Fabrication of Equipment & Manufacturing of Plastic Blocks from Waste Plastic & Result Investigation

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Abstract: Any man made thing would have a flaw which becomes vivid sooner or later."Plastic" undoubtedly an extraordinary invention of 20th Century, but none gave a serious thought to recycle it until mankind started facing the depth of managing waste plastic. This project experiments one of the sustainable and effective ways of managing plastic waste in urban and rural parts of India in order to minimize their adverse environmental impacts. After studying the whole scenario, there seems to be an effective way of utilizing the plastic waste and recycling it into plastic blocks which might withstand high amount of pressure. However due to some physical and chemical properties of plastic which can be disadvantageous to the block created from it, some changes in its design and manufacturing processes can be made to make it an ideal one apart from making it at very low cost to fill the potholes. This project mainly uses different plastics like HDPE (high density polyethylene), PET & other types for recycling. First the waste is shredded and there by heated unto its plasticity zone to make sure that it won't emit any kind of harmful gases into the atmosphere. By using different moulds we can obtain different sizes of the plastic blocks which can be called as bricks or blocks depending upon the size of it, which are then tested for Compressive strength, Impact load, Hardness, Absorption of water and Efflorescence. As the results are satisfactory these blocks can be used to fill the potholes, for construction purposes, Railway sleepers, for the paver blocks, Roof Tiles etc depending upon the need of the hour, due to their high compressive strength.

Index Terms **- Plastic waste, Shredding, Moulds, Heating Chamber, Plunger, Hydraulic compression, Plastic Blocks, Plastic Bricks**

I. INTRODUCTION

By now plastic has become a threat to entire ecosystems and societies. It is deteriorating our planet and people's lives. It is a problem. A material made to last hundreds of years that is only used for minutes, a fraction of its possible lifespan and quickly discarded. All plastic lying around you is a resource, not waste. A material with great potentials, mostly intact qualities and a sea of opportunities waiting to be discovered. If treated correctly, this resource can become the beginning of something new for you, society and the planet at large. This resource lying around everywhere can become a source of income or an educational tool for your community. There is an incredible opportunity of plastic waste to eliminate plastic pollution, reducing the demand for new virgin plastic and closing its materials loop while creating better livelihoods for people around the world.

1.1Plastic types

Plastic (thermoplastics) are further grouped in seven different subcategories often referred to as plastic types. Each plastic type has its specific chemical composition, properties and applications and is given a specific number, called SPI code to differentiate between them. Today, most manufacturers should follow this coding system and place the SPI code on their products, usually molded at the bottom of the product. Knowing what plastic type you're working with is crucial when working with waste Plastic. This will tell you its melting temperature so that you can set your heating chambers at the correct temperature and run a smooth recycling process.

1.2 Plastic codes and the different types of plastic are:

1. PET (polyethylene terephthalate)

This is a very strong plastic that can be easily recognized for its transparent look. All beverage bottles containing our favourite sodas are PET. This plastic is also used in many other products like jars, combs, bags, tote bags, carpets and ropes. Items made from this plastic are commonly recycled. Most recently, PET is often recycled into yarns to make clothes.

2. HDPE (high-density polyethylene)

This plastic is often used for food or drink containers. Items made from this plastic include containers for milk, motor oil, shampoos, soap bottles, detergents, and bleaches. Many toys are also made from this plastic. This plastic works very well.

3. PVC (polyvinyl chloride)

This is toxic and I didn't work with it. PVC is most commonly found in plumbing pipes and releases chloride when heated up.

4. LDPE (low-density polyethylene)

Plastic wrap, sandwich bags, squeezable bottles, and plastic grocery bags all are made from LDPE. Usually, LDPE is not recycled from the industry but works rather good with recycling

5. PP (polypropylene)

This is one of the most commonly available plastic on the market. This type of plastic is strong and can usually withstand higher temperatures. Among much other application, it is consistently used for products that get in contact with food and drink (Tupperware, yoghurt boxes, syrup bottles etc. It also works well with recycling.

6. PS (polystyrene)

PS is most commonly known as Styrofoam. PS can be recycled, but not efficiently; recycling it takes a lot of energy, which means that few places accept it. Disposable coffee cups, plastic food boxes, plastic cutlery and packing foam are made from PS.

