WASTE TO GREEN – ECO CONSTRUCTION

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ABSTRACT

The main objective of this project is to brainstorm, innovate and protype not only a construction material using suitable resources that can be used to replace the natural elements which are extracted from mother earth such as sand and limestone but to also educate the on how to save the environment and realize the importance of coexisting with nature with the help of science and technology. The initiative is to provide Sustainable material that will prevent or reduce climate changes. Our innovation will be applied in the manufacturing of construction building bricks or building blocks while maintaining the required strength and durability required by the standards. This will help to reduce the severity of plastic pollution caused by the low recycling rates combined with the absence of an environmentally friendly cost-effective solution and poor government policies with a lack in funding for R&D and recycling policies. Our Innovation Waste To Green – Eco construction is in line with the Malaysian Government's 2030 Roadmap towards 'Zero Single Use Plastics' and The United Nations Sustainable Development Program goals of achieving 'Industry, Innovation, and Infrastructure' which addresses the main goal of 'Climate Action'.

Keywords: *Innovation, Waste To Green Eco Construction, Sustainable Material, Plastic pollution, Climate Action*

1. INTRODUCTION

My team **EcoGirl** - With research and brainstorming, we came up with the idea of using paddy husk ash and recycled plastic material for the manufacturing of the bricks. We called our innovation 'Waste To Green – Eco construction' . It uses sustainable recycled material to produce construction material.

1.1 PROBLEM STATEMENT

Bricks, Pavement blocks and Roof tiles used in construction is made of either clay or sand. The cost of this materials has been escalating due to the reduction of readily available raw material such as limestone (contained in cement), river sand and clay which are used in the manufacturing of the construction material.

Some of the causes contributing to the environmental issue facing the whole world in the climatic control and the Green-house affects. are due to sand mining and limestone mining which involves the destruction of mountains, its trees, natural habitats, eco-system and erosion of the rivers.

The conventional sand bricks, pavement blocks and roof tiles are made of 1:4 ratio of cement and sand. Some may even use 1:6 ratio for the more inferior quality. This innovation will use sand bricks instead of clay bricks due to the fact that clay bricks involve the burning of the bricks in an oven which increases the residual toxic gases and contributes towards green-house effect.

We are losing almost 21 million hectares per annum of forest due to many reasons. Mining and development contributes towards almost 27% of the loss. **Refer Fig 1.**

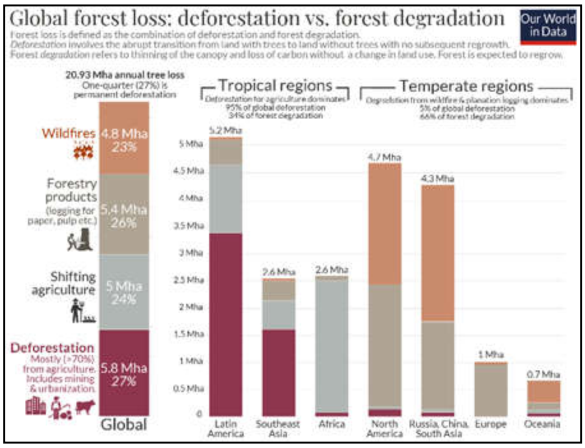

Fig 1. Statistics of global forest loss

Since 1900, the global volume of resources for buildings and transport infrastructure has been increasing by about 2.8% annually, doubling every 25 years. Sand and gravel represent about 79% of this material extraction, almost 29 billion tonnes a year, exceeding fossil fuels and biomass extraction. Nations now mine about 13 billion tonnes of sand annually just for construction. Refer **Fig 2**.

