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REUSE OF POLYMERS IN FIELD OF CONSTRUCTION AND MODERN TECHNOLOGY: CASE STUDY

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Abstract- Plastic waste causes of the most adverse environmental effects which afterwards cause immense heal hazards. Yet the plastic is a very useful substance due to its durability, versatility, and widespread availability. This paper mainly focuses on the use of waste plastic across the construction, technology, and defence sectors, demonstrating how global plastic pollutant can be reused as a source of important raw materials to make new materials. The first case study revolves around the reuse of the plastic as well as other products like Bitumen which can be used in the construction of roads and other construction sites. The second describes about the building construction, showing how plastic-based materials can replace conventional components improving the affordability while promoting environmental sustainability. The third focuses on the military purpose where the uses of potential lightweight plastic materials are used in the production of the light weight Armor. This also examines the recycling of electronic waste, particularly silicon to produce renewable energy, helping to illuminate the production of electricity. In all these activities help us to identify the reuse of the plastic in the field of the construction as well as military purpose along with the production of the renewable energy form the waster polymers like silicon. All these kinds of technologies help prevention of the environmental degradation.

Keywords- Plastic waste management, Recycled plastic, Road construction with plastic, Sustainable construction materials, Military applications of plastics, 3D printing with recycled plastic

I. INTRODUCTION

Plastic has become a serious threat to the present world although its invention was made for using it as versatile [1-4] material for convenience and innovation. Unfortunately, its widespread misuse and improper disposal have resulted in severe environmental issues. From clogging waterways to polluting oceans, plastic waste has become a serious global crisis, even in the human food chain. However, the same qualities that make plastic problematic are its durability, versatility also offer immense potential [3] for sustainable solutions. Recycling and reusing of plastic are no longer just environmental solutions [4] but essential strategies for addressing pressing global issues. Some groundbreaking innovative

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applications of plastic are developed to mitigate its environmental [5] impact. The construction and technology sectors are considered to be the pioneer in showing remarkable potential for integrating recycled plastic into sustainable practices. People can reduce waste and conserve resources by replacing traditional materials with plastic in construction of roads, buildings, and even military technologies and thus can foster economic growth. [6]

This paper explores the transformation of plastic from waste to a valuable resource. The case studies highlight the real-world examples of innovation [7-10], challenges faced during implementation, and the path forward for scaling these solutions globally. Such sustainable practices can not only reduce plastic waste but also redefine its legacy for future generations.

II. CASE STUDY 1: ROAD CONSTRUCTION WITH PLASTIC WASTE

Use of recycled plastics in the field of construction [1] of roads has become a need nowadays which has helped to protect the environment from the harmful effects of plastics. This bold approach was made under the guidance of Mr. K. Ahmed Khan [2], he is currently the MD of KK plastics. According to him the roads which could be made of plastic had more tensile strength and durability than the normal roads constructed traditionally. This method was not only cost effective but also opened a new way of recycling of new products. In this process of road construction, the waste and leftover plastics are turned into fine granules which are then mixed with bitumen during the time of road construction making a more tough yet tensile material for the construction of the road [6-7]. The stability of the mixture increases and the lifetime of the road is enhanced too. This improves the durability of the road protecting it from rutting, cracking, and stripping [8-9] compared to the traditionally built roads. This not only helps the roads to withstand the load of heavy vehicles but also helps the roads to withstand the immense rainfall conditions [10]. There have been real life examples found not only in India but also in various parts of the world too [11].

Village Level Case Studies of India:

Uttar Pradesh: A bold initiative was taken by the students of IIT Kanpur [12 -13] along with the government bodies and the local people who have constructed a plastic road in Uttar Pradesh. This road is more durable and resilient than the traditional roads and has been used to cover the potholes created due to extensive rainfall, and the local people have given extremely positive feedback regarding this initiative.

West Bengal: From the tea gardens of Jalpaiguri there have been lots of plastic wastes derived which have been used by the government of west Bengal and make the plastic road in that area of the city [14-15]. This approach not only helped to improve the road conditions of the hilly mountain areas but also have led to the creation of employment opportunities to collect plastics for road construction.

Meghalaya: Here a community driven project has been led by the common people where the villagers were benefitted by the construction of the well durable roads which once was destroyed due to extensive rainfall [16]. The farmers were benefited by the good road conditions, which helped them to carry the crops easily to the markets.

Global Rural Level Case Studies:

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Kenya: Here the waste plastics have been used effectively to build the CABRO road by mixing plastic with bitumen. [17] This reduced the cost of the construction of the roads supported by the local municipality. They have constructed several kilometres of roads.