7. Other (Mix)

This code is used to identify other types of plastic that are not defined by the other six codes. ABS, Acrylic or Polycarbonate are included in this category and can me more difficult to recycle. We can work with some of this.

8. Mixing plastic

Different plastic types should never be mixed together when working with Plastic as this will make it impossible to recycle them again. Mixing plastics would end their cycle. Moreover, when different types of plastics are melted together they tend to phase-separate, like oil and water, and set in layers resulting in structural weakness and lower quality products.

1.3 Plastic pollution

As the world's population continues to grow, so does the amount of garbage that people produce. On-the-go lifestyles require easily disposable products, such as soda cans or bottles of water, but the accumulation of these products has led to increasing amounts of plastic pollution around the world. As plastic is composed of major toxic pollutants, it has the potential to cause great harm to the environment in the form of air, water and land pollution.

But simply, plastic pollution is when plastic has gathered in an area and has begun to negatively impact the natural environment and create problems for plants, wildlife and even human population. Often this includes killing plant life and posing dangers to local animals. Plastic is an incredibly useful material, but it is also made from toxic compounds known to cause illness, and because it is meant for durability, it is not biodegradable.

- ✓ To reduce the plastic pollution Recycling is the only best solution at this point.

II. LITERATURE REVIEW

2.1 Introduction

Since 1950 we have witnessed the rise of plastics. Plastic products produced from crude oil derivatives – due to continuous technological progress – can be prepared with relatively low manufacturing costs and possess excellent usability characteristics. It is no surprise that global production has increased exponentially. Plastic undoubtedly one of the greatest invention of the 20thcentury. But what's the worst thing is mankind really did not put a serious effort or thought into the used plastic until it ended up into huge mountains of trash thereby becoming a bulwark polluting the land and water.

I used to travel a lot on NH16 during(2010-2014) my study of B.Tech for commuting purposes, back then the highway is filled with lush green trees and everything on the road is simply awesome to gaze upon which used to give a feel as if we are entered the highway to heaven.

But when I travelled the same road in 2016 that kind of feeling never happened, a lot is polluted the sideways of highways is filled with lot of plastic trash. On watching this change over my heart felt real bad. Then I started looking for a solution but ending up in vain then I came across "Dave Hakkens" from "Precious Plastic" on YouTube where he is working on the waste plastic and the crucial information needed is existing for anybody for free of cost over there. Then I felt like why can't I recycle the waste plastic and manufacture useful things out of it

There are ways for recycling plastic but often they are costly, so finding a cost effective recycling method is the need of the hour upon which I have worked intensively. Here is one of the methods for recycling the plastic waste and the problems associated with it.

2.2 Incineration

According to environmental and safety-conscious behavior in the 21th century, it is necessary to strive to reduce all those activities that cause environmental damage in every aspect of life. More emphasis should be placed on recycling, waste-handling and environmental-friendly solutions, due to the increased amount of waste caused by the penetration of plastics. Plastic manufacture is a constantly growing industry – especially the production of packaging – so the amount of plastic waste generated is also growing steadily. Only a part of the accumulated waste is recycled, another part is destroyed and the remaining amount will continue to pollute the environment. One form of destruction may be energy recovery or incineration. Destruction is a form of energy recovery or incineration which is subject to strict legal requirements in addition to other possible activities. It could pose a serious burden on the human and natural environment if the process is not properly controlled and monitored. This is the situation that seemingly a growing amount of plastic waste is used in residential combustion appliances, of which adverse environmental and health effects the majority of citizens are not aware.

2.3 My Point of view

My point of thought is using this waste plastic make it or mould it into new products and solve some of the problems existing in the society or as a replacement to the things already existing which are manufactured in a non environmental friendly manner. For example filling up of pot holes with the blocks made of waste plastic eases a lot of things especially like filling the pot holes at the very point they are formed especially in the rainy season which eliminates the formation of huge ditches thereby avoiding accidents up to some extent. In general railway sleepers and paver blocks are made from cement but manufacturing of

cement itself results in a huge amount of pollution, so if one utilizes this waste plastic and recycle them into paver blocks that reduces the pollution from cement manufacturing and also pollution of waste plastic up to some extent.

