A Sustainable Design Approach for Upcycling Waste Glass

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***Abstract*—**Recycled glass surfaces are considered upcycled when they utilize un-melted glass resources. Melted glass uses energy to transform it into a new products or slabs. The present study investigates the use of post-consumer and industrial waste glass such as bottles, jars, and beverage containers to upscale it for making interior slab surfaces. The waste glass was crushed and ground into small particles between 4.75 mm to 150 microns. Two types of solid surfaces were developed using cement and polyester resin. Three types of concrete mix were prepared using 60%, 50%, and 40% crushed glass and cement plus water in the ratio (1:1). The three concrete mix specimens were cast in plywood molds for 24 hours. They were then removed and cured in water at ambient temperature for 24 hours. Similarly, three polyester resin specimens were prepared using 60%, 50%, and 40% crushed glass with a mix of polyester resin, catalyst, and pigment. Formica plywood molds were used to cast the mixes. The specimens were cured for 6 hours. The project further reviews the properties of these upcycled glass, cement, and polyester resin surfaces. Mechanical tests such as density, compressive strength, and flexural and thermal shock were performed. Stain and chemical resistance tests, cigarette burn tests, and solid surface tests such as water absorption, and knife drop tests, were executed. The casted specimens were compared to locally available granite and slab. Specimens of concrete and resin were compared considering the quantity of waste glass used. Cost analysis demonstrates economic benefits. The recycled glass slabs meet high-performance criteria for quality and durability. The waste glass is upcycled into surfaces that exhibit a unique product and provide elegant design solutions for interior surfaces such as table tops, kitchen sinks, bowls, etc. This sustainable approach will provide a path to create new jobs in local communities. The study sets an example that employs waste management, recycling, upcycling, and responsible manufacturing to support the development of new businesses and jobs. It offers an economical and sustainable design solution, increasing the efficient use of waste resources.

***Keywords*—**Create jobs, upcycle waste glass, design solutions, economic benefits, environmental benefits.

I. Introduction

THE increasing amount and varieties of waste materials, deficiency of landfill space, and lack of natural quarries implore the desperation of finding innovative ways to reuse and recycle waste materials for a better Mauritius. The country's total land area is 2,040 km^2 (790 sq. mt.) with a population of around 1.3 million. In 2018, the total volume of waste disposed at the Mare Chicose Landfill was 543,196 tons, the sole landfill on the island. The types of waste generated in Mauritius are shown in Fig. 1. The composition of municipal solid waste as per the solid waste management division (SWMD) was about 1,488 tons daily of which glass waste was 3% or 44.64 tons [25].

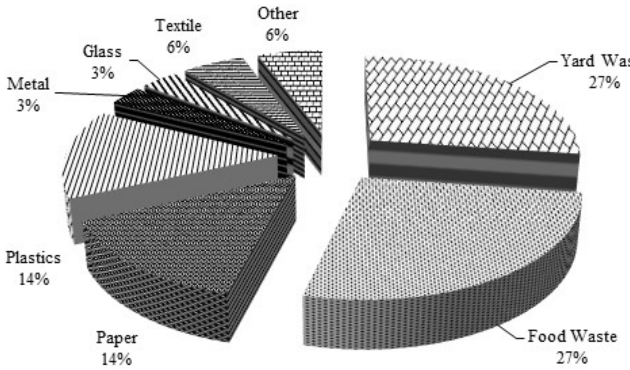

Fig. 1 Types of waste generated [25]

Recycled glass from landfills can be up-cycled into well-designed materials that provide sustainable solutions and applications [24]. The study aimed to analyze the potential of up-cycling waste glass by developing different material matrices for use as surfaces in interior designs. The objectives of the study:

- To investigate the potential of using crushed waste glass with cement and polyester resin to develop surfaces for interior designs.
- To optimize the ratio of material used to develop different matrices.
- To investigate the characteristics and performance of the matrix.
- To study and compare the properties of the matrix with locally available products.
- To perform a cost analysis assessment.

