Utilization Of Sand and Plastic as Substitute Material to Lego-Inspired Blocks

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Abstract: - A shortage of qualified employees, delayed adaptation to new technologies, and increased environmental concerns are among the current engineering structure construction challenges. In construction, employees must have certain amount of knowledge on constructions for them to be employed. The construction industry's productivity and economic benefits have been significantly impacted as a result of these challenges. Plastic is a common material that is utilized all over the world. It is a kind of material that takes a century to decay making it durable. It also has a binding property when exposed to heat and it gets harder after cooling down. Plastic waste can be used to reduce the cost of construction materials and procedures such as hollow blocks while preserving their strength. The study's major purpose is to present and demonstrate the use of sand and plastic as substitute materials for Lego-inspired blocks. Sand and plastic were combined in the design of the Lego-inspired blocks, using an experimental and comparative research technique. In addition to the researchers' tests, the Lego-inspired block was sent to the Unified Geotest Lab to determine the product's effectiveness and efficiency. After discussion and confirmation, the researchers concluded that the Lego-inspired block requires less curing time than hollow blocks. Because of its unique construction method, the time and effort necessary for construction may be decreased. It means that an employee doesn't need much knowledge since stacking a Lego is a very simple task to do. This also means that the blocks can be used in any emergency cases where blocks are of immediate requirement. As a result, the Lego-inspired block's output can be a beneficial reference for future studies and industrial enterprises looking to use them as a hollow block substitute.

Key Words: Sand, Plastic, Lego-inspired blocks.

I. INTRODUCTION

In construction enterprises, large quantities of construction materials are required. Hollow blocks are one of the most common materials. Hollow blocks are utilized to support the structure by forming walls.

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Due to that reason, construction companies usually buy a great quantity of it when erecting a building or establishment, but most of the blocks are breaking even while cautiously holding it, thus wasting some blocks each construction. In addition, even without caution, construction consumes a lot of time, especially when waiting for the cement to reach its best mix and texture instead of continuously stacking blocks without any time lag.

Due to the use of construction materials, precast has proven remarkable success in accelerating building construction in concrete construction, increasing construction sector productivity, safety, and economic and environmental benefits. Despite its success, Aremu (2017) stated that a precast technique has downsides; such as (1) The precast units may be damaged during transport if they are not handled appropriately,

(2) Producing suitable connections between the precast parts becomes tough, (3) Lifting and moving the precast units will necessitate the use of specialized machinery and lastly, (4) The savings made in precast construction are largely offset by the cost of transporting and processing precast members. as a result, earlier research has introduced the creation of interlocking blocks. By building a prototype footbridge, the preliminary design of the blocks was confirmed, and it demonstrated reasonable loading carrying capabilities and sturdiness to external mechanical loading. (Y. Bao & V. Li, 2020).

According to the site worldbank.org, Every year, the Philippines generates 2.7 million tons of plastic waste, with an estimated 20% of it ending up in the ocean. Based to the site emb.gov.ph, shows that the yearly amount of waste in the country rises from 13.48 million tons in 2010 to 14.66 million tons in 2014 and 16.63 million tons in 2020. In the recent years, many studies have been conducted so that possible alternatives will be given attention. However, even though solar energy comes froma free source, the materials needed to produce a decent solar panel is expensive. Hence, the development of cheaper yet effective materials in converting sunlight intoelectricity means a great way to help the lives of people, especially those living in remote areas where there is no electricity.

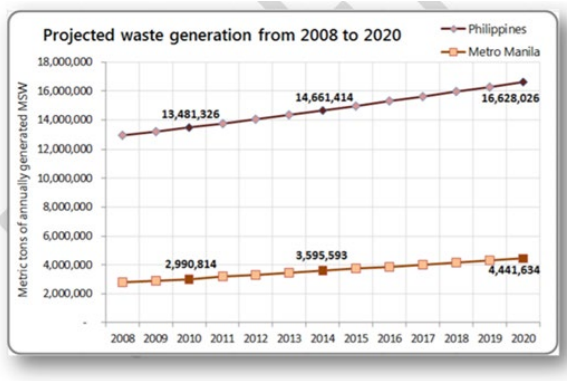


Fig.1. Project waste generation: 2008-2020 (metric tons per year)

Plastic is a common material that is utilized all over the world. It is a kind of material that takes a century to decay making it durable. It also has a binding property when exposed to heat and it gets harder after cooling down. Though in contrast, tons, and tons of it are mostly one-time used and it is quickly disposed of without any thoughts of recycling. With this, plastic wastes have piled up more and more throughout the years. That's why people have thought of ways to incorporate plastics into other things and not just simply recycle or reuse them; some of them are used as materials to make chairs and other furniture.

In a recent study by da Silva et al. (2021), they have examined that employing plastic wastes in the manufacturing of primarily cement-based materials has several advantages. Among the most important are the following: (1) Construction supplies are less expensive. Because plastic is a waste product with high storage costs, it is particularly inexpensive to recycle and reuse in comparison to other materials. The financial benefits are numerous, including very low raw material prices for recycling plants, very low processed raw material prices for construction material manufacturing plants, and decreased dump maintenance costs for plastic waste recycling companies. (2) Improving the characteristics of recycled plastic-based materials. In comparison to traditional cement composites, plastic-based materials have no lower strength metrics. Their absorbability is primarily poor due to the low absorbability of plastic waste. Plastic-based construction materials have higher resilience to bio-corrosion. (3) Plastic waste has low transportation expenses.