These waste plastic blocks and plastic Tiles can also be used for construction purpose especially in earth quake zones as the walls build using this bricks are very light and can with stand high tremors up to a scale of 8.5 on Richter scale. Apart from that plastic is a good insulator so, it can be used in Extreme cold weathers than wood, especially in the Himalayan regions, western countries and also in the heavy rain areas like Mawsynram, or heavy snowfall areas especially in countries like Russia.

III. RESEARCH METHODOLOGY

3.1 Preparation of plastic

3.1.1 Collecting

The first thing a Plastic recycling workspace needs is "plastic" to recycle. It is essential to always have enough plastic waiting to be sorted, shredded and worked with in order to run the workspace effectively. Plastic at this stage is still mixed and dirty.

Fig-1 collection of waste plastic

3.1.2 Sorting

The sorting system is a crucial element for all recycling activities. A thorough and precise sorting effort guarantees smoother processes, better products and easier maintenance. An efficient sorting system allows the team to know exactly what plastic type is being used, which is crucial in order to figure out its melting temperature and set the heating chambers temperature correctly to run the workspace efficiently. Sorting is done manually (even big industries still do it manually) by checking the SPI code.

3.1.3 Shredding

At this stage, bigger plastic objects are chopped into small granulate to reduce its size, enable washing, store more efficiently and be used with the other machines. It is good practice at this stage to separate plastic by color.

3.1.4 Washing

Plastic needs to be clean before undergoing recycling processes. A more efficient way is to wash after shredding using a basic filtering system. At this point, you should place the plastic on a drying plate for a few hours waiting for water to evaporate. It is important that the plastic is dry before being melted.

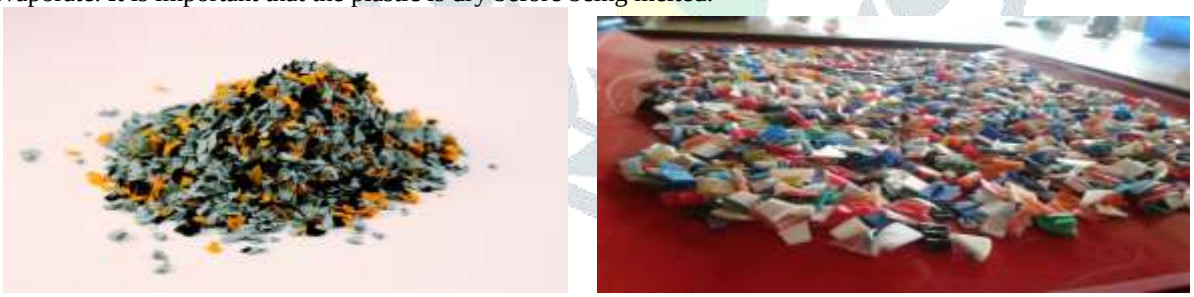

Fig-2 shredded plastic of different sizes

3.1.5 Storing

Once the plastic is dry it can be stored in the provided buckets. Ideally, buckets should be stackable, strong and transparent so you can see the color and nature of the plastic. It is essential that you put it in a bucket with the PS code sticker so that plastic does not get mixed up.

3.2 Fabrication of Heating Chamber

The shredded plastic is fed into the heating chamber to melt the plastic until it reaches its plasticity zone. The heating chamber is prepared with few components depending upon the need of the hour as listed below.

Components used for the design and fabrication of heating Chamber.

- Stainless pipe
- Heating coils
- Thermostat
- Plunger

I've used stainless steel pipe for the melting the shredded plastic in it, one of the reason for using the stainless steel is, it exhibits good thermal properties and the adhesion of plastic is less when compared to other metals.

Specifications of stainless steel pipe**:**

Length = 2 meters
Diameter = 4 inches
Thickness = 4 mm


Fig-3 Heating Chamber & Heating Coils

3.2.1 Heating coils

To melt the plastic in the stainless steel pipe we need an external source of heating device for that purpose heating coils are required. As per the pipe length certain number of coils was needed for the heat generation. The heat energy transferred from heating coils to stainless steel pipe through the conduction. The heating coils were mounted around the steel pipe. The heating element used in coils is Nichrome wire.