II. Literature Review

Environmental concerns are influencing consumer product design. The reuse of waste glass has become an important factor today because of the fast-growing solid waste in the environment [19]. Glass is a kind of material which can be recycled ordinarily without changing its chemical properties [1], [4]. Recycled glass surfaces are considered up-cycled when they utilize un-melted glass resources. Recycling glass does not save much energy or valuable raw material and does not reduce air or water pollution significantly [17]. Reusing glass may be a good choice. Repurposing waste glass into a construction material reduces the consumption of natural resources, minimizes greenhouse emissions, and alleviates landfill scarcity [3]. Waste glass in its crushed condition can be used to about 100% and can find practical applicability [2]. Crushed glass can also be used as aggregate in concrete, road

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development, and asphalt [24], [27]. Using the right amount of waste glass for the specific application is important. When using crushed glass for new applications one must review its physical properties. Glass cullet could be used in numerous ways such as building applications, countertops, paving bricks, tiles, glass fiber, insulation, and eco-blocks [7]-[10]. The application of waste glass can provide high stiffness and load support when used as street or highway foundations [21], [23]. Crushed glass as a replacement in road development has been tested since 1971 and it was seen that it holds heat longer than basic asphalt. This might be advantageous for road developments at low temperatures [11]. The crushed glass eventually increases visibility on roads, during the night as it reflects light. However, the utilization of finely crushed waste glass as an aggregate may diminish its value with an increase in the substitution amount of recycled glass [22]. The mechanical properties such as compressive, tensile, and flexural strength of cement consisting of finely crushed waste glass as aggregate diminish with an increment of crushed glass [26].

III. Experimental Work

Two types of solid surfaces were developed. One consisted of water, white cement, and waste glass [6]. The other was made with polyester resin, catalyst, and waste glass [5]. The materials used were sourced locally.

- Portland white cement - Mauritius Standard MS 36-1 EN 197-1 (BS12:1996).
- Cementone coloring red, blue, and green - BS 1014: 1975.
- Waste glass ground between 4.75 mm and 150 microns.
- Commercial resin NCS 991 PA (isophthalic).
- Catalyst NA2.
- Blue pigment (p340 10%).
- Water.
- Casting molds made with 3/4 inches' plywood and Formica laminated plywood.

A. Concrete Mix

Three types of concrete mixes were prepared using 60%, 50%, and 40% crushed glass and mixed with cement and water in a ratio (1:1). The three concrete mix specimens were cast in plywood molds and cured for 24 hours in water at ambient temperature. Dimensions of casting molds were considered so that the specimens could be used for appropriate tests. Crushed glass and cement were weighed. Table I shows the proportions for the three specimens (volume 100 cm^3). These were combined in a metal bowl and mixed well using a metal spoon. A proportionate amount of water was added stirring constantly for 3 to 4 minutes to form a homogeneous mixture. The mixture was poured gradually to level up to the top of the mold. The molds were placed on a vibrating table for 30 seconds to ensure thorough leveling and removal of any trapped air spaces in the mixture. The concrete specimens were left in the mold for 24 hours at ambient temperature. They were removed with precaution. The specimens were cured by immersing them in a water tub at ambient temperature for 24 hours. Fig. 2 shows concrete specimen C_2.

Fig 2 C2- 50% Glass, 100g Cement, 100 ml Water

TABLE I
CONCRETE MIX (G/CM^3)

	Specimen Mix	Crushed Glass (g)	Cement (g)	Water (ml)
C_1	60% crushed glass	120	80	80
C_2	50% crushed glass	100	100	100
C_3	40% crushed glass	80	120	120

B. Polyester Resin Mix

The polyester resin specimens were a mix of crushed glass, polyester resin, and catalyst. Table II shows the proportions for the three specimens (volume 100 cm^3). Fig. 3 shows Polyester Resin Specimen R_2.

