mentioned previously PlasticRoadEU's product when maintenance occurs on the networks all connections that lie within the road will be interrupted for the duration of the works which could be hours, days or even weeks.

There are concerns regarding health and environmental hazards; microplastics within the road can break down and wash into bodies of water and soils causing contamination. White (2019) reported however that toxic fume generation and leachates from plastic road constructions were negligible and did not have any overall adverse effects on the environment (White and Reid, 2019) Training of staff may be an issue as awareness of plastic waste management in road construction is currently limited. Combined with this regulatory framework will also have to be drafted to ensure that they are HAPAS approved (HAPAS, 2020) and meet certain standards. Improvements in all of these areas will have to be made if they are to become a fully viable, there is a positive future for plastic roads as a whole if the engineering continues to progress, which inevitably will be the case due to continued topical

global warming issues leading to the increase of government funding. Other methods that utilise plastic waste include Nappy Roofing from Canadian company Knowaste that turn nappies into rooftiles saving up to 110,000 tonnes of CO2 emissions into the atmosphere each year (skynews, 2020) Bath University have also looked at 'Plastic Concretes' where they have discovered that 10% of sand that is used within concrete can be replaced with plastic without compromising the overall durability of the concrete (Bath.ac.uk. 2020).

5.1 Conclusion

Plastic production is increasing day by day the need for alternative solutions to the waste is becoming an ever-increasing issue globally. By incorporating plastic waste into roads is one of the best methods for the disposal of waste plastics as the vast majority is not recyclable using them in this fashion will have a positive impact on the amount of this waste disposed and accomplishes it in an eco-friendly method. The use of these new techniques in companies such as MacRebur and PlasticRoadEU etc. will help countries reach recycling targets and aid in reduced emissions and damage to the environment. However, although recent plastic road constructions have shown positive outcomes in pavement performance the technology is still very young and long-term outcomes after the roads life cycle still begs a few questions like 'where does the plastic used initially in these roads end up then?' and 'How does maintenance of these road constructions work?' etc. The future however is positive and hopefully with continued support in this industry plastic waste as a construction material will increase for not only roads but other construction industries too.

Word Count : 2742

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