3.2.2 Thermostat

A Thermostat is a component which senses the temperature of a system so that the system's temperature is maintained near a desired point. The temperature range of thermostat that has been used is from 0^0 C to 250 ^{0}C.

3.2.3 Plunger

Plunger is used to push the melted plastic out of the stainless steel pipe. Extraction can be done either manually or automated. The piston head is made up of stainless steel and the extension joint of the piston is made up of mild steel. The diameter of the piston head is same as the internal diameter of the stainless steel pipe with 2mm clearance.

3.3 Melting points of different Plastics

Material	Temperature (^{0}C)	Time(min)	Weight(kgs)
PP	170	18	5
HDPE	130	18	5
PET	260	20	5

Table – 1 melting temperatures of different plastics according to CIPET, Chennai

Note: The table is carved according to the plastic block requirements.

3.4 Fabrication of mould

Different moulds are needed to be fabricated for different applications like Potholes, Bricks & Paver blocks .By obtaining an average pothole dimensions and general clay brick dimensions I have designed moulds with respect to the average pothole size by measuring different potholes and keeping the equipment available in mind..

- Average pothole dimensions :

  Length = 35 cm
  Breadth = 25 cm
  Depth = 5 to7 cm

It is quite a tough task to fabricate a mould but once you have obtained it with perfection you would be amazed by the products we can make with it. Moulds are an integral part of the Plastic ecosystem and could almost be considered a world on its own. Moulds give shape to the molten plastic and create the final product. For an easy extraction of the plastic block from the mould I have employed a Bolt and Nut system. The metal we used for the fabrication of mould is Mild steel which has good strength and low in cost. The mould has three basic parts 1.Mould cabin 2.Mould piston 3.Base plate. Scrap Mild steel plates of thickness 12mm for base plate, 10mm for side walls & 12mm for piston plates were used for the preparation of mould cabin. By aligning the plates in rectangular shape and then followed by Arc welding. Angular plates which are slotted are welded along breadth which facilitates fastening of bolt and nut with greater ease. As the melted plastic is injected into the cabin it will be in the hot condition which we can lift with the help of handles employed. The handles are welded to the cabin.

Length (cm)	Breadth (cm)	Thickness (mm)	No of plates
40	26	12	1
25	35	10	2
36	20	10	2

26	20	10	2

Table- 2 Metal plates Dimensions

3.5 Manufacturing of Plastic Blocks

The required amount of shredded plastic is weighed as per plastic block needed. Plastic is inserted from the hopper, into the heating chamber. Close either side of the heating chamber with SS plates which are of the size of inner diameter of the heating chamber. The heating is achieved from the nichrome coils mounted on the chamber bring the plastic to a melting state (semi liquid) within a period of time. Once sufficiently melted the plastic can eventually get out through the nozzle by applying external force using the plunger from the rear end of the chamber. Temperature can be set by using the thermostat from the controllers on the electronic box.


Fig 4 Final Moulds

3.5.1 Production

- A melted plastic is now flowing out of the heating chamber.
- The flow and pressure of the injection can be adjusted as the plunger is operated manually.
- Remember that it takes roughly 10-20minutes for the plastic to melt until plasticity zone



Fig-5: Injection and Applying Hydraulic load, Final Block of size 35X25X7cm

Hydraulic load is applied in order to increase the strength of the block and to remove air gaps. Wait a minute or two and release by unloading. Withdraw the mould from the compression machine and cool in atmospheric air or if you are going for mass production one can quench the mould. Once the mould is cold you can open and check your new product.

- The hydraulic load of 200 KN is applied if you are using HDPE
- Hydraulic load of 150 KN is applied if you are using LDPE or soft plastics

Note:

The mould should be cooled by natural air for better properties of block. The mould may be subjected to quenching in case of mass production but it may changes the properties of the block, the block gets brittle if the block is quenched rather than the mould

3.6 Precautions:

- Wear a leather gloves and leather shoes which protect us from burns.
- Though we don't burn the plastic up to some extent it release fumes that leads to health issues by continuous inhaling so it's better to have a Carbon mask.
- Use clear and white spectacles in order to prevent reddening of eyes.
- The electric circuits must be properly insulated and there should not be any loose connections.
- Fire extinguishers should be kept near and handy at the plant.