TABLE II
POLYESTER RESIN MIX (G/CM^3)

	Specimen Mix	Crushed glass (g)	Resin (g)	Catalyst (g)
R_1	60% crushed glass	120	80	1.6
R_2	50% crushed glass	100	100	2
R_3	40% crushed glass	80	120	2.4

Fig. 3 R2: 50% Glass, 100 g Polyester Resin, 2 g Catalyst

Three mixes were prepared using 60%, 50%, and 40% crushed glass. The crushed glass was washed, dried, and weighed. It was evenly spread into the Formica laminated molds. The corresponding amount of polyester resin and catalyst was accurately weighed and mixed. This mix was poured onto the crushed glass pieces to fill up to the top of the mold. The mold was placed on a vibrating table for 30 seconds to spread the resin evenly between the crushed glasses and remove any trapped air. The specimens were allowed to dry for 6 hours at ambient temperature to cure the mix. The specimens were successfully unmolded without any cracked or damaged edges. The glass particles in the matrix were in an anisotropy arrangement.

IV. Testing and Evaluation

The specimens were placed in water for 24 hours before each test and carried out as per standard test procedures. Destructive and non-destructive tests were performed [13]. The destructive tests consisted of the Compressive Strength and Flexure test. Non-destructive tests were density, water absorption, and thermal shock. Other solid surface tests namely impact test, knife drop test, skillet drop test, cigarette burn test, stain, and chemical resistance were also performed. The specimens were compared to locally available granite and slab (M10). A cost analysis was also performed.

A. Destructive Tests

1. Compressive Strength

ASTM C 170 standard was used. The specimens of 40 x 40 x 40 cm cubes were cured for 28 days before testing. The compressive strength is calculated by using the equation:

$$\text{Compressive Strength F } (N/mm^2) = P/A$$

F = Compressive strength of the specimen (in MPa); P = Maximum load applied to the specimen (in N); A = Cross-sectional area of the specimen (in mm^2).

TABLE III
Compressive Strength

Specimen Mix		Compressive Strength (N/mm^2)	Grade of material
Granite	Natural stone	72	M70
Slab	Control mix (M10)	9.8	M10
C_1	60% crushed glass	20.4	M20
C_2	50% crushed glass	21.8	M20
C_3	40% crushed glass	22.8	M20
R_1	60% crushed glass	35.4	M35
R_2	50% crushed glass	40.1	M40
R_3	40% crushed glass	48.7	M50

As seen in Table III, Granite has the best compressive strength. The control mix M10 is usually used for flooring or casting of slabs. M10 is a concrete cube of 150 mm with a strength of 10 N/mm^2 after 28 days of curing. A decrease in waste glass content improved the compressive strength. M15, M20, and M25 grades are mostly used for general applications. Therefore, analyzing the specimens, it can be concluded that all three concrete specimens can be used for applications in buildings such as flooring. The resin specimens had a higher compressive strength value. Therefore, it can be used for applications where hardness and stiffness are priorities. A resin tabletop or a kitchen countertop may be an appropriate application. The amount of glass can be varied for different applications for aesthetic appeal.

2. Flexure Test

The flexural test was conducted under ASTM D 790. The specimens used were 25 x 4 x 1.5 cm. A 3-point bending test was used to test whether the materials could support loads without bending. A span length of 200 mm was considered for the test at a speed of 2.000 mm/min and a load was applied to the center of the specimen. Concrete specimens were cured for 28 days to attain full strength before being tested. Parameters considered for the test were loading speed, support span, and maximum deflection. The machine stops when a 5% deflection is reached. The bending strength was calculated using 'σ' in N/mm^2, where $\sigma = 3FL/2bd^2$, 'F' is the load at a given point on the deflection curve (N), 'L' is the support span (mm), 'b' is the width of the specimen (mm), and 'd' is the thickness (mm).