Ghana: There has been research in Ghana which showed that mixing HDPE with bitumen under 170 degree Celsius created tougher properties of the mixture later used to lay roads. The laboratory test reports showed penetration, softening point and viscosity which suggested the better performance of the roads. [18]

Bangladesh: There has been constant research done by the researchers of Bangladesh for utilizing the waste materials of 13 cities in this regard which demonstrates that plastics have 50% more durability than traditionally built roads. If the plastics thrown into the landfills could be used in making roads, then it could meet the 100% repair needs of roads [19-23].

Despite of the successful implementation of plastics there have been thousands of difficulties in this regard as still people are unaware about this technology and there has been lack of funds by the government bodies [24].

III. CASE STUDY 2: USE OF WASTE PLASTIC IN CONSTRUCTION INDUSTRY

Another possibility for recycling plastic into construction [25] is in building and construction. Traditional materials [26], e.g., bricks, cement, and metal rods can be replaced partially by plastic-based alternatives. High-density polyethylene (HDPE) [27], a durable material resistant to water, has been widely used in the waterproofing of basements [28]. Another versatile material, PVC pipe, can even replace the metal reinforcements of building structures. For that, the civil engineer uses plastic polymers [30] of high-density polyethylene in the construction of the pillar so that the usual method of coating the sand and cement [31] is replaced by the plastic coating, which makes the pillar stronger and protective from the layers of water that is used and will generally lead to the rusting of the iron rods used below the earth.

At the Village: Innovations from India: Recycled plastic for construction

For Maharashtra (Amravati Region): Faculty members and students of an engineering college in the Amravati region of Maharashtra tried developing bricks by blending plastic waste with the normal brick-making process. The products possessed lower water absorption, higher compressive strengths, and lighter weight, which was quite suitable for rural areas where there were few waste management disposal systems [32].

Tamil Nadu: A community initiative in Tamil Nadu constructed a 400 ft² room in a school campus using PET bottles stuffed with plastic waste and covered with UV-resistant paint. It showed a replicable modular and sustainable design for rural schools and community centres [33-34].

Majuli (Assam): Authorities in Majuli organized a special programme at a Solid Liquid Resource Management (SLRM) facility -- popularly known as a plastic waste centre -- on the occasion of World Environment Day, which is celebrated on June 5 here. The above method was found low-cost, durable and environment-friendly and is highly advantageous in flood-prone riverside areas [35].

Village-Level Case Studies (Non-Indian Examples)

Indonesia: Researchers in Indonesia studied the use of HDPE plastic waste as a replacement for fine aggregate in the production of CLC [36]. The experimental mixes of 0%, 5%, 10% and 15% HDPE indicated that compressive strength slightly decreased with the increase of HDPE content, whereby it has

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an advantage in reducing environmental pollutants and helps to achieve optimum density in lightweight bricks.

Malaysia: A Malaysian trial studied recycled HDPE in concrete mix for flat roofs. The mixes had 2–6% plastic and were tested for compressive strength, thermal insulation, and water absorption. A mixture with a 2% HDPE–cement ratio satisfied the Grade 20 compressive strength but decreased thermal conductivity by about 12% and can be proposed for sustainable flat roof construction [37].

Iraq: In Iraq, the natural course was substituted with shredded HDPE waste up to 30%. The results were wonderful; although the load-carrying capacity decreased slightly (~7%), the beam toughness [38] enhanced by ~24%, and the failure phenomena of the tensile failure modes in the E-BEAM did not change much compared with the conventional beam.

Japan – Disaster Management is treated as a Plastic-Like Reinforcement

For Japan [39], which has very high levels of sensitivity to earthquakes, the development of technology for disaster-resilient construction cost is enormous. One prospective new structural element is in carbon-fibre composite rods—lightweight non-metal reinforcements that have a similar nature to plastic composites and can be produced from composites and the like. An example is the project in Nomi-city, Ishikawa prefecture, for which the architect Kengo Kuma [39] used this system for the retrofit of the Fa-Bo showroom and laboratory for Komatsu Seiren. Such a structure mobilized 1,031 bars between the roof and the ground as an external anchor, and 2,778 bars as an interior network reinforcing stairwells and parapets [39–41]. It's strong as hell. It's seven to ten times stronger than steel, and, of course, it's much lighter, and it's in a rope-Ish form, like traditional Japanese stuff. You have the culture, and also the best science. From a functional perspective, the system enhances seismic resistance by dynamic tension—when the building shakes during an earthquake, rods on the opposite side resist the movement and reduce deformation [40]. The shield effect produced by the curtains splits the force and dissipates it throughout the structure, improving overall stability. Its significance as a material was further emphasized with the official standardization of CABKOMA [42] as JIS A 5571 in 2019. It provides a one-fifth density of iron, a tenfold tensile strength, and an excellent corrosion resistance and has already been put into practical use, for instance, in heritage buildings such as Kyozo Sutra Repository in Zenkoji Temple, which was intended to make priorities both in strength in structures as a building and in beauty when structured [43].