The room should be properly ventilated.

IV. RESULTS

4.1 Compression test of different specimen

Clay, cement and varied plastic specimens are considered for compression testing and evaluated using the equation, the compressive stress= load per unit area is calculated. The obtained values are tabulated below.

Inference: From the below results from the tests conducted we can notice that recycled HDPE can sustain high compression, and post failure the bonding still exists where as blocks of PET can sustain high pressure but during failure it broke into pieces. So blocks made of HDPE can be used to fill pot holes and PET for construction

Fig- 6: Recycled HDPE Specimen

S.No	Type of specimen	Area in cm^2	Compressive load KN	Stress Kg/cm^2
1	Clay Brick	200	50	25.484
2	Cement	200	150	76.45
3	HDPE Block (Fresh Plastic)	200	420	214.1
4	HDPE Block	200	220	112.13
5	HDPE with 10% metal scrap chips	200	130	66.3
6	PET Bottles	200	300	152.9

Table 3 Compressive Stress of various specimens

4.2 Izod Impact Test

Izod impact testing is a method of determining the impact resistance of materials ASTM D256 standards notched sample of size 63.5 X12.7 X 3.2 mm is generally used to determine impact energy and notch sensitivity. For the following specimens of PET, HDPE the impact resistance is 38-40J/cm^2

Fig- 7: Izod Test specimen before and after testing

S.No	Type of Plastic	Impact Energy Absorbed(J/cm^2)
1	Fresh HDPE	40
2	HDPE(Recycled)	38
3	HDPE with 10% scrap metal chip	38
4	PET	38

Table 4 Impact Energy Readings

Inference: From the above tests conducted we can notice that all recycled plastic of different compositions can sustain same kind of impact energy near to the fresh plastic.

4.3 Efflorescence test

In this test a brick is immersed in fresh water for 24 hours and then it's taken out from water and allowed to dry in shade. Efflorescence is a whitish crystalline deposit on surface of the bricks. Usually magnesium sulphate, calcium sulphate and carbonate of sodium and potassium are found in efflorescence. The presence of alkalis in bricks if used for construction is harmful and they form a grey or white layer on brick surface by absorbing moisture. To find out the presence of alkalis in bricks this test is performed.

Inference The plastic blocks has low alkali content and so no white or grey patches are formed over the surface. So it is safe to use these blocks

4.4 Water Absorption Test

In this the bricks first weighted in dry condition and they are immersed completely in water for 24 hours. After that they are taken out from water and they are wiped out with cloth. Then the difference between the dry and wet bricks percentage are calculated. HDPE Recycled in pictures (below)

Fig-8(a) Before Soaking **Fig-8(b) After Soaking**

S.No.	Type of Block	Average Water Absorption %
1	Fresh HDPE	0
2	HDPE Recycled	1
3	HDPE(10% scrap metal peels)	4
4	PET	2
5	Clay Brick	33
6	Cement Brick	47

Table 5 Water Absorption percentages

Inference: From this test we can infer that these blocks are very bad for absorption. So they can be used as roof tiles especially in cold countries or paver blocks in any country.

4.5 Brinnel Hardness Test {Brinell (HBW)}

Brinell indentation provides a large impression with a tungsten carbide ball or steel ball, and is denoted as HBW. The indent size is read optically using Brinnel microscope to establish the hardness. The load range is 1-3000 kgf, and the indenter types are 1/2.5/5/10 mm diameter balls. In this case we used a 10mm steel ball indenter. For softer materials, a smaller force is used; for harder materials, a tungsten carbide ball is substituted for the steel ball. The indentation is measured and hardness calculated as

$$\mathrm{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

According to ASTM D2583 standards a standard specimen of 6.5mm thickness is considered for the following tests. The dent is very small and is not clearly legible for the camera lens because of which the pictures are not included BHN = Brinell hardness number (kgf/mm^2) , P = applied load in kilogram-force (kgf), D = diameter of indenter (mm) , d = diameter of indentation (mm)

S.No.	Type of Block Type of Plastic Block	HB (kgf/mm$^{2)}$

1	Fresh HDPE	0.2
2	Recycled HDPE	0.1
3	Recycled HDPE with 10% scrap metal chips	0.1
4	PET	0.08

Table- 6 Hardness Test Readings

Inference: From the test results of hardness we can infer that Plastic materials in general are soft in nature unless they are treated by reinforcing other materials as in the case of bullet proof windshields etc.