Moreover, According to Lenkiewicz and Webster (2017), You can use a variety of construction materials to make a cheaper version of concrete. They set rapidly and are durable. You can manufacture floor or paving tiles, as well as bricks for walls, depending on the mold. The theory of an interlocking system has been frequently employed as an alternative to a conventional system. The interlocking brick form, it may be said, varies with simplicity, resulting in simple and quick design and installation in building systems. Apart from that, all sorts of interlocking block interlocking systems can interlock the generated blocks in different positions. They found that the interlocking bricks meet the basic specifications and requirements of the British and American standards based on their research into the structural behavior of interlocking bricks. It has also been shown that interlocking bricks can be used as either load-bearing or non-load-bearing wall (Amin Al-Fakih et al., 2018).

It was also discussed in a previous study by A. Sajad et al. (2014) that Interlocking blocks have numerous advantages over other types of construction materials. Interlocking blocks' main characteristics are (a) When compared to traditional bricks; interlocking blocks have a very high compressive strength. (b) In comparison to traditional bricks, these blocks have a very high bearing capacity. (c) The interlocking block has a substantially lower effective cost per unit than bricks covering the same area. (d) The procedure of making these blocks is simple and easy. And lastly, (e) There is no need for mortar

during the adhesion of a single block since the compressive strength remains the same whether mortar is used or not.

In line with the aforecited information, the researchers found that plastic waste can be used to reduce the cost of construction materials and procedures such as hollow blocks while preserving their strength. The researchers came up with the idea of introducing the Utilization of sand and plastic as substitute materials for Lego-Inspired Blocks which is an eco-friendly, sustainable, innovative, and cost-and-time effective method in construction. Using the plastic sand interlocking blocks will lessen the cost of buying ordinary hollow blocks and at the same time, it will save time due to its unique method of construction that doesn't need time for the mortar to harden as Lego-Inspired Blocks made with plastic and sand will only need to be stacked to construct. Hence this project intends to study the possibility of using sand and plastic as substitute materials in the development of Lego-Inspired Blocks.

II. METHODOLOGY

This chapter presents the research method which contains the research design, data collecting, and data analysis. The purpose of the study is to utilize sand and plastic as substitute materials to Lego-Inspired Blocks through experimentation. This study sought to answer the following queries: (1) Is it possible to use plastic as a binder while building Lego-Inspired Blocks? (2) Is it possible that you can save money by constructing a concrete structure when you use plastic and sand-filled Lego-Inspired Blocks? (3) Does the Lego-inspired Blocks composed of sand and plastic have the same durability as regular hollow blocks?

2.1. Research Design

The main goal of the research study was to introduce and showcase the utilization of sand and plastic as substitute materials for Lego-inspired blocks. The research employs an experimental and comparative research approach where sand and plastic were integrated into the design of the Lego-inspired blocks. To identify the effectiveness and efficiency of the product, the Lego-inspired block was sent to the Unified Geotest Lab and was done by the researchers. The data collected were tabulated and compared to the properties of regular hollow blocks. The results upon comparison showed the advantages of the Lego-inspired blocks against regular hollow blocks. The researchers have decided to use three (3) different ratios of sand and plastic in terms of mass. The ratio of sand and plastic present in the Lego-inspired blocks was controlled to be 60 percent of plastic and 40 percent of sand, Since the CE-Laboratory on the main campus is currently unavailable due to the pandemic the researchers experimented with one of the researcher's homes.

2.2. Procedure

2.2.1 Materials and Equipment

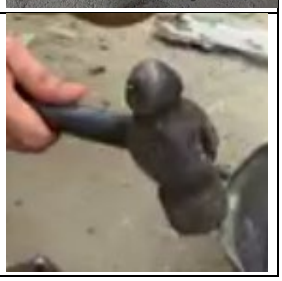
Materials

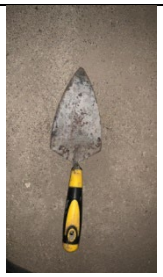
Table 1: Materials in making Lego-Inspired block

Sand – Manufactured sand taken from the backyard of one of the researchers and sieved to the desired size.	
Plastic – PET bottles and large sack of plastic that use to hold junk foods and biscuits. Cut into little pieces to aid melting process.	

Equipment

Table.2. Equipment in making Lego-Inspired block

Wok - a bowl-shaped frying pan used typically in Chinese cooking.	
Gas Stove - a stove that uses natural gas as a fuel source.	
Mold - pincers with parallel, flat, and typically serrated surfaces, used chiefly for gripping small objects or bending wire.	
Hammer - a hand tool, consisting of a weighted "head" fixed to a long handle that is swung to deliver an impact to a small area of an object.	

Tape measure - is a flexible ruler used to measure size or distance. It consists of a ribbon of cloth, plastic, fiber glass, or metal strip with linear measurement markings.	
Weighing scale - is a device used to measure weight or mass. These are also known as mass scales, weight scales, mass balances, and weight balances.	
Chisel - is a device used to measure weight or mass. These are also known as mass scales, weight scales, mass balances, and weight balances.	
Wire mesh - an arrangement of interlocking metal links or wires with evenly spaced, uniform small openings between	
Hand Shovel - an arrangement of interlocking metal links or wires with evenly spaced, uniform small openings between	
Shovel - a tool with a broad flat blade and typically upturned sides, used for moving coal, earth, snow or other material.	

