Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

Review on Utilization of Waste plastic in Civil Engineering Construction Projects

Aman Thakur
Department of Civil Engineering
Guru Nanak Dev Engineering College
Ludhiana, India

Agamjot Singh
Department of Civil Engineering
Guru Nanak Dev Engineering College
Ludhiana, India

Abstract— **Plastic material is consistently used worldwide without even thinking about the impact on sustainable development; this type of utilization makes it possible to attain the hazardous phase of life. The emerging plastic waste is a major challenge to the environment. The use of plastic waste in civil engineering construction projects needs special attention to tackle this problem and enhance the project's economic aspects. The reduction of plastic waste is an urgent need. Plastic waste has been used in various forms. Plastic waste is used as aggregate in the concrete; it acts as a binding material in floor tiles. This use helps decrease the amount of waste material and enhances the construction material's properties. The main contribution of this work lies in a study of using plastic waste in civil engineering construction projects. This study helps to use plastic waste in different construction materials like concrete, floor tiles. In Europe, nine countries have recovered more than 95 percent of de-inked plastic waste. From 2009 to 2014, the amount of garbage produced increased by around 1.7 million. In the period under study, waste volumes have reduced by 4.9 million tons in the last eight years, while recovery volumes have increased by 6.2 million tons. As per comfort and progression in innovative work, the creation of plastic heightens disregarding the "Guideline of Sustainable Development," and the tremendous measure of waste unloaded in the sea and landfill Formation of plastic ordinarily prompts extra adaptability and mechanical property.**

The biodegradation of waste plastics is acquiring fame since it can decrease contamination. Landfilling, burning, reusing, and change into vaporous and fluid fills are strategies used to deal with squander plastic.

Keywords— plastic waste, plastic tiles, recycled plastic aggregates, solid waste management

I. INTRODUCTION

An increase in urbanization and the need for economic benefits has led to a drastic rise in waste plastics. This waste plastic is either send to the oceans, which deteriorates the aquatic life. Disposed to landfills that decrease the quality of soils and release the foul smells or burnt in the incinerators, which depletes the atmospheric air at a large scale [1] In day-to-day life, the demand for plastic is increasing. But with the expanding market, the management of plastic waste is far behind. Plastics are used in different ways like shopping bags, toothpaste, books cover, packaging covers. Life without plastic nowadays is complicated as plastic has made a vast part of one's life. Polyethylene (P.E.), polypropylene (P.P.), polyvinyl chloride (PVC), polystyrene (P.S.), polyurethane (PUR), and polyethylene terephthalate (PET) are six different types of plastics that are widely used in the markets to fulfil the daily needs. [2]

Fig. 1. Classification of plastic

To reduce the amount of waste plastic, plastics in the construction industry is a great effort. Many efforts are going on to use the plastic wastes in construction in either way. Plastic material can be used instead of aggregates in concrete, used in the pavement, airports, and roads. In the case of plastic tiles, cement is entirely replaced by plastics. Plastic is used as a binding material instead of glue. [3]

Plastics are not interested defined by their composition, but by, more specifically, their mouldable ability defines them.

Thermosetting: plastic that cannot be remoulded and reprocessed after first use. This plastic attains a glassy state by lowering the temperature below the glass transition temperature (Ta) and brittle material. Still, once the temperature exceeds "Ta," brittle plastic becomes elastic.

Thermosetting plastic can be used as a replacement for the fine sand. Compression Strength and shear strength decrease while the ductility increases with increases in waste plastic. Concrete production with thermosetting helps the traditional concrete attain rigid and strong molecular bonds due to cross-link polymer. Overall better mechanical property is appropriate for the construction industry.[4]

Plastic material is consistently used worldwide without even thinking about the impact on sustainable development; this type of utilization makes it possible to attain the hazardous phase of life. Polyethylene terephthalate is used on a large scale to pack food items and contributes a significant role in plastic pollution for the ecosystem. The recycling pace of plastic is much slower than the production rate of virgin plastic.[5]

Reduction in the use of plastic and making an effort by using technology to re-use plastic can significantly manage the waste plastic.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

Building a house by plastic jugs utilized for the dividers, joist roof, and substantial segment offers us 45% lessening in the last expense. The molecular structure has a significant impact on the thermal characteristics of thermoplastics. Glass transition, crystallite melting, and heat breakdown of macromolecular chains are examples of thermoplastic resin phase transitions. Specific volume, heat capacity, heat conduction, and thermal conduction are examples of physical qualities influenced by the temperature of the material.

Researchers at the University of California found a new way to decompose polymethyl acrylamide (PMMA) in PVC. The process is similar to that used in paper and plastic bottles, among other materials

Their molecular structure influences the thermal properties of thermoplastics. Thermoplastic resin phase transitions include glass transition, crystallite melting, and heat breakdown of macromolecular chains. Physical properties impacted by the temperature of the material have specific volume, heat capacity, heat conduction, and thermal conduction. The University of California discovered [6] a new approach to break down polymethyl acrylamide (PMMA) in polyvinyl chloride (PVC). The method is comparable to that used in paper and plastic bottles, among other things.

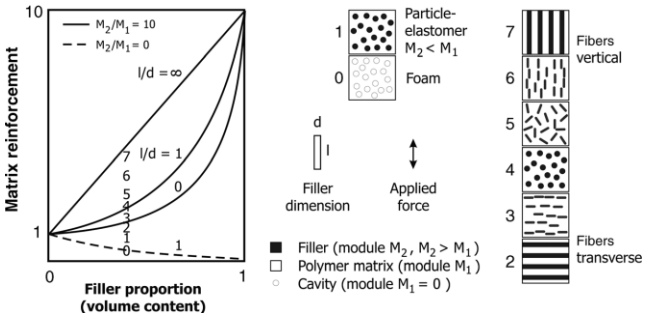

Fig. 2. Dependence of the reinforcement on the type and structure of the filler material.[6]