TABLE IV
Flexure Test

Specimen Mix		Bending Strength (N/mm^2)
Granite	Natural stone	11.787
Slab	Control mix (M10)	4.230
C_1	60% crushed glass	3.813
C_2	50% crushed glass	4.863
C_3	40% crushed glass	4.630
R_1	60% crushed glass	8.817
R_2	50% crushed glass	9.143
R_3	40% crushed glass	10.423

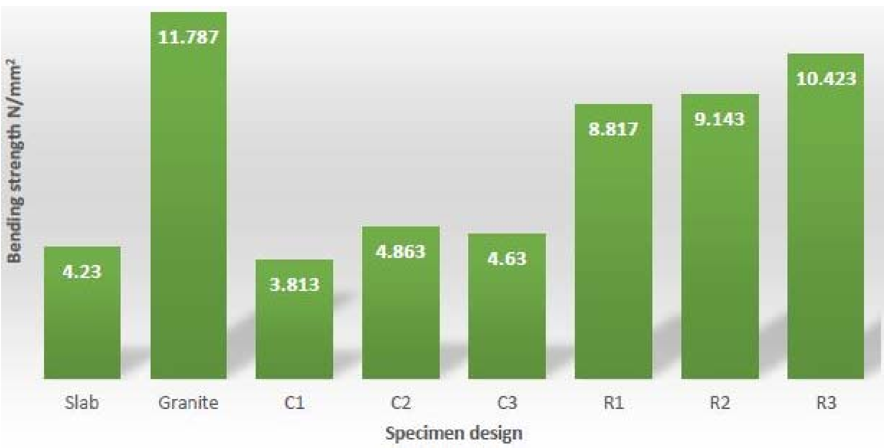

Fig. 4 Comparison Flexure Test

Table IV shows the results of the flexure test and a comparison is seen in Fig. 4. Granite gave the best performance followed by resin and concrete specimens C_2 and C_3. Concrete specimen C_1 shows poor results. With a decrease in waste glass content, there is an improvement in the bending strength. The bending strength of R_3 was 1.364 N/mm^2 less than granite and 6.193 N/mm^2 more compared to slab. Considering the concrete specimens, C_2 gave the best results with 0.633 N/mm^2 bending strength more than the slab and 6.924 N/mm^2 less than granite.

B. Non-Destructive Tests

1. Density

The densities of control samples of slab and granite were determined and compared with concrete and polyester resin specimens by finding the dry mass and volume. The specimens used were 5 x 5 x 4 cm. All the specimens were placed in water for 24 hours. They were removed and placed in an oven at 105 °C for 24 hours. They were weighed on an electronic weighing machine to determine the dry mass in grams. The volume and density of each specimen was determined by the following formula:

Volume (v) = length (l) x width (w) height (h)

Density (g/cm^3) = mass (g)/ volume (cm^3)

TABLE V
DENSITY TEST

Specimen Mix		Density g/cm^3	Density reduction compared to granite %	Density reduction compared to concrete %
Granite	Natural stone	2.65	Nil	Nil
Slab (M10)	Control mix	2.79	Nil	Nil
C_1	60% crushed glass	2.06	0.59	0.73
C_2	50% crushed glass	2.02	0.63	0.77
C_3	40% crushed glass	2.00	0.65	0.79
R_1	60% crushed glass	1.86	0.79	0.93
R_2	50% crushed glass	1.76	0.89	1.03
R_3	40% crushed glass	1.58	1.07	1.21

As seen in Table V the highest density is demonstrated for slab followed by granite. Concrete specimen C_1, of 2.06 g/cm^3 density shows a 0.73% decrease compared to concrete and 0.59% to granite. The resin specimen R_1 was dense however much lighter than the slab with a decrease of 0.92% and 0.79% as compared to granite. Compared to the control mix and granite, all the specimens can be classified as light material.