2.2.2 Gathering of Materials

The research focused on the two primary raw materials, which are plastic and sand. The plastic was collected in the household of the researchers which are the plastic bottled from beverages and plastic from the packaging of the foods. For the sand, the researcher used manufactured sand that is available on any construction hardware that is abundant and readily available.

2.2.3 Preparation of Materials Gathered and Sample

The obtained plastic and sand were undergoing to different process. The plastic was cut into small pieces no larger than 2 inches with the use of a pair of scissors to ensure that every part of the plastic melted. On the other hand, sand was sieved 4.75 mm with the use of a manual sand sieving stand. The ingredients are ready to be used in the following step.

2.2.4 Creating mold use

The researchers created a mold for the Lego-inspired Blocks. The mold dimension is 400 mm x 200 mm x 200 mm and made of a steel plate and looked like Lego-Inspired Blocks via a welding machine *Figure 2: 3D model of the mold*

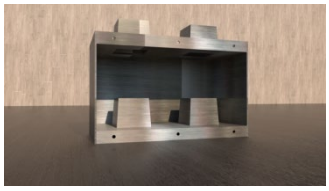
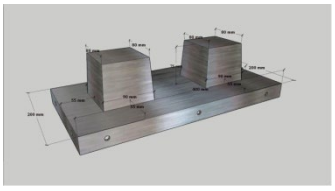
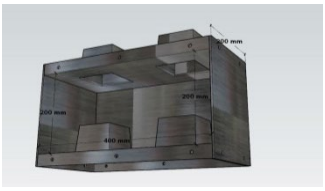


Fig. 3&4: Dimension of the top & body portion of the mold





2.2.5 Production of Material

When the cut plastic and sieved sand are ready, the wok (kawa) is ready to heat then the sand is place to heat too. Once, the sand is heated gradually add the plastic and stir it well until the desired consistency is achieved. Next, the heated material is placed into the mold and compacted via hammer, and let cool. If no adjustments are required, the samples would be tested in the Unified Geotest Lab the day after the sample is created, simply 1 day curing and ready for testing since there is no code/provision regarding the curing process of plastic and sand mixture and it's not like cement mixture that needed to be under in curing process of 28 days.

The researchers are required to provide 4 samples of Lego-Inspired Blocks for the following test: Flexural strength test, Compressive strength test, Drop test, and Chisel test with dimensions of 200 mm x 120 mm x 100 mm, 50 mm x 50 mm x 50 mm, 400 mm x 200 mm x 200 mm, and 200 mm x 120 mm x 100 mm respectively. The molds are assembled via bolts on

each side. Then put some oil (changed oil from a motor) into the molds preventing the mixture to stick strongly bind to it.

Figure 5: Assembling the mold

Figure 6: Putting oil

The researchers start by preparing the raw materials to be used which are sands and plastics. The plastics are cut into small pieces using a pair of scissors while the sand is undergoing sieving for a wire mesh and drying under the sun. Where the 60% plastics weigh 12.36 kg and for the 40% sands weigh 8.24 kg. (For the detailed computation of the ratio of sand and plastic please refer to appendix C).

Figure 7: Cutting the plastics

Figure 8: Sieving the sand

Afterward, the researchers prepared the stuff to be used in the cooking of the mixture. The wok (kawa) is heated up, and the sand was gradually added and stirred until it is heated too. Once the sand is heated, start adding the plastics and stir until the plastic melts and binds to the sand, and add again the sand and plastic gradually until the consistency is achieved.

Figure 9: Adding the sand

Figure 10: Cooking the mixture

Once the mixture is ready it is now put in place in the molds and start the compaction. Lastly, it is cooled and hardened for 24 hours then it is ready to remove from the molds.

Figure 11: Placing on the mold

Figure 12: Compaction

Outcomes;

Figure 13: 50 mm x 50 mm x 50 mm sample block

Figure 13: 50 mm x 50 mm x 50 mm sample block

Figure 14: 200 mm x 120 mm x 100 mm sample block

Figure 15: 400 mm x 200 mm x 200 mm sample block

Figure 16: Interlocking of Lego-Inspired Blocks

As the final output of a Lego-inspired blocks with a dimension of 400 mm x 200 mm x 200 mm it weighs of 20.6 kg.

2.2.6 Material Testing

In a previous study by Alaloul W. et al. (2020), the interlocking was tested for compressive strength, impact, and flexural strength, the test data were placed into the Response Surface Methodology (RSM) to assess dependability. PET (polyethylene terephthalate), in a 60/40 ratio is allowed for use as a non-load bearing masonry brick and as partition walls, according to the findings. Where, PET is a clear, strong, and lightweight plastic that is widely used for packaging foods and beverages, especially convenience-sized soft drinks, juices, and water.

Therefore, the sample will be sent to the Unified Geotest Lab for testing, which will include compressive, and flexural

strength tests. The researchers then examined the samples for the drop test and chisel test.

2.3. Data Analysis

The previous researchers determined the various qualities of bricks by performing various tests on them. Compression and water absorption tests are the most common tests performed on blocks by numerous investigators. However, the usage of such bricks in the industry is quite limited. The researchers are making it easier for users to utilize such bricks and encourage them to be used more. Plastic waste is used as a binder in the production of Lego-Inspired Blocks. The impact of adding plastic trash on strength qualities, water absorption, and durability, among other things, would be discussed. (Sadek, D., 2011).

The Universal Testing Machine (UTM), which would acquire from the Unified Geotest Lab's test, would be used to assess compressive strength and flexural strength. The remaining data were acquired using a variety of tests.