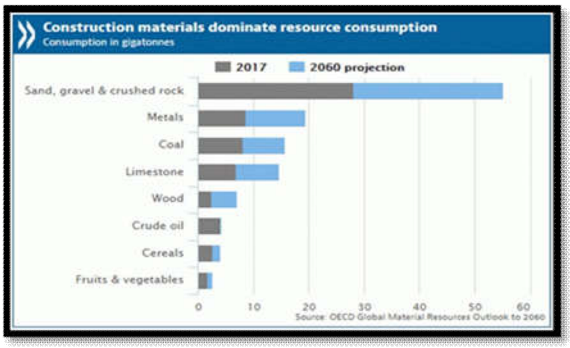

Fig 2. Statistics on Mining

In addition to the sustainability of the resources, the severity of plastic pollution is also increasing. This is not only destroying the marine and land eco system but also contributes towards the greenhouse effect and global warming. Statistics show that almost 8 billion tons of plastic waste is generated every year and is forecasted to reach 25 billion tons by year 2050 if we do not take proactive action. **Refer Fig 3**.

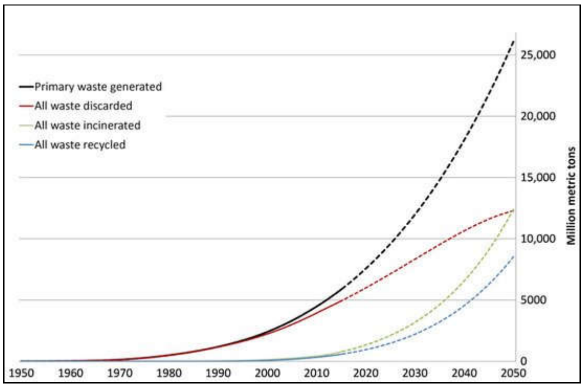

Fig 3. Statistics of plastic waste

Hence the team decided to concentrate on eco-friendly materials and processes where possible. This innovation is also expected to reduce the weight and cost of the construction material.

1.3 RESEARCH AND FINDINGS

With research and brainstorming, we came up with the idea of using paddy husk ash and recycled plastic material for the manufacturing of the bricks. There are many types of plastic materials that are currently being recycled. Some of them include PP (polypropylene), PET (Polyethylene), HDPE (High Density Polyethylene), PVC (Polyvinylchloride) and many more. PP can be obtained from recycled chemical resistance pipes and chairs, PET can be obtained through recycled mineral water bottles, HDPE can be obtained through recycled water pipes and plastic road barriers while PVC can be obtained through recycled Cables and drinking bottles. Our team decided to go for the weakest plastic material PP and the strongest of HDPE which were more readily available. This material was intended to be crushed to produce the same granular like material in replacement of sand. The paddy husk was a suitable replacement for cement due to the high silica content which is much required in replacement of cement.

2.0 METHOD AND EXPERIMENTAL DETAILS

The following processes were involved in the prototyping and testing of the innovation. **Refer Fig 4.**