2. Water Absorption

The water absorption test was carried out as per ASTM C 97 standard for all samples. The specimens used were 10 x 10 x 10 cm^3. They were placed in water for 24 hours and dried in an oven for 36 hours. They were cooled and weighted to determine the dry mass. The specimens were boiled in deionized water for one hour and then placed under vacuum for 2 hours. The excess water was removed and the wet mass was recorded. In the second part of the test, the specimens were soaked in water for 96 hours. The excess water was wiped off and the wet mass was recorded.

Water Absorption% = (Wet weight – Dry weight) / Dry weight) ×100

Table VI shows the results of the water absorption test. Granite is more resistant to water with 0.20% for the 1-hour test and 0.32% for the 96-hour test. The resin specimens, R_1, are also less permeable to water, R_1 with 0.28%, R_2, with 0.30% and R_3 0.32% for the 1-hour test, being the closest to granite. The concrete specimens were most vulnerable in this test. The control mix has the highest absorption rate with 3.10% for the 1 hour and 5.57% for the 96 hours' test. The concrete specimen C_1 was less resistant to water with an absorption rate of 2.80% for the 1 hour and 4.64% for the 96 hours' test. It can be seen that as the percentage of crushed glass decreases, the resistance increases. Therefore, to make the concrete specimens more resistant to water, epoxy enamel can be used to seal the surface for applications such as flooring or kitchen countertops.

TABLE VI
WATER ABSORPTION TEST

Specimen Mix		Water absorbed % 1 hour boiling	Water absorbed % 96 hours soaking
Slab	Control mix (M10)	3.10	5.57
Granite	Natural stone	0.20	0.32
C_1	60% crushed glass	2.80	4.64
C_2	50% crushed glass	2.64	4.34
C_3	40% crushed glass	2.50	4.14
R_1	60% crushed glass	0.39	0.70
R_2	50% crushed glass	0.30	0.63
R_3	40% crushed glass	0.28	0.58

3. Thermal Shock Test

The thermal shock test was done using BS EN 14066:2013 standard. Two different specimens were considered for this test. Small specimens with dimensions of 5 x 5 x 2 cm and large specimens of 5 x 10 x 22 cm. A furnace was used to heat small metal bars to different temperatures of 176 °C, 232 °C, 287 °C, and 371 °C. The metal bars were placed on the specimens after being heated for 15 minutes to determine burns and cracks. After the metal bars attained the required temperature, they were removed and kept on the specimens for 2 minutes. The bars were removed and the specimens were inspected for burned marks and cracks caused by the high temperature. The specimens were cooled for 1 hour after each test. Thermal shock test results for the small and large specimens are summarized in Tables VII and VIII respectively. All the casted specimens were resistant to burns and cracks.

C. Solid Surface Test

A series of solid surface tests namely, surface test, knife drop test, impact test, stain resistance test, chemical resistance test, skillet drop test, and cigarette burn test, were carried out to determine the strength, restoration, and precautions to be taken and to avoid defects. The tests were conducted by ANSI/ICPA SS-1-2001 standard.

TABLE VII
THERMAL SHOCK TEST SMALL SPECIMENS

Specimen	176 °C (350 °F)	232 °C (450 °F)	287 °C (550 °F)	371 °C (700 °F)
Granite	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks but the specimen was hot	No signs of cracks, but there light burn mark on top
Slab	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks.	No signs of burns or cracks, the specimen was hot
C_1	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks, the specimen was hot
C_2	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks, the specimen was hot
C_3	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks, the specimen was hot
R_1	No signs of burns or cracks	No signs of burns or cracks but the specimen absorbed most of the heat	No signs of burns or cracks, the specimen was hot	No signs of burns or cracks, the specimen was very hot
R_2	No signs of burns or cracks	No signs of burns or cracks but the specimen absorbed most of the heat	No signs of burns or cracks, the specimen was hot	No signs of burns or cracks, the specimen was very hot
R_3	No signs of burns or cracks	No signs of burn or cracks but the specimen absorbed most of the heat	No signs of burns or cracks, the specimen was hot	No signs of burns or cracks, the specimen was very hot