II. PRODUCTION OF PLASTIC TILES`

Plastic tiles are made using sand and plastic waste. In the case of sand, well-graded sand free from any organic material should be used. And waste plastic mainly contains polypropylene which is found significant in plastic chairs. The first part of the production is that the waste plastic is cut and crushed into small pieces and then melted at around 150 to 170 ° C. When the waste is melted, sand is added into the same container. Then both the plastic waste and sand are stirred continuously. Sand should be added to waste plastic in small quantities. Once the mixture becomes homogenous, poured that material into the mould of a definite size, say 30 x 30 x 2.5 cm. The mould prior should be oiled for no obstructions in demoulding. Once the mixture cools down and becomes stiff, demould it by air cooling or putting it into the water.[7]

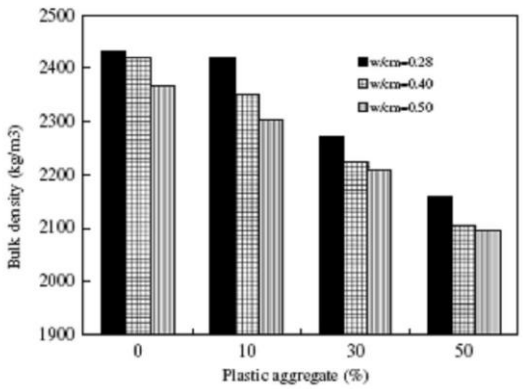

Fig. 3. Bulk Density Vs Plastic Aggregate [3]

LDPE (low-density polyethylene) is a thermoplastic made from monomer ethylene. It is widely used in day-to-day life due to its versatile nature. After the usage, these LDPE-made materials are dumped in landfills which leads to pollution. The use of recyclable LDPE plastic waste in tiles is a solution to reduce the pollution caused by LDPE plastic. Moreover, thermoplastics have low melting points and can be recycled or deformed by heat, whereas thermosetting plastics have very high melting points that cannot be remoulded easily. In daily use, thermoplastics consists of 80% of plastics whereas thermosetting plastics 20%.

The two cases are compared below. In the first case, the material used was packaging plastic with LDPE written on it. The plastic weight was separated manually with any unwanted substances like paper, wooden pieces. The plastic waste was divided into small parts with scissors.[[8], [9], [10]] In the other case, LDPE plastics were taken from the dumpsite, which consists of plastic bottles, food bags. Then the plastic was sorted and washed with soap.[[11], [8]] The shredded pieces of plastics were added to the mould. The source of heating was the electric heater. After the plastic becomes soft enough to become deformable, it is structured into the required shape[11]. In the other case, the LDPE plastic was added to the mould with sand in the ratio of 1:1, 1:2, 1:3 and 1:4. Then LDPE was heated at 160 degrees Celsius until the slurry was formed, and then sand was added [12]. The sample of the homogeneous mixture was allowed to cool for 24 hours.[8] In the first case, a compression test was done according to the ASTM D 695- 2015, and the result came out was 17.26 MPa[11]. In the other case, there were different compressive strengths for different ratios of plastic and sand. And the ultimate compressive strength comes out was 1.787 N/mm2 at 1: 3 (plastic to sand).[8] Therefore, we can find that the LDPE can be used in manufacturing tiles. Many properties of LDPE were better than conventional tiles. So, it can replace the traditional tiles in the coming years.

In the other case, the material used is three plastic waste types (plastic bottles, water sachets and water bags), electric furnaces and moulds.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

TABLE I. **PROPERTIES OF PLASTIC TILES FOR ALUMINIUM AND PLASTIC CASES**

(A) WATER ABSORPTION FOR THE PLASTIC

Sno.	***Property***	***Test result for different percentage of waste plastic***				***Normal Cement tiles***
1.	Water absorption	30%	40%	50%	60%	9.5
		3.8	3.5	2.34	1.01	

(B) WATER ABSORPTION FOR THE ALUMINIUM TILE

Sno.	***Property***	***Aluminium tile***	***Water sachets***	***Water bags***	***Water bottles***	***Polythene bags***
1.	Water absorption	NILL	3	2.67	2.81	2.62

The procedure, in this case, involves different steps. Firstly, plastic was collected, and all unwanted materials like bottle caps, skin were removed. Then waste plastic materials were chopped into small pieces. After removing the unwanted things in the plastic, the plastic waste was washed out. Then all the plastic waste was put into the pot and then melted at different temperatures like 170°, 155°, 120° and 60°C. After thawing, the pouring of molten plastic into moulds includes an uncontrolled and controlled cooling method. In the wild cooling method, the molten plastic was allowed to cool at room temperature. Still, in the controlled mode, molten plastic was poured into the forms and then pressed and covered with the thick metal sheet to delay the thermal equilibrium.[13]

In the first case, the test on water absorption was done according to the Indian standards, but in the second case, the water absorption test was carried out using ASTM D570. Regular cement tiles used commonly in India have high water absorption capacity, which deteriorates the strength property, and in aluminum tiles, there is no water absorption. But in the case of plastic tiles, there is low water absorption capacity, which makes it optimum for use in the case where much standing water.

The transverse strength increases when plastic waste increases and performs better than standard tiles when the waste plastic is 60 percent. In other cases, the power of plastic tiles without sand in between is significantly less than the aluminum tiles.

TABLE II. **TRANSVERSE STRENGTH** [9]

Sno.	***Property***	***Test result for different percentage of waste plastic***				***Normal Cement tiles***
1.	Transverse Strength (MPa)	30%	40%	50%	60%	22.75
		10.8	13.74	20.80	26.29	

Sno.	**Property**	**Aluminium tile**	Water sachets	Water bags	Water bottles	Polythene bag
1.	Transverse Strength (MPa)	27.5	6.286	6.112	4.720	5.113

III. PLASTIC RECYCLING

Historically, recycling in the polymers market was handled as part of the routine production process within manufacturing businesses. For example, in extrusion, material and heat are frequently combined. In-house scrap will be treated if contamination limits are allowed to improve final material manufacturing with virgin material generates Commercial and post-consumer plastic garbage is accumulating to the landfill.

Thermoplastic can be reprocessed by remelting and solidifying the required temperature without initially decomposing. Still, the thermosetting cannot be reutilized as this type of plastic possess cross-link during the process.