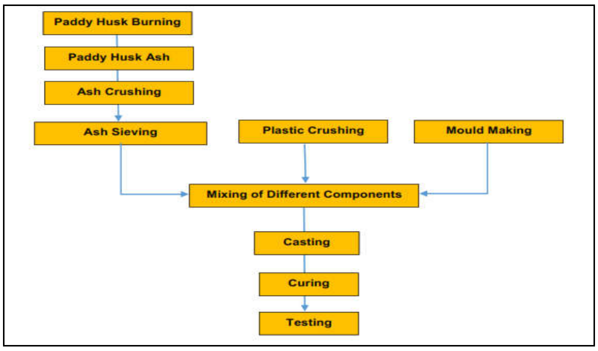

Fig 4. Process Flow diagram

The first step was to burn the paddy husk to ash by burning it above 400ºC but ideally it should have been 700ºC to maintain the silica for maximum reaction. This should have been carried out in a controlled environment such as an incinerator plant with a secondary process burning of up to 850ºC to ensure no toxic gases were released. However, we only had the facility of a metal bin, burning torch, some camphor and petrol to start the fire and burn the paddy husk making sure that it does not turn into carbon by turning them over and over and with watchful eye that the fire does not go out. The gathered ash was blended from coarse grade to fine grade to maximise reaction. Initially we were planning to use full replacement of the ash but due to not able to facilitate control burning temperature and process we decided to use a mixture of cement ash ratio. Once the process of blending was completed the blended paddy husk had to be sieved to remove the ash from the unburned material. The ashes were filtered for carbon and unburned material. Carbon when mixed with the brick mixture may reduce the strength of the material. The second process involved the gathering PP pipes and HDPE water pipes and the crushing of the recycled plastic material. Initially we used a vegetable grater to grate the plastic HDPE pipe and PP pipes which was laborious and time consuming. We managed to engage a friendly recycler who helped us with the crushing. The preparation of the different test specimens included getting ready of Cement, Sand, crushed HDPE material, crushed PP material and crushed and sieved Paddy Husk Ash. The specimens for the different mixtures were prepared with the different ratios and categorized into 3 mixtures: **Refer Fig 4.**

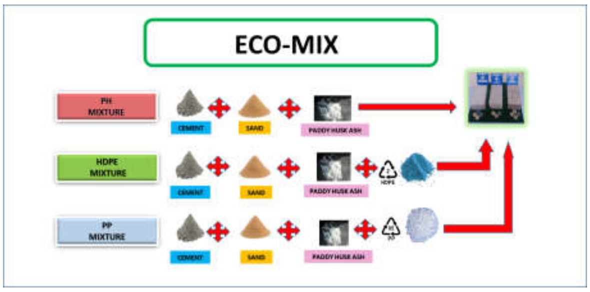

Fig 4. Mixtures of bricks

1. Cement / Sand / Paddy Husk Ash with a mixture *ratios of;* ***1 : 5 : 3*** *and* ***1 : 5 : 4***
2. Cement / Sand / Paddy Husk Ash / HDPE with a mixture *ratio of:* ***1 : 4 : 1 : 4*** *and* ***1 : 4 : 1 : 5***
3. Cement / Sand / Paddy Husk Ash / PP with a mixture *ratio of:* ***1 : 4 : 1 : 4*** *and* ***1 : 4 : 1 : 5***

Our mixture proposal effectively reduces the amount of cement by 50% and sand by approximately 50% which enhance the sustainability of our rivers, mountains, eco-system and reduces the green-house effect.

Prior to mixing the specimens a wooden mould and timber platform was made. The specimens are mixed together with water and poured in a timber mould with flat plywood bed. The bricks were sized to 8 x 4 x 2 ½ inch and tested in line with the General Brick Specifications as per Malaysia Standard MS 7.6: 1972 / British Standard BS 3921: 1985. Refer **Table 1**.

Table 1 - MS 7.6: 1972 / BS 3921: 1985

Specified Dimensions	Overall Dimension of 24 bricks
Height: 65 + 1.875 mm	1560 + 45 mm
Width: 102.5 + 1.875 mm	2460 + 45 mm
Length: 215 + 3 mm	5160 + 75
Minimum Strength (load bearing)	5.2 N/mm2
Absorption	< 20%

A standard measurement mould was created to measure the mixture ratio. A measuring beaker was used but instead we a standard 1 kg Baby's milk tin to measure the different ratios of mixtures in multiples. Each specimen is mixed in a pail with standard measurement following the individual ratios with a hand-drill and a pail.

Each specimen was prepared and casted using the prepared mould in multiples of 9. This is to record results for curing after 7 days, 14 days, 21 days,28 days and also absorption testing.

After 1 day of casting the moulds were removed and the samples were marked with white paint marker indicating the specimen type and testing days. These are then soaked for 7 days, 14 days and 21days for the testing.

To produce good quality of structure, good quality materials are required. To decide the quality of the materials some tests are to be conducted on bricks. Absorption Test, Crushing/ Compression Strength Test and Efflorescence Test is required to determine its suitability for construction works.

Absorption test was conducted on brick to find out the amount of moisture content absorbed by brick under extreme conditions. In this test, sample dry bricks were taken and weighed. After weighing these bricks were placed in water for a period of 24 hours.

Then the weight of the wet brick and note down its value. water absorption should not exceed 10% of weight of dry brick.