TABLE VIII
THERMAL SHOCK TEST LARGE SPECIMENS

Specimen	176 °C (350 °F)	232 °C (450 °F)	287 °C (550 °F)	371 °C (700 °F)
Granite	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks but the specimen was hot	No signs of cracks, but there were light burn marks on the top
Slab	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks.	No signs of burns or cracks, the specimen was hot
C_1	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks, the specimen was hot
C_2	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks, the specimen was hot
C_3	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks	No signs of burns or cracks, the specimen was hot
R_1	No signs of burns or cracks	No signs of burns or cracks but the specimen absorbed most of the heat	No signs of burns or cracks, the specimen was hot	No signs of burns or cracks, the specimen was very hot
R_2	No signs of burns or cracks	No signs of burns or cracks but the specimen absorbed most of the heat	No signs of burns or cracks, the specimen was hot	No signs of burns or cracks, the specimen was very hot
R_3	No signs of burns or cracks	No signs of burn or cracks but the specimen absorbed most of the heat	No signs of burns or cracks, the specimen was hot	No signs of burns or cracks, the specimen was very hot

1. Surface Test

Two types of surface tests were conducted. The specimens were washed with detergent and water, rinsed, and dried completely. They were inspected with a naked eye from a distance of 1 foot with a light source pointing at the specimens. Black washable ink mixed with water was poured on the specimens for the second test. The specimens were rinsed with water and dried. The light was used for inspection. The surfaces were washed and dried. They showed no defect except for the slab, where small holes were spotted. Granite retained some spots on the surface when black washable ink was poured on the specimens. The casted specimens were unaffected.

2. Impact Test

A 1.5-inch steel ball weighing ½ lbs. was used. The steel ball was dropped vertically in the middle of the specimen from a height of 2 feet. The specimens were inspected for fractures. The impact test was successful for all the specimens and no fractures were identified.

3. Knife Drop Test

Knife drop test determines the specimens' resistance to cracks or fractures. A steel knife with a sharp edge was dropped, tip down, on the specimens from a height of two feet at two distinct points. The knife drop test affected all the specimens except the three concrete specimens. The most affected specimen was the slab. The knife tip made a deep hole in the surface. The granite had a small deep dent of around 2 mm in diameter. The resin specimens had a tiny scratch. The scratches on the resin's surface were restored after polishing with 1000-grit silicone paper. The specimen regained its original surface. Granite and the slab could not be restored from polishing as the dents were quite deep. The resin specimens regained their original surface on polishing.

4. Skillet Drop Test

The test was done using an iron skillet of 5-inch diameter and a weight of 3 pounds. The skillet was dropped on the specimens from a height of 1 foot. The specimens were analyzed for cracks or fractures. No fractures or cracks were identified.

5. Cigarette Burn Test

Three different brands of cigarettes were used. They were placed 1 inch from the edge of each specimen and allowed to burn for 2 minutes. The burned area was wiped with cloth and sanded with 2000 grit of abrasive paper to remove stains for inspection. The cigarette burn test showed no ignition or continuous burns after removing the cigarettes. Burn marks and tar were identified on all the specimens. The burned spots were wiped with a clean cloth and a 1000 grit silicone paper was used to remove the stains. The concrete specimen was unaffected after sanding, the resin specimen regained its original look. The slab retained the burned marks after sanding, washing, and drying. The surface of the granite was unaffected, but it seemed to have absorbed the tar and the marks were visible.

6. Stain Resistance Test

The reagents used were black crayons, shoe polish, blue washable ink, beef blood, lipstick, grape juice, hair dye, and tea. Two drops of each reagent were placed on the specimens for 16 hours. One part was covered and the other part was uncovered. The specimens were cleaned and rated on a scale of 0 to 5 where 0 shows no resistance to staining and 5 maximum traces of staining as in Table IX.