In Europe, nine countries have recovered more than 95 percent of de-inked plastic waste. There is a landfill ban in these nations. In addition, six of these countries are among the 11 with the most significant recycling rates (>30%).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

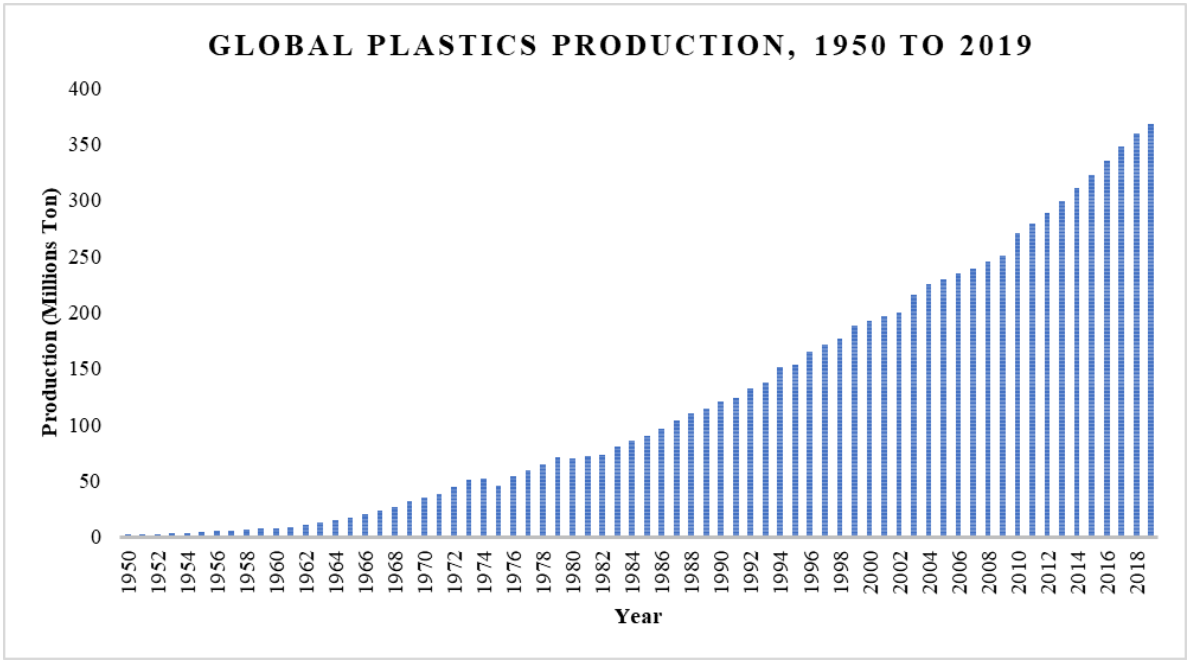

Fig. 4. Annual global polymer resin and per production (plastic production), measured in metric tonnes per year.

As a result, "divert from landfill" promotes higher recovery and recycling rates, including for waste streams that have not yet been recovered. The assessment of filth generation from 2006 to 2014 reveals a modest increase. Plastic parts with lower weight (e.g., plastic bottles) play a significant role in this process, in addition to economic implications. From 2009 to 2014, the amount of waste produced increased by around 1.7 million. In the period under study, waste volumes have reduced by 4.9 million tons in the last eight years, while recovery volumes have increased by 6.2 million tons. Up to 17.9 million tons.

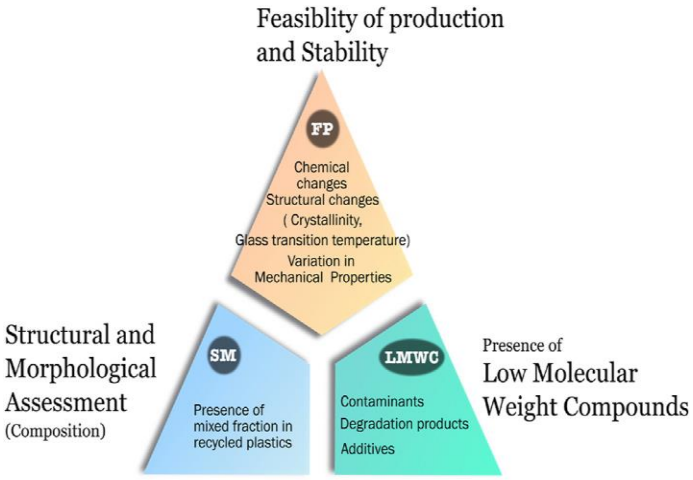

Fig. 5. The technical framework for quality assessment of recycled plastics. Adapted from [[14], [15], [16]]

IV. Sustainable Development

Without comprising future resources to develop bottles, the house is the new and trending topic among researchers and environmental activists. Generally, bottle house is based on the bioclimate design principle, which attains theta in required ambient temperature surrounding by replacing traditional tin bricks. By doing so, the manufacturing of cement gets decreases, and CO2 emission significantly comes down. [2]

The significant polymers are standard plastics. Polyolefins are the most widely recognized item classification. 34% polyethylene Polypropylene represents 24% of the aggregate. Designing Plastics is a small yet significant section of the market. Elite Polymers are intended to meet the most arduous prerequisites. Weight-wise, standard plastics rule the worldwide market. Designing plastics represents roughly 10% of all plastics devoured around the world. Asia represents more than 49% of global creation, with China driving the way (28%). Europe and NAFTA are relative, with each having a portion of around 18-19%. Surprisingly fast, China has ascended to turn into the world's biggest maker of plastics. Any remaining locales saw a diminishing in their worldwide creation share. In 2015, worldwide plastic creation expanded by 3.4 percent more than in 2014. Polyolefins represent a more significant part of the overall interest in plastics materials. After polyolefins, PVC is the second most normal tar type. Standard plastics (Polyolefins, PVC, P.S. and EPS, PET) represent around 85% off by considerable interest.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