2.3.1 Flexural Strength

According to ASTM C31/C31M – 19 (Standard Practice for Making and Curing Concrete Test Specimens in the Field), the specimen for the flexural strength test shall be hardened in the horizontal position. The minimum cross-sectional dimension of the specimen shall be as stated in the specification. Unless otherwise specified by the specifier of tests, the standard specimen shall be 150 by 150 mm [6 by 6 in.] in cross-section. But it is also stated that the specifier of tests must provide the specimen dimension and the number of specimens to be tested to obtain the flexural test result. So, as per the requirements of the Unified Geotest Lab for the flexural strength test of the Lego-inspired blocks, the dimensions of the block should be 200 mm in length, 120 mm in depth, and 100 mm in width.

According to Ametek Co., flexural testing is performed to determine a material's flex or bending qualities. It entails inserting a sample between two points or supports and beginning a load with a third point or with two points, which is referred to as 3-Point Bend and 4-Point Bend testing, respectively. The maximum flexural load and maximum flexural stress of the Lego-inspired Blocks and the regular hollow blocks before fracture would be compared to determine flexural strength. The specimen would be placed in the testing equipment and a focused bending load delivered to the specimen's center. The Universal Testing Machine would be used to conduct the test. (ASTM D1037-12)

Figure 17: Sample from Unified Geotest Lab with a dimension of 200mm x 120mm x 100mm

Figure 18: Mold for flexural test specimen with a dimension of 200mm x 120mm x 100mm

2.3.1.1 Machine to be used

Universal Testing Machine for Flexural Strength Test. A universal testing machine for flexural strength is used to determine the flexural strength of concrete beams, curbs, interlocking pavers, flagstones, and various-sized blocks. Moreover, flexural testing machines are used to assess a material's flexural modulus or flexural strength. The sample specimen is horizontally placed over two points of contact (lower support span), and a force is applied to the top of the specimen through one or two points of contact (upper loading span) until it fails. The flexural strength of that sample taken is represented by the maximum recorded force.

The tensile strength of concrete is evaluated indirectly using the flexural test. It determines if an unreinforced concrete beam or slab can sustain bending failure. The results of a concrete flexural test are expressed as a modulus of rupture (MR) in MPa or psi. The three-point load test (ASTM C78) or the center point load test can be used to perform flexural tests on concrete (ASTM C293). The center point load test was performed to identify the flexural strength of the Lego-inspired blocks.

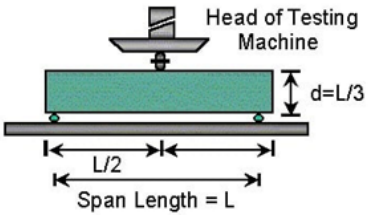


Figure 19: Center point load test

2.3.1.2 Process

How does Universal Testing Machine for Flexural Strength Test work?

- The first step is to start the machine and insert the sample specimen to be evaluated. The following are the tasks that must be completed to complete the test:
- Selecting test parameters such as the test rate (only required when the specimen type is changed).
- Press the START button on the control unit.
- If the specimen fails, the machine begins a rapid approach, shifts the test speed after 1 percent of the machine's load capacity, and then stops.
- Test parameters and results are saved automatically.

Figure 20: *Actual photos of UTM for Flexural Strength in Unified Geotest Laboratory*

2.3.2 Compressive Strength

A universal testing machine for flexural strength is used to determine the flexural strength of concrete beams, curbs, interlocking pavers, flagstones, and various-sized blocks. Moreover, flexural testing machines are used to assess a material's flexural modulus or flexural strength. The sample specimen is horizontally placed over two points of contact (lower support span), and a force is applied to the top of the specimen through one or two points of contact (upper loading span) until it fails. The flexural strength of that sample taken is represented by the maximum recorded force.

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2.3.2.1 Test Procedure in Compressive Strength Test

According to the website, www.civilengineeringforum.me, the following is the test procedure for executing the compressive strength test on concrete blocks.

Step 1: Measure the length and width of the specimen that will be loaded.
Step 2: Place the specimen in the proper test machine location. Note that the weight will be applied perpendicular to the casting direction.
Step 3: Align the specimen in the center of the machine's base plate.
Step 4: Make the machine's moveable portion touch the specimen's top surface.
Step 5: Gradually increase the load to 140 kg/cm2/minute until the specimen fails.
Step 6: Record the maximum load.

2.3.3. Drop Test

A drop test is the most basic method of determining a construction block's strength. Drop the block on the hard ground surface at a height of 4 to 4.5 feet, which is closer to your chest level. After crushing over the ground surface, the concrete block should be in good shape with no damage. If the sample block splits into pieces or develops a crack, the concrete block is not in good shape and failed the test.

Procedure:

1. Lift the block at about 4 – 4.5 ft. which is nearer to your chest level and drop it on the hard ground surface.

2. Vertical Drop: The length of the block should be kept in a vertical position before dropping it on the ground. The concrete block should be intact in shape without any damage after crushing over the ground surface. If the sample block breaks into pieces or develops a crack, then it is better to reject such concrete blocks.

2.3.4. Chisel Test

Using a chisel, cut a groove into the solid concrete blocks that run horizontally on all four sides of equal depth. It should be cut through the middle of the block until it splits into two parts. If the sample block is difficult to chisel and cutting it out takes a long time, it indicates that the block is of good quality. If the block splits into multiple parts during this process, it indicates that the block is weak.
In this test, you will find the quality of the blocks by the two actions.