TABLE IX
RATING OF STAIN RESISTANCE TEST

Slab/Granite/Concrete/ Resin (covered)	Reagent	Slab/ Granite/ Concrete/ Resin (uncovered)
0/2/2/2	Black crayon	0/2/2/2
0/2/1/2	Brown shoe polish	0/2/1/2
0/1/1/2	Blue washable ink	0/1/1/2
0/1/2/2	Beef blood	0/1/2/2
0/1/2/2	Lipstick	0/1/2/2
0/1/1/1	Grape juice	0/1/1/1
0/2/1/2	Hair dye	0/2/1/2
0/0/2/2	Tea	0/0/2/2

The resin specimen was the most resistant for both covered and uncovered tests. Only grape juice left a small trace on the specimen. The concrete specimen performance was good with only some marks remaining on the surface. Granite showed traces on the surface especially tea stains were completely absorbed. The resin and concrete specimens gave good results for the stain resistance test. Slab showed poor performance.

7. Chemical Resistance Test

Acetone, citric acid, acetic acid, soap solution, and olive oil were used for testing. Two drops of each reagent were placed on the specimens for 16 hours with one part covered and the other uncovered. The surface was wiped and the specimens were kept at 23 °C and 50% humidity for 24 hours and inspected. The slab absorbed all the reagents. Granite absorbed most of the reagents. Resin and concrete specimens showed good resistance. The casted specimens were chemical resistant.

D. Cost Analysis

A cost analysis was performed for the casted specimens. The cost analysis was based on a specimen size of 100 cm^3. Granite and slab were considered for comparison as shown in Table X. The cost of the mold, labor, water, and electricity were not included (1 USD = 46 MUR approx.). For the resin specimens, the cost of polyester resin, pigment, catalyst, and crushed waste glass was considered as for the concrete, cement, Cementone (pigment), and waste glass were included as seen in Tables XI and XII. Prices are in Mauritian Rupees (MUR)

TABLE X
PRICE FOR CHEAPEST LOCALLY AVAILABLE MATERIALS

Specimen Mix		Price/ MUR
Slab	Control mix (M10)	1.25
Granite	Natural stone	11.67

TABLE XI
PRICE OF MATERIALS FOR CONCRETE SPECIMENS (MUR)

	Specimen Mix	Cement	Cementone	Waste glass	Total
C_1	60% crushed glass	2.20	1.05	3.00	6.25
C_2	50% crushed glass	2.75	1.05	2.50	6.30
C_3	40% crushed glass	3.30	1.05	2.00	6.35

TABLE XII
PRICE OF MATERIALS FOR POLYESTER RESIN SPECIMENS (MUR)

	Specimen Mix	Resin	Catalyst	Waste glass	Pigment	Total
R_1	60% crushed glass	12.95	0.28	3.25	0.02	16.50
R_2	50% crushed glass	18.50	0.40	2.50	0.02	21.14
R_3	40% crushed glass	24.05	0.52	1.75	0.02	26.34

The slab is the most cost-effective material. Concrete specimens are less expensive than granite and can find applications in kitchen countertops and tabletops. The resin specimens were the most expensive compared to concrete specimens, slab, and granite with a decrease in waste glass and an increase in resin, the cost escalates.

V. PROTOTYPING COLORING POLISHING

Colors were added to the mixtures to produce different types of specimens. Multi-colored specimens were cast. Customized combinations can also be cast based on the end use and desired aesthetics. The properties of the specimens can be controlled and varied. 50% Waste glass, Cement, Water, and Red Cementone were used to produce colorful concrete specimens as seen in Fig. 5.

Fig. 5 Concrete Specimen

Fig. 6 shows a multi-colored specimen with mixed glass. Stone sealant was used to seal the surface and make it resistant to water, stain, and chemical reagents.