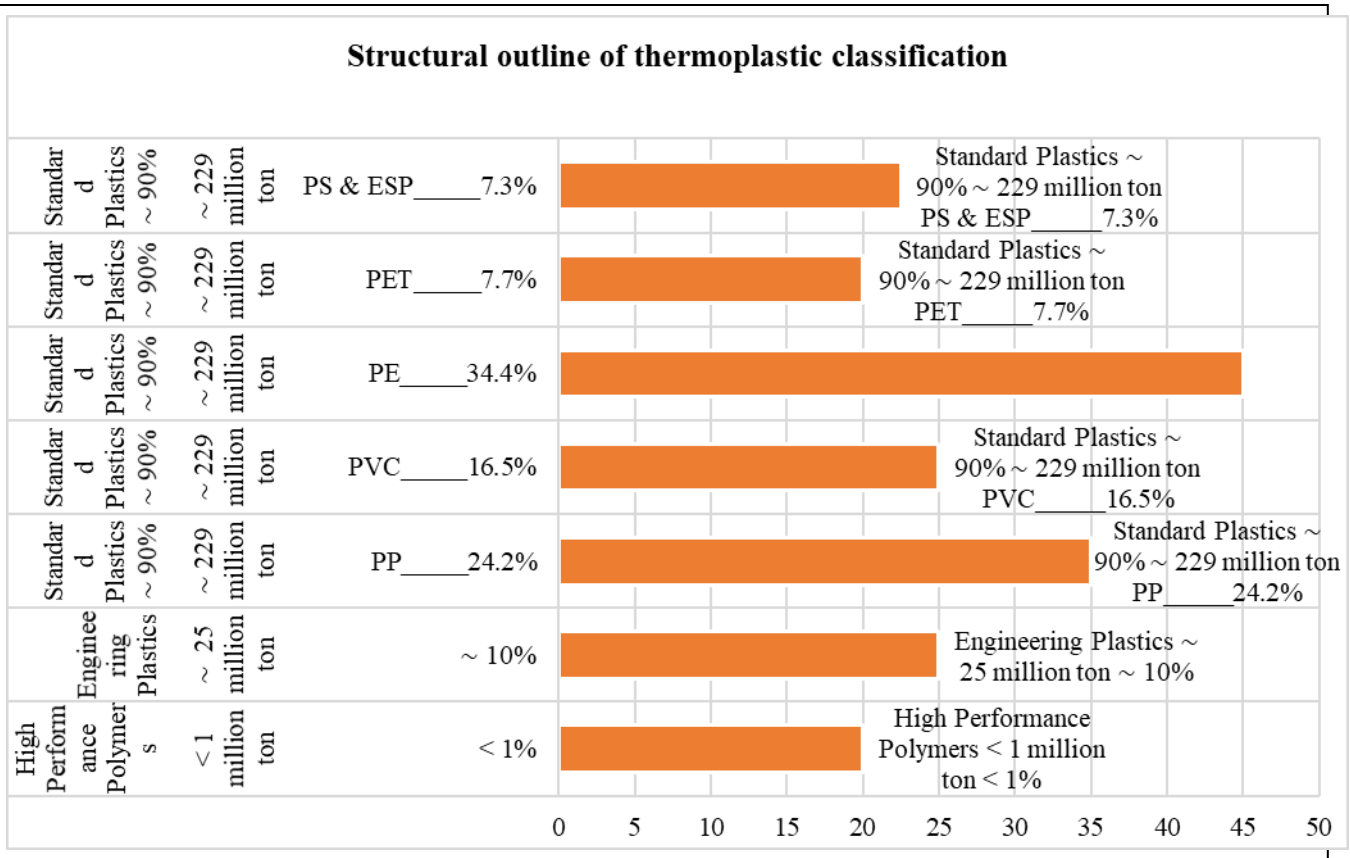

Fig.6. Thermoplastic market share 2015 (**Source: PlasticsEuropeMarket Research Group (PEMRG) / Consultic Marketing & Industrieberatung GmbH)**