2.3.4.1. Hardness

If it is harder to chisel the block and if it takes more time for cutting out in comparison to all other sample blocks, then it gives you a hint that the blocks of that particular batch are of good quality.

2.3.4.2. Breakage

If the block breaks into several pieces at this process, then it is better to drop that batch of the block from your list.

2. 3.5 Cost Analysis

Tabulated below is the cost analysis in generating a 400 mm x 200 mm x 200 mm in Lego-Inspired Block:

- **COSTING SHEET**

Name : **Lego-Inspired Blocks**

Unit Weight (kg): **20.6**

Production in a year (pcs): **24528**

Unit cost per block : **PHP 21.182**

Table 3: Fixed Cost

	Item No.	Item Description	Unit	Qty.	Unit price	rate	Amount
Fixed Cost	1	Mold	piece	1	2000	0.082	0.082
	2	Wok (kawa)	piece	1	1100	0.045	0.045
	3	Gas Stove Burner	piece	1	1290	0.053	0.053
						Sub total:	0.179

Table 4: Variable cost

	Item No.	Item Description	Unit	Qty.	Unit price	rate	Amount
Variable Cost	1	Solane	tank	20.44	879	0.036	0.733
						Sub total:	0.733

Table 5: Direct cost

	Item No.	Item Description	Unit	Qty.	Unit price	Amount
Direct Cost	1	Sand	kg	8.24	0.96	7.910
	2	Plastic	kg	12.36	1	12.36
					Sub total:	20.270

- **COMPUTATION**

Table 6: Computation

Details per block

	Direct cost details			Variable cost details			Fixed cost details	
No.	Item	Qty/Unit	No.	Item	Price/Unit	No.	Item	Qty/Unit
1	Sand	8.24 kg	1	Solane	879 pesos	1	Mold	2000 pesos
2	Plastic	12.36 kg				2	Wok (kawa)	1100 pesos
						3	Gas Stove Burner	1290 pesos

Solving the total production in a year

Where,

>> Capacity of solane gas is 300 hours per tank, S

>> 8760 hours, total hours in a year = 24 hours in a day x 365 days in a year

>> 6132 hours use in cooking in a year = only 70% of the total hours in a year will be used, Hc

>> 1 hour need for the production of 4 Lego-Inspired Blocks, P

Total production of blocks per year

$$= H_c \times P$$

$$= 6132 \text{ hours} \times \frac{4 \text{ Blocks}}{1 \text{ hour}}$$

$$= 24,528 \text{ blocks in a year}$$

Number of Solane will be use in a year

$$= \frac{H_c}{S}$$

$$= \frac{6132 \text{ hours}}{\frac{300 \text{ hours}}{\text{tank}}}$$

$$= 20.44 \text{ tanks}$$

- The mold, wok (kawa), and gas stove burner are fixed assets in the production of 400mm x 200mm x 200mm Lego-inspired blocks. The fixed cost expected lifetime is one year. The material that is being used for the variable cost of producing Lego-inspired blocks is gas solane. Within each batch, the variable cost of the gas solane was calculated.
- For direct cost of the raw materials in producing the Lego-inspired block, sand and plastic were being used. As observed in the cost analysis, the amount of raw materials used was not based on factory price because they were only purchased for the sample manufacturing, which resulted in an excessively high unit cost for Lego-inspired blocks.

III. RESULTS AND DISCUSSION

3.1 Result from Flexural Strength Test

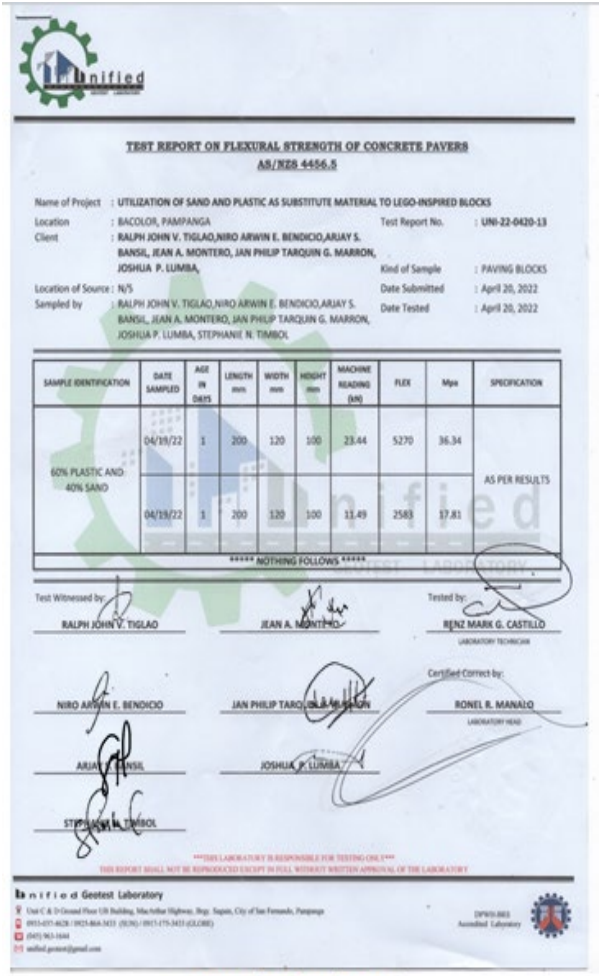
The researchers made a sample of sand and plastic Lego-inspired blocks with a dimension based on the personnel of Unified Geotest Laboratory, of 200 mm x 120 mm x 100 mm in testing the sample for the Flexural strength test.