Formula for absorption rate:

$$\textbf{\% Absorption} = \frac{\textbf{Mass after - Mass before}}{\textbf{Mass before}} \textbf{ x 100\%}$$

Compression Testing is a very important element of determining the suitability of the bricks for construction. It determines the load carrying capacity of the bricks. The Crushing strength of bricks was determined by placing brick in compression testing machine. After placing the brick in compression testing machine, we apply load on it until the brick broke.

The value of failure load was recorded. Minimum crushing strength of brick should be 2.50N/mm2.

Formula for compression testing:

$$\textbf{Compressive strength} = \frac{\textbf{Load at failure (N)}}{\textbf{Area (mm2)}}$$

The final test would be Efflorescence Test. A good quality brick should not contain any soluble salts in it. If soluble salts are there, then it will cause efflorescence on brick surfaces. To know the presence of soluble salts in a brick, place it in a bowl of minimum size of 200mm x 200mm with water up to a height of

20mm until all traces of water evaporates. The cycle is repeated again until all water evaporates.

The bricks are checked for efflorescence scales or flakings. **Refer Table 2.**

Table 2 – Efflorescence Test Conditions

None/Nil	If there is no noticeable deposit of efflorescence.
Slight	when less than 10% of exposed area of brick is covered by a thin layer of salt.
Moderate	When there is a heavier deposit than under 'slight' and covering up to 50 percent of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surface.
Heavy	When there is a heavy deposit of salts covering 50 percent or more of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surface.
Serious	when there is heavy deposit of salt acquired by powdering and/or flaking of exposed surface.

3.0 RESULTS AND DISCUSSION

3.1 RESULTS

The following tables show the test results recorded for the Absorption Test, Compression Test and Observation of Efflorescence for 3 different mixture types.

Table 3 -Test Results for PP Mixture

Compression Test Results for PH Mixtures (Cement:Sand:Ash)

Ratio	Days	Area (mm²)	Brick 1	Brick 2	Average (N/mm²)
1:5:3	7	20,000	5.57 (111,400N)	5.80 (116,000N)	5.69
	14	20,000	6.50 (130,000N)	6.92 (138,400N)	6.71
	21	20,000	8.14 (162,760N)	8.54 (170,750N)	8.34
	28	20,000	9.64 (192,860N)	10.11 (202,280N)	9.88
1:5:4	7	20,000	5.12 (102,410N)	5.16 (103,210N)	5.14
	14	20,000	6.00 (119,910N)	6.11 (122,200N)	6.06
	21	20,000	7.83 (156,600N)	7.91 (158,150N)	7.87
	28	20,000	8.99 (179,820N)	8.78 (175,610N)	8.87

Table 4 -Test Results for HDPE Mixture

Compression Test Results for HDPE Mixtures (Cement:Sand:Ash:HDPE)

Ratio	Days	Area (mm²)	Brick 1	Brick 2	Average (N/mm²)
1:4:1:4	7	20,000	2.25 (45,000N)	2.25 (45,000N)	2.25
	14	20,000	2.65 (53,000N)	2.58 (51,600N)	2.62
	21	20,000	2.90 (57,540N)	2.72 (54,570N)	2.81
	28	20,000	3.21 (64,210N)	3.00 (59,920N)	3.10
1:4:1:5	7	20,000	2.41 (48,210N)	2.38 (47,600N)	2.40
	14	20,000	2.70 (54,000N)	2.72 (54,400N)	2.71
	21	20,000	3.02 (64,000N)	3.10 (62,000N)	3.06
	28	20,000	3.35 (67,000N)	3.48 (69,600N)	3.41

Table 5 -Test Results for PH Mixture

Compression Test Results for PP Mixtures (Cement:Sand:Ash:PP)