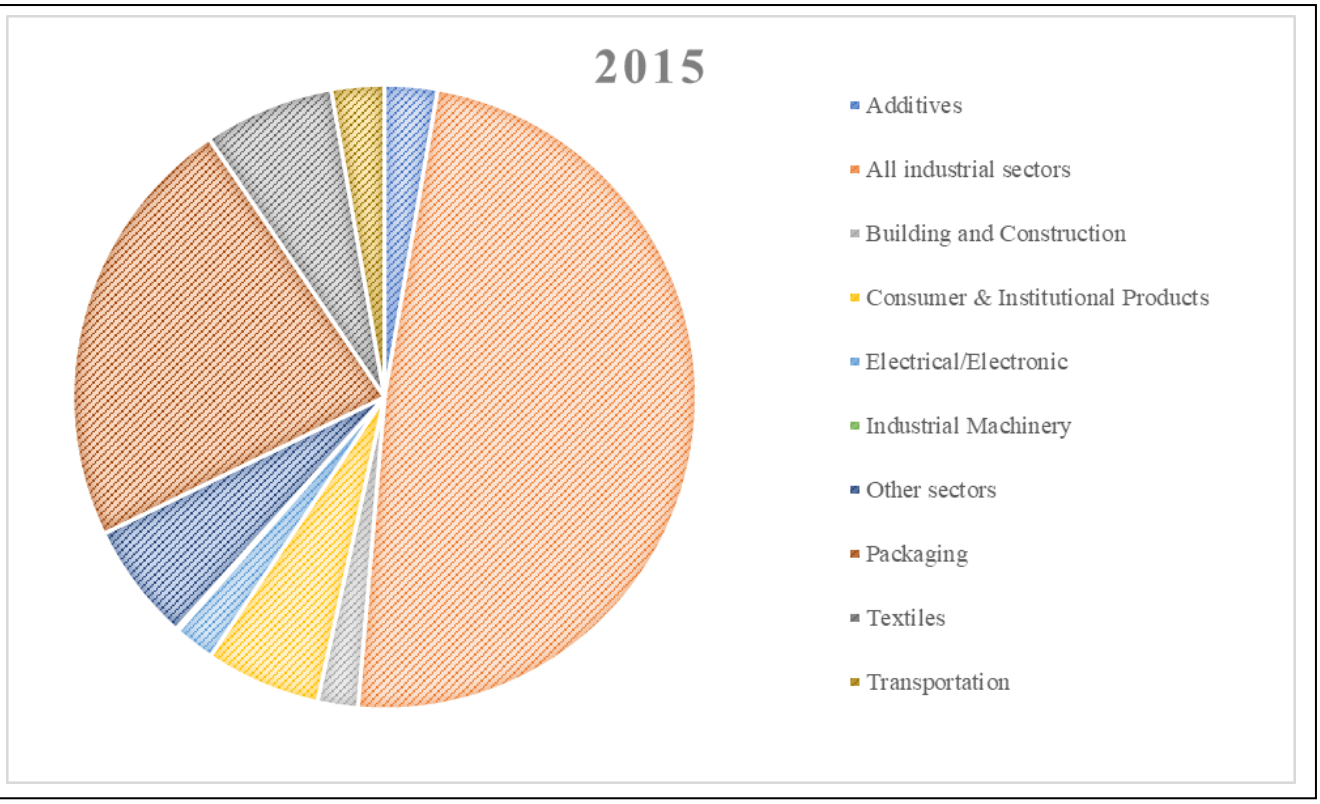

Fig.7. Plastic waste by sector [17]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

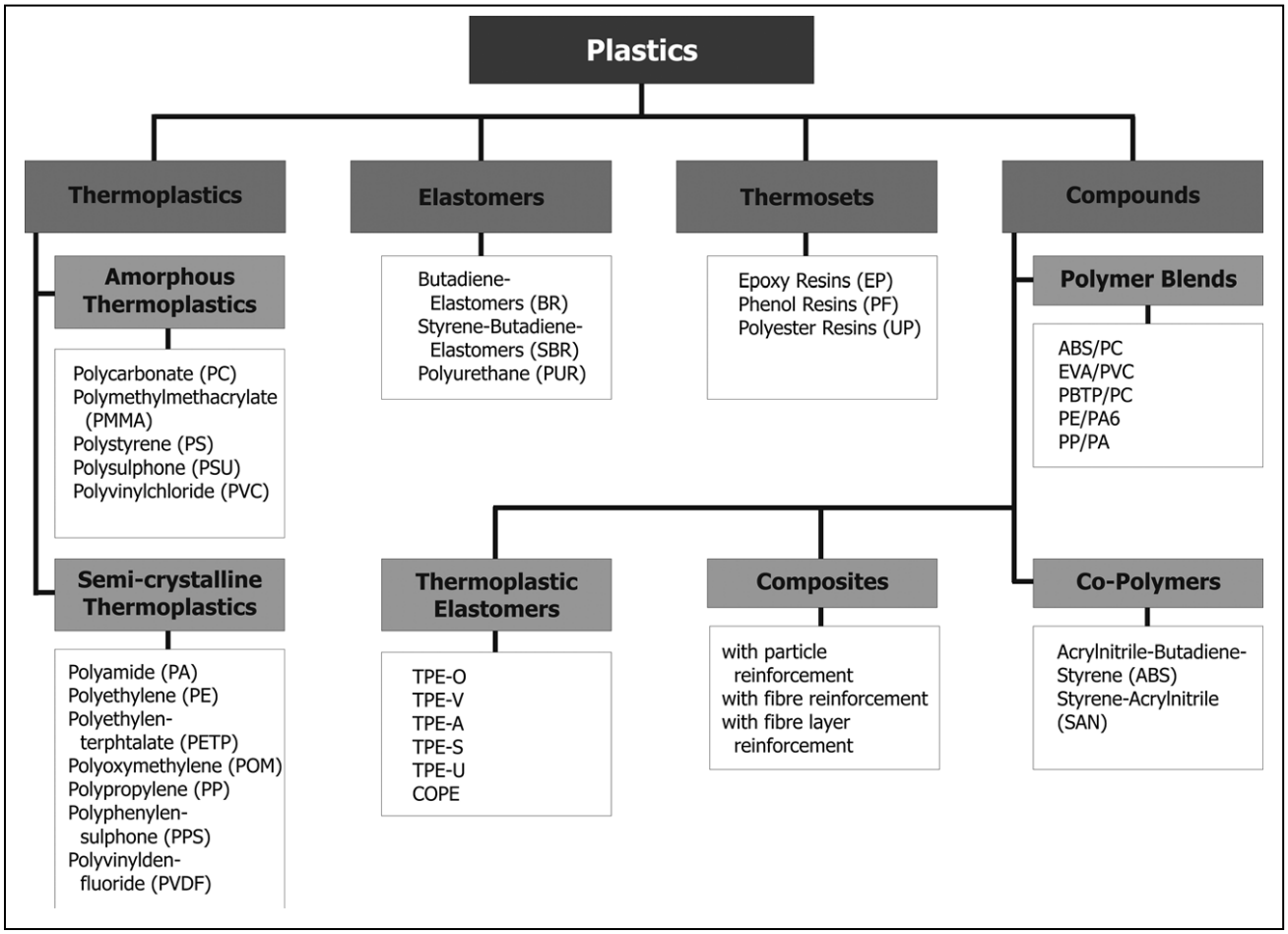

Fig.8. Classification of plastics. [6]

V. Result and Discussion

Oluwarotimi et al. [18] concluded using HIPS and LDPE to replace fine aggregate in concrete to attain $2*10^4$ kN/m^2 of strength and found a significant decrement in the density and workability of concrete. There might be chances to gain desired power with a combination of LDPE and HIPS. After a particular point, there is a severe decrement in strength and other reasonable properties.

The replacement of traditional binding material with waste plastic and quarry dust proves problematic investment in heat impedance equally reflexes in load-bearing.[19]

P. Ganesh Prabhu: PET perhaps considered as nigh grievous thermoplastic in the polyester clan. [20]

Humans have used natural polymers for a long time, and production is continuously increasing by rapid demand in various industries. According to convenience and advancement in research and development, the production of plastic escalate without considering the "Principle of Sustainable Development," and the enormous amount of waste dumped in ocean and landfill Formation of plastic usually leads to additional flexibility and mechanical property. Plastic that posses higher flexibility and durability serves more and is recycled more than once.