The center load point test was carried out to obtain the flexural strength of the Lego-inspired blocks according to ASTM C293. This test used a rectangular prism specimen with a dimension of 200 mm in length, 120 mm in depth, and 100 mm in width. The specimen is comprising 60% plastic and 40% sand, with 1 day age (curing day(s)).

As shown in the table, the flexural strength of plastic and sand interlocking blocks ranges from 17.81 MPa to 36.34 MPa with an average of 27.075 MPa. The flexural strength of the Lego-inspired block obtained in the test was too high compared to hollow blocks with a value of 0.46 MPa and 0.28 MPa for solid blocks. According to Rastandi (2018), the addition of crushed polypropylene plastic waste gives significant improvement to the shear strength and flexural strength of concrete, by adding 0.5 percent and 0.7 percent crushed plastic waste, the appropriate value increases concrete shear strength and concrete flexural strength by 43 percent and 17 percent, respectively. Since the specimen is comprising 60% of plastic, it contributed to the increased flexural strength of the Lego-inspired blocks. Therefore, the sand and plastic Lego-inspired block passed the flexural strength test to be a substitute for a hollow block.

Table.1. Flexural Strength of Hollow Blocks, Solid Blocks, and Lego-inspired Blocks

Flexural Strength Test Result (MPA)		
Hollow blocks	Lego-inspired blocks	Solid blocks
0.46	27.075	0.28



TEST REPORT ON FLEXURAL STRENGTH OF CONCRETE PAVERS
AS/NZS 4456.5

Name of Project : UTILIZATION OF SAND AND PLASTIC AS SUBSTITUTE MATERIAL TO LEGO-INSPIRED BLOCKS
Location : BACOLOR, PAMPANGA
Client : RALPH JOHN V. TIGLAO,NIRO ARWIN E. BENDICIO,ARJAY S. BANSIL, JEAN A. MONTERO, JAN PHILIP TARQUIN G. MARRON, JOSHUA P. LUMBA,
Location of Source : N/S
Sampled by : RALPH JOHN V. TIGLAO,NIRO ARWIN E. BENDICIO,ARJAY S. BANSIL, JEAN A. MONTERO, JAN PHILIP TARQUIN G. MARRON, JOSHUA P. LUMBA, STEPHANIE N. TIMBOL
Test Report No. : UNI-22-0420-13
Kind of Sample : PAVING BLOCKS
Date Submitted : April 20, 2022
Date Tested : April 20, 2022

SAMPLE IDENTIFICATION	DATE SAMPLED	AGE IN DAYS	LENGTH mm	WIDTH mm	HEIGHT mm	MACHINE READING (kN)	FLEX	Mpa	SPECIFICATION
60% PLASTIC AND 40% SAND	04/19/22	1	200	120	100	23.44	5270	36.34	AS PER RESULTS
	04/19/22	1	200	120	100	11.49	2583	17.81	

***** NOTHING FOLLOWS *****

Test Witnessed by: RALPH JOHN V. TIGLAO, JEAN A. MONTERO
Tested by: RENZ MARK G. CASTILLO, LABORATORY TECHNICIAN
Certified Correct by: RONEL B. MANALO, LABORATORY HEAD
NIRO ARWIN E. BENDICIO, ARJAY S. BANSIL, JAN PHILIP TARQUIN G. MARRON, JOSHUA P. LUMBA, STEPHANIE N. TIMBOL

THIS LABORATORY IS RESPONSIBLE FOR TESTING ONLY
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT WRITTEN APPROVAL OF THE LABORATORY

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(045) 963-3644
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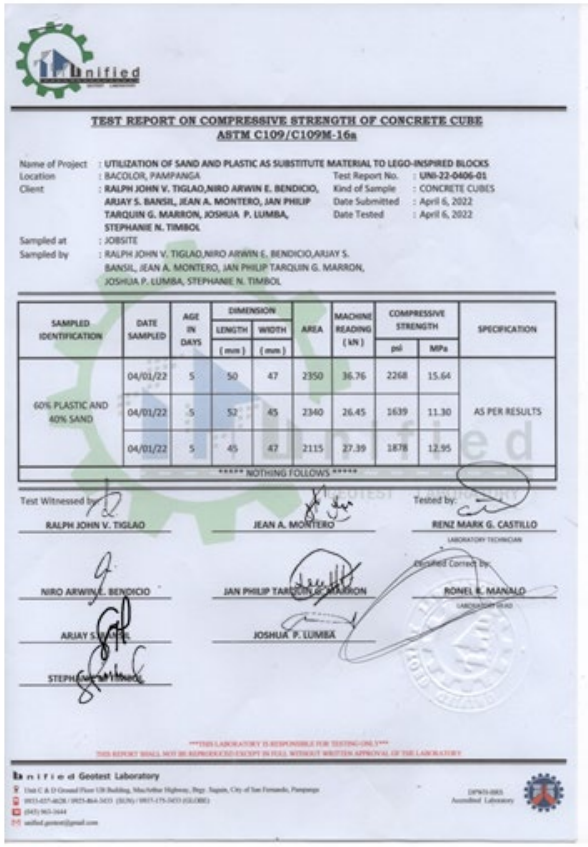
DPWH-BRS Accredited Laboratory