One imaginative [44] application is combining shreds of plastic chunks with concrete to produce stronger walls and roofs. This provides not only a reduction in conventional material usage but also takes advantage of the long degradability period of plastic [45]: approximately up to two million years by extending the life cycle of the structures. Plastic is effectively utilized in furniture, partitions, and home appliances within interiors [46]. Electrical wiring and equipment are insulated with plastic for safety and durability requirements. In addition to which, Novolac, a phenol-formaldehyde polymer [47-48], has been a fundamental building block in the paint industry, providing buildings with both aesthetic and protective properties. Although the opportunity for plastic construction [27] is huge, hurdles such as public disbelief [49], finance and technology are holding it back. However, further evidence-based and awareness [50] raising programs may lay the foundation for its widespread adoption.

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IV. CASE STUDY 3: REUSED PLASTIC IN MILITARY APPLICATIONS

Military applications provide an opportunity for plastic reuse [51]. Plastics or polymeric materials are highly desirable because they are lightweight, strong, and are increasingly being incorporated into the design of weapons [51-54], equipment, and vehicles. Polymer thermosetting resins can be moulded into shape and are the perfect material for making hard-wearing military equipment that is also transportable. In the Line of Control (LOC) and in other hostile areas, plastic composites have been found to be beneficial in equipment [55-57]. These are less cumbersome and more transportable versus the metal devices. On the one hand, radioactive-titivating polymers [55] have been proved to be eligible candidates for advanced weaponry, which could provide an economical alternative to conventional materials. Military [56] and incorporating recycled plastics into it can cut costs and minimize its environmental impact, while improving operational efficiency.

The US [58] Army Research Laboratory has developed a method to recycle plastics into 3D-printing filament. This means that trained veterans can now rapidly manufacture replacement parts for military vehicles, weapons, and equipment.] Filaments of the composite thermoplastics were produced through a process known as solid-state shear pulverization by ARL (as detailed here [58]). In this process, shredded waste, primarily plastic bottles with some paper and cardboard, was ground in a twin-screw extruder to produce a powder. This powder is subsequently converted into 3D [58] printer filament by means of melt-processing.

Some of the actual test subjects are:

3D Printing of Spare Parts (U.S. Army Research Lab): Researchers at the U.S. Army Lab, including Capt. Anthony Molnar and Dr. Nicole Zander, developed a process to recycle PET bottles, cardboard, and paper into 3D-printing filaments using solid-state shear pulverization. These filaments (~70 MPa tensile strength) were successfully used to produce essential parts, such as vehicle radio brackets, from as few as 10 bottles within two hours [59–60].

Composite Armor & Light Vehicles: In partnership with AM General and TPI Composites, the U.S. Army reinforced the HMMWV with carbon-fibre Armor, reducing vehicle weight by about 900 pounds compared to steel or aluminium. The design improved mobility, range, and fuel efficiency.

HDPE-Based Body Armor: Recycled HDPE blended with 5–15 wt.% granite microparticles [62] demonstrated higher mechanical performance—impact strength (+18%), hardness (+52%), and compressive strength (+33%). With ~70 MPa tensile strength, these composites show promise for lightweight Armor, 3D printing, and military applications.

Role of Mechanical Recycling: Mechanical recycling remains central to the circular economy, consuming less energy and avoiding harmful by-products compared to chemical methods. Studies confirm its applicability for construction, 3D-printing feedstock, and composites [64–65]. Yet, challenges such as corruption, bureaucracy, and talent loss restrict progress. Overcoming these issues will require focused R&D and stronger government support to secure both sustainability and military readiness

V. CONCLUSION

In the above case studies, we have got a clear idea about hoe the reuse of plastic can be very helpful for the development of the society as well as it can make the environment free of pollution and help in the production of the new things from the discarded wastes. Not only roads but also buildings as well as

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many military equipment can be made with the help of the reuse of the polymers [62-65]. Some of their applications are in renewable energy. However, the success of these initiatives depends on overcoming of barriers of public sarcasm.

By doing innovative research and fostering collaboration among governments bodies industries, and communities, the potential of recycled plastic can be fully realized

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