The shares of plastic induce direct impact by contributing to waste generation. Engineering plastic utilization is comparatively less and produces less toxic to the environment. Plastic manufacturing reached 299 million tonnes in 2013, up 3.9 percent from the previous year [21]. In 2014, global plastics output surpassed 300 million metric tonnes for the first time. Glucose bottles, I.V. sets, disposable syringes, disposable needle sets, cannulas, catheters, and other plastic waste products are produced daily. Packaging, construction, electronics, electrical products, furniture, vehicles, homes, agriculture, and other industrial applications are among the most prevalent uses of plastics. The characteristics of plastic determine its applicability in medical equipment, from the prosthesis to blood bags. Plastics may also be beneficial to the environment and health perspective.

The handling of plastic trash is a serious environmental issue. Plastics in the environment have a long history of being slow to degrade and highly stable. Plastic waste management issues [22] have arisen due to the widespread use of plastics in agriculture, industry, transportation, and packaging in recent decades.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

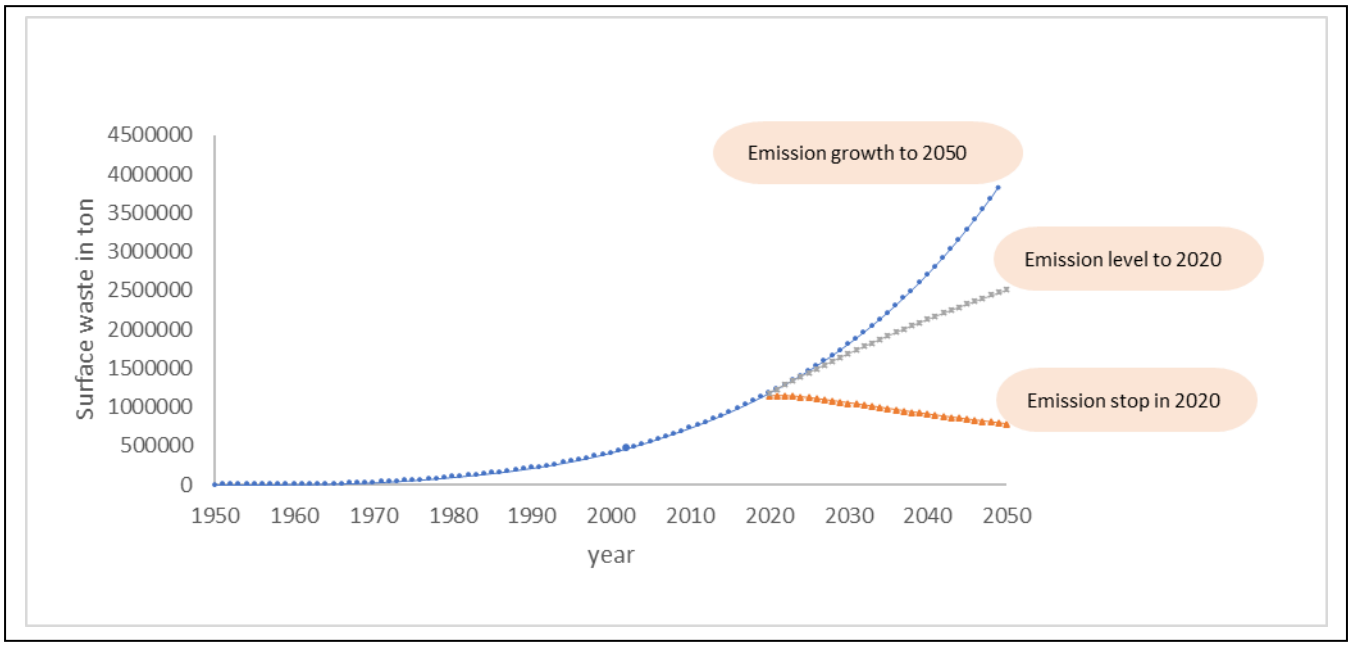

Fig.9. Macro-plastic in the ocean [23] Bulk Density Vs Plastic Aggregate [3]

Toxic components, such as DEHP and BPA, [24] are dangerous in plastics, putting humans at risk. The plastics sector is critical for foreign exchange earnings; however, wastewater effluent discharge from the industry is Many severe bacteria in landfills are involved in the biodegradation of some polymers. Hayden et al. [21] researched plastic degradation and its environmental consequences, focusing on poly (ethylene terephthalate). They found that plastic buildup is a severe environmental problem in the world's seas. Biodegradation is the most effective and ecologically beneficial method of disposing of plastic trash.

Recycling may reduce the amount of garbage that has to be disposed of and CO_2 emissions and oil consumption. [26] The amount of recycled plastics varies depending on the use and kind of plastic. Recycling is the most incredible option in the solid waste administration hierarchy to reduce the impacts of end-of-use and end-of-life post-consumer plastic packaging wastes. Every year, 300 million tonnes of plastic are manufactured throughout the world. Plastics are resistant and inert to microbial assault and can survive for a very long period in nature. Plastic items that are improperly disposed of are a potential source of natural pollution