Figure 21: Flexural Strength Test Result



TEST REPORT ON COMPRESSIVE STRENGTH OF CONCRETE CUBE
ASTM C109/C109M-16a

Name of Project : UTILIZATION OF SAND AND PLASTIC AS SUBSTITUTE MATERIAL TO LEGO-INSPIRED BLOCKS
Location : BACOLOR, PAMPANGA
Client : RALPH JOHN V. TIGLAO,NIRO ARWIN E. BENDICIO, ARJAY S. BANSIL, JEAN A. MONTERO, JAN PHILIP TARQUIN G. MARRON, JOSHUA P. LUMBA, STEPHANIE N. TIMBOL
Sampled at : JOBSITE
Sampled by : RALPH JOHN V. TIGLAO,NIRO ARWIN E. BENDICIO,ARJAY S. BANSIL, JEAN A. MONTERO, JAN PHILIP TARQUIN G. MARRON, JOSHUA P. LUMBA, STEPHANIE N. TIMBOL
Test Report No. : UNI-22-0406-01
Kind of Sample : CONCRETE CUBES
Date Submitted : April 6, 2022
Date Tested : April 6, 2022

SAMPLED IDENTIFICATION	DATE SAMPLED	AGE IN DAYS	DIMENSION LENGTH (mm)	DIMENSION WIDTH (mm)	AREA	MACHINE READING (kN)	COMPRESSIVE STRENGTH psi	COMPRESSIVE STRENGTH MPa	SPECIFICATION
60% PLASTIC AND 40% SAND	04/01/22	5	50	47	2350	36.76	2268	15.64	AS PER RESULTS
	04/01/22	5	52	45	2340	26.45	1639	11.30	
	04/01/22	5	45	47	2115	27.39	1878	12.95	

***** NOTHING FOLLOWS *****

Test Witnessed by: RALPH JOHN V. TIGLAO, JEAN A. MONTERO
Tested by: RENZ MARK G. CASTILLO, LABORATORY TECHNICIAN
NIRO ARWIN E. BENDICIO, JAN PHILIP TARQUIN G. MARRON, ARJAY S. BANSIL, JOSHUA P. LUMBA, STEPHANIE N. TIMBOL
Checked Correct by: RONEL B. MANALO, LABORATORY HEAD

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Figure 22: Compressive Strength Test Result

3.2 Result from Compressive Strength Test

The researchers made a sample of sand and plastic Lego-inspired blocks with a dimension of 50mm x 50 mm x 50 mm (2" x 2" x 2") cube that was recommended by the UniFied Geotest Laboratory in testing the sample for the compressive strength test. The following data shows the result of the test.

Table.2. Compressive Strength of Hollow Blocks, Solid Blocks, and Lego-inspired Blocks

Compressive Strength Test Result (MPA)		
Hollow blocks	**Lego-inspired blocks**	**Solid blocks**
8.56	15.64	3.35

Based on the results shown on the compressive strength test conducted by the Unified Geotest Laboratory with a sample of 60% plastic and 40% sand mixture on 5 days of age (curing days) on a 50mm x 50 mm x 50 mm (2" x 2" x 2") cube dimension. Table 2 shows the comparison between the regular blocks and solid blocks which is standard for industrial constructions, according to Hasan et al. (2021), the compressive strength of hollow blocks is 8.56 MPa while solid blocks are 5.35 MPa. When compared to hollow blocks, the compressive strength of Lego-inspired interlocking blocks developed in the study is comparatively high, with a value of 15.64 MPa. The lego-inspired blocks surpassed the minimum compressive strength of non-load bearing CHB which 400 psi (2.76 Mpa). Therefore, the sand and plastic Lego-inspired block passed the compressive strength test to be a substitute for a hollow block.

3.3 Result from Drop Test

The researchers conduct the drop test for the sand and plastic Lego-inspired block with a dimension of 400mm x 200mm x 200mm. The test starts by measuring the high of the Lego-inspired blocks which must be 4 to 4.5 ft above the ground then

the sample would be dropped on the ground and observed what happens on the sample. Lastly, the researchers conduct a result of the Drop Test.

Figure 23: measuring 4 m above the ground

Figure 24: Result after the drop test

The Lego-Inspired Block with a dimension of 400mm x 200mm x 200mm was tested using Drop Test to see its strength and how it will look after falling from 4 feet high above the ground surface. As shown in the performed test the Lego Block managed to remain as a whole piece without having any cracks on it. It means that the sample is strong enough to prevent getting damaged from falling under pressure. Withstanding being cracked into pieces was possible because of the melted plastic that mixed with the sand and binds it to make it attached and well-formed inside the mold. But if the sample happened to crash and turn into pieces, then it shows that it lacks strength and must reject. In the end, the result of the Lego block has proven to be quality in its strength and capacity to use as a material in construction. Therefore, the Lego-inspired block passed the drop test.

The Test results of the Inspired Lego Block were a success for it survived the impact of the force by falling from a standard height of the drop test. The use of plastic as the binding material for the Lego-inspired block contributed a lot to preventing cracks or damage in the product. It stated according to studentsrebuild.org that if the block was able to survive then it is quality enough to go for building construction. Through this, it was proven that it is durable and has the strength as an alternate material for hollow blocks.

3.4 Result from Chisel Test

The researchers made a sample of sand and plastic Lego-inspired blocks with a dimension of 200mm x 120mm x 100mm and a mixture of 60% plastic and 40% sand. The process starts by using a chisel to cut the sample in the middle and continue to chisel until the same cut and observation were followed for the interpretation of the test.