Fig. 7 shows a specimen with 50% Waste glass, Polyester Resin, and Blue pigment.

A Sander machine was used to polish the rough surfaces of the specimen with 180 grits of paper. Silicone abrasive papers ranging from 400-2000 grits were used to polish and shine the surface as seen in Fig. 8.

Considering the aesthetics and properties of the specimens, a bathroom sink and countertop were designed and developed. The prototype is a testimony of the feasibility, and functions as a viable solution to use the material. Fig. 9 shows the final product. The product has an appealing, attractive desirable look. It is easy to maintain and can be cleaned with a damp cloth, liquid soap, or mild detergent. It is scratch and stain-resistant. The fabrication of these surfaces is easy and uses the same equipment and techniques as those used for masonry work.

Fig. 6 Multi-colored specimen

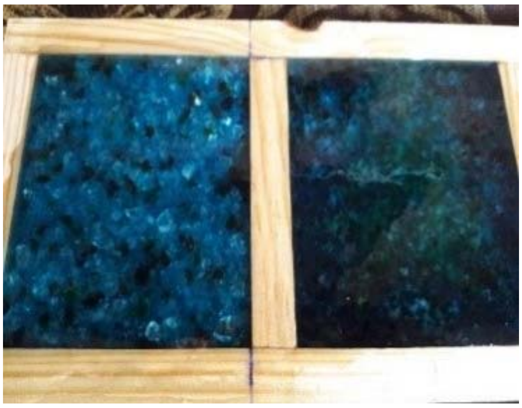

Fig. 7 Resin Specimen

Fig. 8 Polishing with Sander Machine

Fig. 9 Prototype Bathroom Sink and Counter Top

There is great potential for the utilization of waste glass in several forms. This will provide greater opportunities for value-addition.

VI. Conclusion

The growing amount of waste glass being disposed of at landfills has reintroduced its exploitation for application of waste glass into novel products. The versatility of glass keeps increasing as it finds new applications. This paper presents the prospect of using waste glass for making interior slab surfaces. Waste glass is transformed into artistic products. The project shows prospects for commercialization. All the specimens developed were lighter than granite and slab. The results obtained conclude that, the proportion of waste glass used can be manipulated to get required properties. The resin specimens had the best resistance for water absorption followed by granite. The concrete specimens gave better resistance to water than the control mix (M10). It was also found that less percentage of the waste glass made the specimens more water-resistant. The increase in the percentage of the waste glass reduced the bending strength. The concrete specimen C_1 containing 60% of waste glass gave poor results. Polyester resin specimen with 40% of crushed glass ranked second best just after granite. The compressive strength of the specimens showed that with a decrease in waste glass content, the compressive strength increased. The concrete specimens were of grade M20 and the resin varied from M35 to M40. The casted specimens were resistant to high temperatures. There were no defects or burn marks on the casted specimens and the granite retained marks on its surface. The casted specimens had a polished surface with no cracks or defects but granite had multiple cracks on the surface and could not be restored even after sanding. All the specimens were resistant to the impact and skillet drop tests. The concrete specimen gave the best results for the knife drop test with no cracks or fractures. The resin's specimen was restored after having a light scratch and the granite and slab failed the test. The resin and the concrete specimens were resistant to the cigarette burn test with the original surfaces restored after sanding. Granite and slab could not restore their surfaces. Slab and granite performed poorly in the stain test and absorbed most of the reagents. The concrete and resin specimens are unaffected by the stain and chemical resistance test. Recycled glass surfaces meet high-performance criteria for quality, durability, and maintenance. The recycled glass surfaces exhibit a unique product that provides elegant design solutions for interior surfaces such as table tops, kitchen sinks, bowls, etc. Recycling materials is also a step toward creating new jobs in local communities. The utilization of waste glass can have significant environmental and economic benefits. It will help in the use of waste glass to create a greener environment.

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