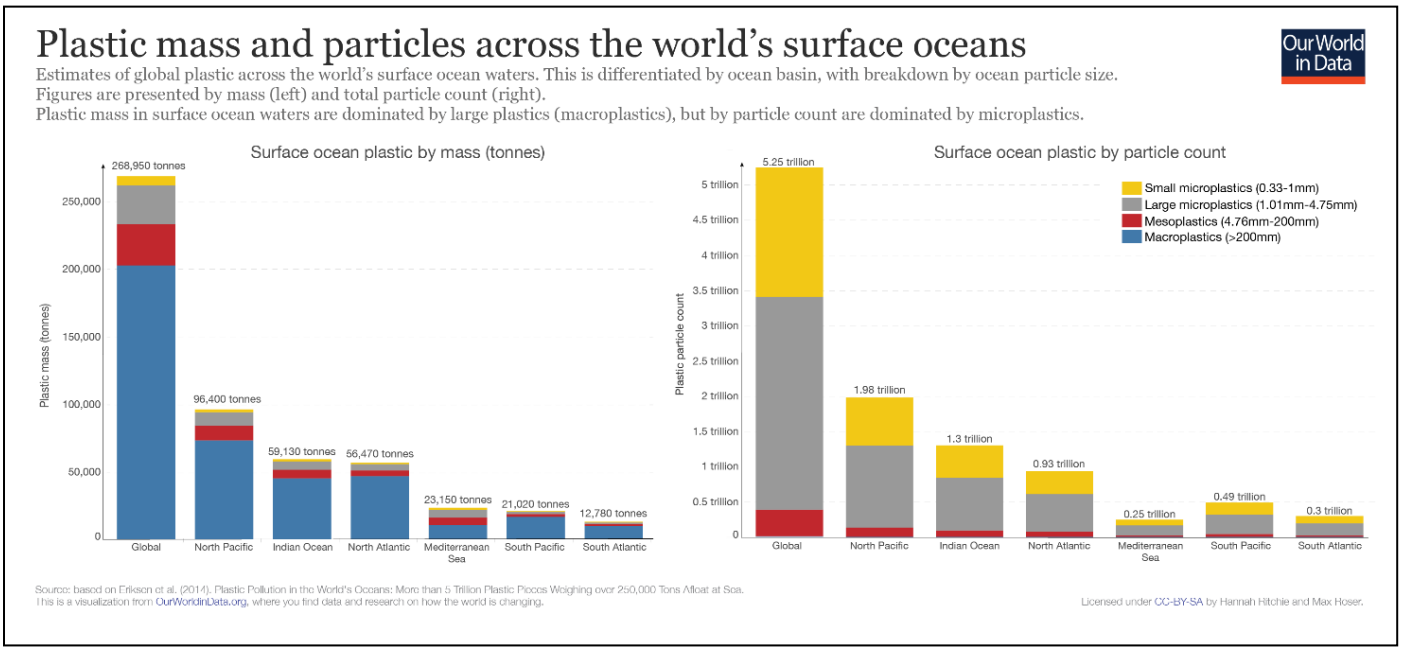

Fig.10. Plastic mass and particles across the world's surface ocean [25]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

The biodegradation of waste plastics is gaining popularity because it has the potential to reduce pollution. Although most plastics are resistant to biodegradation, some plastics are biodegradable. Biodegradation has the potential to reduce the quantity of sludge, rubbish, and rubbish on the planet. Plastics degrade through four mechanisms: biodegradation by microorganisms, hydrolytic degradation, thermo oxidative degradation and photodegradation [27]. According to a study, mangrove soil is

a good source of bacteria that may degrade plastics and polythene [28]. Landfilling, incineration, recycling, and conversion into gaseous and liquid fuels are used to handle waste plastic [29].

their techniques for converting raw materials into usable items demonstrate that much more effort in waste plastics management is required to grasp better the scope of approaches used in waste plastics management.[30] This study also sought to uncover plastics' applications. However, it was discovered that plastics are involved in practically every other use, either directly or indirectly. The information gathered in this systematic literature review will aid the scientific community and practitioners in determining where they should begin further study and where waste plastics should be headed

CONCLUSION

The utilization of plastic waste in structural designing development extends needs extraordinary regard for tackling this issue and improving the monetary parts of the venture. Plastic waste is being used as total in the substantial, and it goes about as a limiting material in floor tiles. To diminish the measure of waste plastic, the utilization of plastics in the development business is an extraordinary exertion. Plastic material can be utilized rather than totals insubstantial, used in asphalt, air terminals, and streets. In another case, the strength of plastic tiles with no utilization of sand in the middle is highly less when contrasted with the aluminum tiles. The supplanting conventional restricting material with squander plastic and quarry dust demonstrates tricky interest in heat impedance, similar to the reflexes in load-bearing. PET may be considered as near egregious thermoplastic in the polyester family. As per comfort and progression in innovative work, the creation of plastic heightens disregarding the "Guideline of Sustainable Development," and the tremendous measure of waste unloaded in the sea and landfill Formation of plastic ordinarily prompts extra adaptability and mechanical property. The biodegradation of waste plastics is acquiring fame since it can decrease contamination. Landfilling, burning, reusing, and change into vaporous and fluid fills are strategies used to deal with squander plastic. The executives are needed to acquire a more exact handle of the extent of approaches utilized in squander plastics management. This concentrate likewise looked to uncover plastics' applications. The utilization of recyclable LDPE plastic waste in tiles is an answer for lessening LDPE plastic contamination.

Notwithstanding, it was found that plastics are engaged with basically every other use, either straight forwardly or in a roundabout way. The data assembled in this methodical writing survey will help mainstream researchers and specialists determine where to start further review and where to squander plastics should behead. Recycling might lessen the measure of trash that must be discarded, just as CO_2 outflows and oil utilization. The standard of reused plastics changes relying upon the utilization and sort of plastic. Reusing is the most inconceivable alternative in the strong waste organization chain of importance to diminish the effects of end-of-utilization and end-of-life post-shopper plastic bundling squanders.

REFERENCES

[1] F. K. Bin, W. Alqahtani, G. S. Ghataora, and S. Dirar, "Production of Recycled Plastic Aggregates and Its Utilization in Concrete Production of Recycled Plastic Aggregates and its Utilization in Concrete," no. December 2017, 2016, DOI: 10.1061/(ASCE)MT.1943-5533.0001765.

[2] M. Valinejadshoubi, M. Valinejadshoubi, and A. Shakibabarough, "Investigating the Application of Plastic Bottle as a Sustainable Material in the Building Construction," no. January 2013.

[3] "Re-use of Plastic Waste as Palletized Aggregates for Concrete Infrastructure Principal Investigator : Dr . Khan Shahzada," p. 30.

[4] R. N. Uma, "A Critical Review on the Application of Bakelite as a Partial Replacement of Fine and Coarse Aggregate," no. January 2018.