Figure 25: performing the chisel test

Figure 26: Result after the chisel test

The researcher observed that the Lego-inspired blocks spilled into perfectly half of their length. For the hardness, the observation was it is hard to chisel the sample and that indicates and is considered of good quality for the block. For breakage, the observation was the sample was split into half which indicated and considered good quality. Therefore, the Lego-inspired block passed the Chisel Test.

As shown in the performed test the Test Piece managed to remain even after it cuts 20 times by using a chisel. Later, continuing the cutting of the test piece was cut only into two pieces. This is also good because if it is broken into many pieces then it indicates low strength

IV. CONCLUSION AND RECOMMENDATION

The results of the tests done by the researchers and the unified geotest laboratory were analyzed and tabulated by the researchers. After further discussion and confirmation, the researchers have concluded the following:

The process of creating a Lego-inspired block is not manual labor-friendly. This is because the plastic that is being melted releases harmful chemicals that affect the laborer and could lead up to more serious diseases. “Burning of plastic waste increase the risk of heart disease, aggravates respiratory ailments such as asthma and emphysema and causes rashes, nausea or headaches, and damages the nervous system” according to the study “Toxic Pollutants from Plastic Waste – A Review.” Therefore, the plastic should melt using an extruder. An extruder is a machine that completes the extrusion process which warms the product and drives it through the die to generate the desired shape that uses a system of barrels and cylinders. This will keep the laborers safe from harmful chemicals released by plastics while melting.

The Lego-inspired block compared to hollow blocks doesn’t need a lot of time on curing. It is quick to dry thus decreasing the amount of time needed to reproduce them on a factory scale. The researchers only waited for a full day for the Lego-inspired block to complete its curing. The downside is that, production phasing takes a long time and requires a large number of molds.

The time needed to remove the product from the mold is also large thus increasing the overall time needed for the product to be useable. Meanwhile, the hollow block needs a minimum of 7 days of curing time in addition to covering with a plastic sheet or tarpaulin and kept damp and shaded to effectively cure according to the Global Shelter Cluster.

This also means that the blocks can be used when there's an emergency that requires immediate construction blocks. An example would be if an earthquake or typhoon struck a place, Lego-inspired blocks can be used to quickly create temporary shelter for the victims who need it. Dr. Gerhard Dust (2016) inventor of Lego blocks figured that the only way he could help people hit by natural disasters was by building sustainable houses that work like Lego so they can rebuild them fast. He also stated that "when they shatter, you don't have to start from scratch; you just need another piece to rebuild the house".

The required time for construction as well as the effort needed in constructing could also be reduced because of its unique way of building. The researchers tried to stack them together and concluded that the block doesn't even need a binding material or reinforcing steel bars. This is due to the interlocking properties that a Lego-inspired block has.

During the Invest in Namibia Conference 2016, four untrained local laborers built a model house on the parking lot of a hotel in just two days. With a large crowd of people coming by to view and feel the house, the societal acceptance of this construction approach was demonstrated with amazing success.

This research demonstrated that the potential of Lego-inspired blocks to be a substitute for hollow blocks is very possible. This is because of the high level of strength and characteristics it showed during the test conducted and its efficiency when being used in construction. Therefore, the Lego-inspired block's result can be a useful reference for future researchers and industrial companies that has a plan on using them as a substitute material for hollow blocks.

V. RECOMMENDATION

Most experiments in this research were performed for the first time, therefore resulting in primary findings which necessitate more practical perfections. These verdicts however enlightened several prospective matters for future research. The following are the areas for further research that were not possible to undertake within this study.A comparative study that seeks to understand if using different varieties of plastic will affect or change the outcome of the previous test on Lego-inspired blocks drastically.

- A comparative study that seeks to understand if using different varieties of plastic will affect or change the outcome of the previous test on Lego-inspired blocks drastically.
- A feasibility study is to be performed for practical implementation of the research findings, to increase and excellent the development flexibility performance described in this thesis.
- The possibility of conducting a test to determine the penetration of plastic across the area or find ways on how to determine the consistency of the mixture. It is proposed to use gauge scale in measuring the consistency of the mixture.
- The possibility of using Quarry dust as a substitute material along with plastic waste in creating a Lego-Inspired block.
- For Structural Engineers to find the required minimum thickness on the embossed part on the top of the Lego-inspired block to sustain the lateral forces.
- Further work is required to include special interlock blocks for mortarless technology to ease the building of complicated wall configurations.
- Investigations of acceptable and simple methods for measuring surface imperfections of Lego Inspired blocks as a top-quality control measure.
- A long-term study for interlock wall strength following lifetime disturbances is to be performed on the local movements: of foundations, mechanical shocks (due to door slamming), and major shocks (caused by earthquakes).
- Find means to speed up the production and removal process by employing either new technique or technology in such a way that the molds can be used multiple times in a day.
- It is suggested to create a handle for the mold (improvised) so that the block can be easily removed in the mold.
- To use an Extruder to create the Lego-inspired block instead of manual labor to prevent the risk of inhaling harmful chemicals released by heating plastic wastes. To also speed up the process of melting the plastic and combining the mixture.
- A future study to test and find out if the Lego-inspired blocks can be used for load-bearing walls.

- A fire resistance tests to know the resistance of Lego-inspired blocks made with sand and plastic against fire and heat.
- The possibility of using Lego-inspired block to lower the cost of construction project by not using any mortar or reinforcing bars.

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