Ratio	Days	Area (mm²)	Brick 1	Brick 2	Average (N/mm²)
1:4:1:4	7	20,000	0.40 (8,000N)	0.47 (9,400N)	0.44
	14	20,000	0.44 (8,800N)	0.57 (11,400N)	0.49
	21	20,000	0.60 (11,790N)	0.63 (12,790N)	0.62
	28	20,000	0.81 (16,230N)	0.82 (16,440N)	0.81
1:4:1:5	7	20,000	0.42 (8,400N)	0.44 (8,800N)	0.43
	14	20,000	0.46 (9,200N)	0.44 (8,800N)	0.45
	21	20,000	0.66 (13,200N)	0.65 (13,000N)	0.66
	28	20,000	0.88 (17,600N)	0.85 (17,000 N)	0.87

3.2 DISCUSSSION

The PH bricks had the highest compression strength with an average compression strength of 9.88N/mm2 and the HDPE bricks had a compression strength of 3.10N/mm2. The weakest brick was the PP bricks with only 0.81N/mm2. The HDPE bricks had the best absorption rate of 10%. PH bricks had 13% absorption rate. PP absorption rate exceeded 20%. All PP, PH and HDPE showed no signs of Efflorescence.

Table 5– Comparisons of Results

MIXTURE	COMPRESSION STRENGTH	ABSORPTION RATE	EFLORESCENCE
PH	HIGH	MEDIUM	NONE
HDPE	MEDIUM	LOW	NONE
PP	VERY LOW	VERY HIGH	NONE

4.0 CONCLUSION

All materials can be used for construction. Except that, due to the strength and absorption rate the PP bricks cannot be used for load bearing walls. The PH bricks can be used for this purpose. **Table 6** below shows the different application for the different mixtures types.

Table 6 – Practical application

PH mixture	HDPE mixture	PP mixture
Roof Tiles	Pavement Blocks	Garden Patios
House Brick walls	Decorative Walls < 5 feet	Hardscape

The pandemic and funds have restricted us from further proceeding in our venture in using these material for future innovations. **EcoGirls** are planning to use the different composition of the material in the production of other construction materials such as:

1. Cement Bricks (Eco-bricks)
2. Concrete Roof Tiles (Eco-Roof tiles)
3. Pavement Blocks (Eco-pave)
4. Floor/ Wall Tiles (Eco-Tiles)

We are also planning to use other organic and non-organic material to produce innovative products using sustainable recycled material.

Examples of recycled Raw Organic Material include paddy husk, sugar cane husk, jut straws, banana skin, potato skin and recycled paper. Examples of Non-Organic Material can include recycled plastic, recycled Oil and recycled construction waste.

5.0 ACKNOWLEDGEMENT

We acknowledge and thank our Mentor, Mr.Surendran Veerasamy for guiding us with the innovation and technical requirements. We thank our teacher and supervisor Mrs.Gan Bin Hoon for spending her time and effort in training us, improving our presentation and analytic thinking. We also like to thank Manipal University Nilai, Malaysia for allowing us to use their Material Testing Laboratory to carry out some of the tests. Finally, we are grateful for the advise and collaboration provided by Universiti Putra Malaysia (UPM).

Our effort and innovation has been recognized by the following National and International achievements:-

[1] Platinum award - International Summit on Innovation & Design Exposition (University of Malaya)

[2] Gold Medal - Asia- Pacific Con-ference of Young Scientist (APCYS2021) - Mexico

[3] Gold Award - Malaysia International Young Scientist Conference & Exhibition (MYSE)

[4] Gold Medal - The 5th International Innovation, Design and Articulation - UTM Perlis (i- IDeA) and Special awards by UNIZA Trengganu

[5] Gold Medal - International festival innovation on green technology (i-FINOG)

[6] Gold Medal - International STEM Teaching & Educational Manipulatives Festival (Taylor's University)

[7] Gold Medal - Pertandingan Inovasi Cilik Bestari (PICB) National Level

[8] Gold Medal - Online Recycling Idea Competition (ORIcom) National Level

[9] Gold Medal - Inovasi Made in Malaysia- Agensi Nuklear Malaysia

[10] Silver Medal - Pertandingan Inovasi Teknologi Hijau National level (UPM)

[11] Bronze Medal - International Innovation Competition - USIM (INNOCOM)

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