Final Inference: But they can sustain high compressive forces and can elongate unlike breaking easily. Because of this high compressive strength of these blocks they are suitable to be used to replace the potholes, plastic bricks for construction, and paver blocks on foot paths, Roof tiles etc**.** An average size of 35X25X7cm recycled block of HDPE can with stand a load of 98 tonnes according to the calculations from the tests conducted which is remarkable.

V. DISCUSSION

5.1 Filling of Potholes Using the Plastic Blocks

The biggest challenge of filling pot holes is majority of them are formed during rainy season and one cannot fill them with bitumen and rock chips when the roads are wet, that is why I have particularly worked on this project. With this Plastic block one can fill the pot hole irrespective of the climatic conditions, whether wet, hot, dry it doesn't matter at all. Potholes are one of the major problems in any world class city due to the increase of vehicular traffic on roads. According to the statistics it shows that the automobile vehicular traffic is going to get increased by two folds by the next decade. The following pictures depict leveling of the pothole and fastening of the plastic block into the pothole. Fastening should be done in a peculiar way that a screw is fastened to the block and strip and a nail is used for the strip and road and the diameters of the screw and nail depends upon the requirement of the size of the block. If any gap is left even after fixing the plastic block then polyurethane foam can be sprayed for better look and finishing. After a week or two the nails, screws and metal strips can be remove. Later on when new road is laid it can be laid on this block directly without any problem.

Fig-9: Leveling, Fixing & Fixed pothole

5.2 Railway Sleepers/Ties

Already many of the western countries are implementing the usage of recycled railway sleepers, which is not yet started in India, hope it starts soon. As there is plenty of plastic available in India which even reduce the maintenance cost for railways. As plastic railway ties are much long lasting than the concrete or metal ties which are having some disadvantages too.

5.3 Paver Blocks & Construction of houses and walls using Plastic Bricks

If many questions are lurking in your mind that if it is okay to construct house using plastic bricks. Is it safe or not in the long run and all then my calculation is, in one's life time one might produce plastic waste which is enough to recycle and convert into paver Plastic bricks to construct the compound wall of his/her home and the paver blocks in the garden. If someone produces it beyond that amount, even we can use to manufacture roof tiles and also one can build parapet walls using these bricks and in cold countries these bricks serve as good insulation from the bone chilling weather and also especially in the heavy rain zones.

Already people from different parts of the world are already using the plastic bricks and plastic paver blocks. But in India it does not exist even if exists it is not ventured into the mass production sector yet. So I am planning for mass production in the near future.

5.2.1 Construction process of wall

Unlike the normal clay brick or cement brick construction fashion, construction of walls using the plastic bricks is lego building construction type. Apart from that these bricks are inserted into the protruded iron rods and then mesh is wounded around these walls which is made up of jute or iron to make the cement stick to these bricks to give insulation during fire accidents. A company named "By fusion "owned by a New Zealand engineer has already started constructing using this fashion.

Fig-10: Plastic Sleeper ties & Paver blocks

VI. CONCLUSION

After preparing different kind of blocks using plastic waste it can be concluded that this project would be very helpful for the entire world in case of filling the potholes a massive problem with many derivatives but often not projected or seen in that perspective. Apart from that rural and coastal region people are facing a great impact due to environmental pollution created by plastic wastes, people of these areas will be free from the harm of waste around them if that waste can be used for construction of their houses or compound walls which generally get washed away during monsoon season as they are constructed using mud. This project is an effective way of dealing an existing macro level problem with another existing problem to solve the problem, a new idea in itself. Very soon in the near future we can do many more things once 3D printing becomes cheap.

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