[5] L. Mohammed, R. Mahmmod, Z. Muhammad, R. Abdul, and M. S. Radhi, "precast flooring concrete slabs Sustainable utilization of polyethylene terephthalate in producing local precast flooring concrete slabs," no. December 2019, DOI: 10.21533/pen.v7i4.958.

[6] M. Properties, "Material Properties of Plastics," 2011.

[7] S. E. Chidiac and S. N. Mihaljevic, "Cement & Concrete Composites Performance of dry cast concrete blocks containing waste glass powder or polyethylene aggregates," *Cem. Concr. Compos.*, vol. 33, no. 8, pp. 855–863, 2011, doi: 10.1016/j.cemconcomp.2011.05.004.

[8] J. O. Osarumwense, O. Salokun, and A. O. Okundaye, "Utilization of Low-Density Polyethylene (LDPE) Plastic wastes in the Production of Paving Tiles," vol. 2508, no. 12, pp. 2052–2060, 2020.

[9] C. Holder, "Resin Bonded (Plastic Waste) Tiles," 2018.

[10] A. G. Castellanos, H. Mawson, V. Burke, and P. Prabhakar, "Fly-ash cenosphere / clay blended composites for impact resistant tiles," *Constr. Build. Mater.*, vol. 156, pp. 307–313, 2017, DOI: 10.1016/j.conbuildmat.2017.08.151.

[11] A. Hardikar, O. Borhade, S. Wagholikar, A. Shivdeo, and R. Bhikule, "Comparative Analysis of Tiles Made from Recyclable LDPE Plastic Waste," vol. 8, no. 02, pp. 22–25, 2019.

[12] V. Sanz, A. Sab, and T. Ce, "NON-PLASTIC MATERIALS."

[13] S. E. E. Profile and S. E. E. Profile, "Concrete production using recycled waste plastic as aggregate," no. June 2018.

[14] S. Karlsson, "Recycled Polyolefins . Material Properties and Means for Quality Determination," pp. 201–229, 2004, DOI: 10.1007/b94173.

[15] F. Vilaplana and S. Karlsson, "Quality Concepts for the Improved Use of Recycled Polymeric Materials : A Review," pp. 274–297,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 09, September-2021

2008, DOI: 10.1002/mame.200700393.

[16] F. A. Cruz, H. Boudaoud, M. Camargo, and J. M. Pearce, "Plastic recycling in additive manufacturing : A systematic literature review and opportunities for the circular economy," *J. Clean. Prod.*, vol. 264, p. 121602, 2020, DOI: 10.1016/j.jclepro.2020.121602.

[17] G. Tapkire, P. Patil, and H. R. Kumavat, "RECYCLED PLASTIC USED IN CONCRETE PAVER BLOCK," pp. 2319–2321, 2014.

[18] O. Olofinnade, S. Chandra, and P. Chakraborty, "Materials Today : Proceedings Recycling of high impact polystyrene and low-density polyethylene plastic wastes in lightweight based concrete for sustainable construction," *Mater. Today Proc.*, 2020, DOI: 10.1016/j.matpr.2020.05.176.

[19] B. Shanmugavalli, "Re-use of Plastic Waste in Paver Blocks," vol. 6, no. 02, pp. 313–315, 2017.

[20] N. D. Shiri, P. V. Kajava, H. V Ranjan, N. L. Pais, and V. M. Naik, "Processing of Waste Plastics into Building Materials Using a Plastic Extruder and Compression Testing of Plastic Bricks," vol. 5, pp. 39–42, 2015, DOI: 10.5923/c.jmea.201502.08.

[21] H. K. Webb, J. Arnott, R. J. Crawford, and E. P. Ivanova, "Plastic Degradation and Its Environmental Implications with Special Reference to Poly(ethylene terephthalate)," pp. 1–18, 2013, DOI: 10.3390/polym5010001.

[22] P. Kannan, A. Al Shoaibi, and C. Srinivasakannan, "Computers & Fluids Energy recovery from co-gasification of waste polyethylene and polyethylene terephthalate blends," *Comput. FLUIDS*, vol. 88, pp. 38–42, 2013, DOI: 10.1016/j.compfluid.2013.09.004.

[23] L. Lebreton, M. Egger, and B. Slat, "OPEN A global mass budget for positively buoyant macroplastic debris in the ocean," no. October 2018, pp. 1–10, 2019.

[24] R. U. Halden, "Plastics and Health Risks," 2010, DOI: 10.1146/annurev.publhealth.012809.103714.

[25] T. Afloat *et al.*, "Plastic Pollution in the World' s Oceans : More than 5 Trillion Plastic Pieces Plastic Pollution in the World' s Oceans : More than 5 Trillion Plastic Pieces Weighing over 250, 000 Tons Afloat at Sea Plastic pollution is ubiquitous throughout the marine environment, yet estimates of," no. December, pp. 0–15, 2014, DOI: 10.1371/journal.pone.0111913.

[26] C. Mohanraj, "A review on conversion techniques of liquid fuel from waste plastic materials," 2017, DOI: 10.1002/er.

[27] S. M. Al-salem, A. Antelava, A. Constantinou, G. Manos, and A. Dutta, "A review on thermal and catalytic pyrolysis of plastic solid waste," *J. Environ. Manage.*, vol. 197, no. 1408, pp. 177–198, 2017, DOI: 10.1016/j.jenvman.2017.03.084.

[28] D. K. A. Barnes *et al.*, "Accumulation and fragmentation of plastic debris in global environments Accumulation and fragmentation of plastic debris in global environments," no. June 2009, DOI: 10.1098/rstb.2008.0205.

[29] B. Singh, T. C. Bhalla, and N. Sharma, "Induction of Biodegradability in the Plastic Waste Through Graft Copolymerization," pp. 1324–1332, 2009, DOI: 10.1080/03602550903204204.

[30] L. C. Lange, A. Frederico, and M. Ferreira, "The effect of recycled plastics and cooking oil on coke quality," 2016, DOI: 10.1016/j.wasman.2016.08.039.