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Flexural Strength Determination of Reinforced Concrete Elements with Waste Glass as Partial Replacement for Fine Aggregate

ABSTRACT

The problem faced in the availability of fine aggregate especially sharp sand paved way for the quest in search of a substitute material, this fact coupled with the excess of glass as a waste in our environment brought about the replacement of sand with glass particles as fine aggregate in concrete mix. From various research work, glass particles has been used as replacement for coarse aggregate, fine aggregate and even cement and its possibility to give relatively good concreter strength was not ruled out. In this work, Glass was used as a partial replacement for sand as a fine aggregate in Reinforced Concrete; Mixes of 0%, 10%, 20% and 30% glass content were cast into short beams for flexural strength test. Result shows that Glass particles does not have much effect in the flexural strength of a reinforced concrete section especially when the glass content does not go beyond 30% of the fine aggregate mix ratio. Also it has no negative effect on the reinforcement in the section; the reinforcement in other way reduced the effect of cracks in the concrete section.

Keywords: Glass, Sand, Flexural Strength and Reinforced Concrete.

INTRODUCTION

During the last decades it has been recognized that Sheet Glass waste is of large volume and is increasing year by year in the Shops, construction areas and factories. It is a major component of the solid waste stream in many countries. Solid waste materials usually include industrial waste, medical waste, domestic waste and in particular, construction waste which is the output result of construction and destruction, rehabilitation, repair, removal of existing structures, and installations. This waste is composed of sand, stone, gravel, tiles, ceramic, marble, glass, aluminum, wood, plastic, paper, paints, plumbing pipes, electric parts and asbestos, and other materials. Theoretically, glass is a fully recyclable material; it can be recycled without any loss of quality [1]. Using waste glass in the concrete construction sector is advantageous, as the production cost of concrete will go down. The production cost of waste glasses for concrete will go down through the development of reprocessing technology and the extension of reprocessing facilities, which will make concrete containing waste glasses economically viable. [2].

Concrete a composite inert material which consist of a binder course (e.g. cement), mineral filler (body) or aggregates and water is a major material in concrete construction sector which is used on a large scale daily. Communities around the world rely on concrete as a safe, strong and simple building material, the availability of the concrete constituent's materials is beginning to poise challenges to the construction industry. This availability problem however gives room for the improvement on the idea of using waste products as replacements in the production of concrete. The growing environmental concerns, increasing scarcity of landfills, rapidly depleting sources of quality (virgin) aggregate in some regions coupled with the increasing haulage and growing landfill costs are the driving forces promoting the recycling of concrete demolition waste in new concrete [3]. The recycling of construction waste, including concrete, and the landfill-bound constituents of the municipal solid waste stream, including glass which occurs largely as mixed-color waste glass with limited market value, are considered important steps towards sustainable construction practices.

Glass is a hard, impermeable, transparent material formed from sand, soda ash, limestone and dolomite; used for many applications especially window glazing [4]. Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing [2]. Molten glass may be blown, cast, drawn, rolled, or pressed in a variety of shapes. Centuries ago, window glass was thin, generally of poor quality, often green or violet in hue, streaked with air bubbles, After about 1700, the manufacturing processes improved significantly so that the price of glass dropped significantly, the sizes of panes increased, and the use of window glass became more widespread. [4] Nowadays, the civil construction industries search the alternatives to satisfy the increasing needs for the concrete production. The most widely used fine aggregate for the making of concrete is the natural sand mined from the riverbeds. However, the availability of river sand for the preparation of concrete is becoming scarce due to the excessive nonscientific methods of mining from the riverbeds, lowering of water table, sinking of the bridge piers, etc. are becoming common treats [5]. The present scenario demands identification of substitute materials for the river sand for making concrete. Many studies have been emerging worldwide highlighting the reuse of waste glass in construction technology, Recently, some attempts have been made to use ground glass as a replacement in concrete [6] The attractive use of the waste glass in the construction materials is caused by the fact that not all waste glass can be recycled into new glass. The recycling of waste glass is a major issue in urban areas of developed countries [7] [6], which has resulted in significant interest of late in utilizing it in concrete. Meyer et al (2001) discussed the various steps that need to be taken by recyclers to collect the glass, separate it from the other materials, clean it and crush it to obtain the appropriate grading to meet the specifications for specific applications as aggregate in concrete, either in commodity products, with the only objective being to utilize as much glass as possible, or in value-added products that make full use of the physical and esthetic properties of color-sorted crushed glass.[8] Crushed glass or cullet, if properly sized and processed, can exhibit characteristics similar to that of gravel or sand.

This study focused on the use of sheet glass powder as fine aggregate replacement to reinforced concrete. The result of this study would benefit the civil engineers and the environment as well. Civil engineers because the study could provide an alternative fine aggregate that is economical yet durable. Environment, for it is an ecofriendly resource. Instead of damping the materials, it can be recycled into another form of product. This study examines the possibility of using glass powder as a replacement in fine aggregate for a new reinforced concrete, natural sand was partially replaced (10%, 20% and 30%), with glass powder.

MATERIALS & METHODS

The raw materials, used for this study are natural coarse aggregate, fine aggregate, Waste glass Powder aggregate and Dangote Portland cement.

Cement

Dangote Portland Cement, locally available cement was used in this research work, it is a widely spread cement available in every part of our environment and used in over 97% construction sites. Its chemical composition as tested in the laboratory is as shown below.

TABLE 3.1 DANGOTE CEMENT ANALYSES

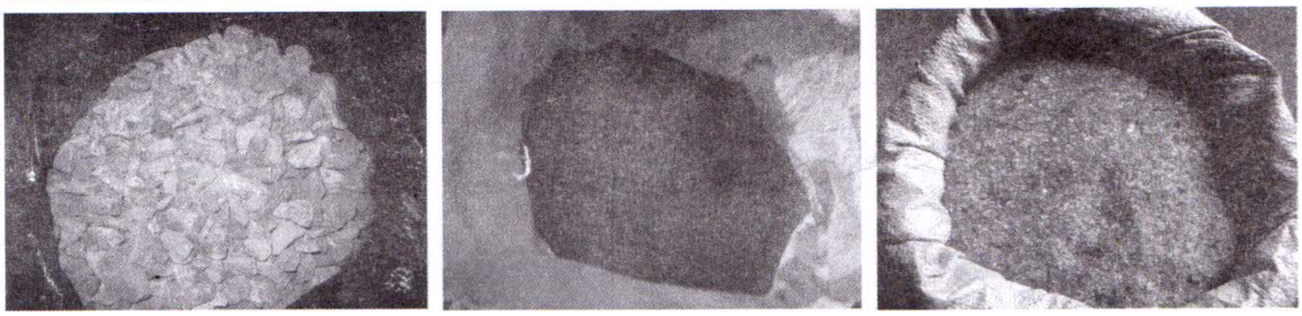
Parameter	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O	SO_3	L.O.1
%	63.51	19.12	5.37	0.73	2.05	0.81	0.54	0.65	0.027

Aggregate

All the aggregate materials used for this project work are locally available natural materials which conform to the standard aggregate sizes. The figure below shows samples of the granite and the natural sand used.

Waste Glass

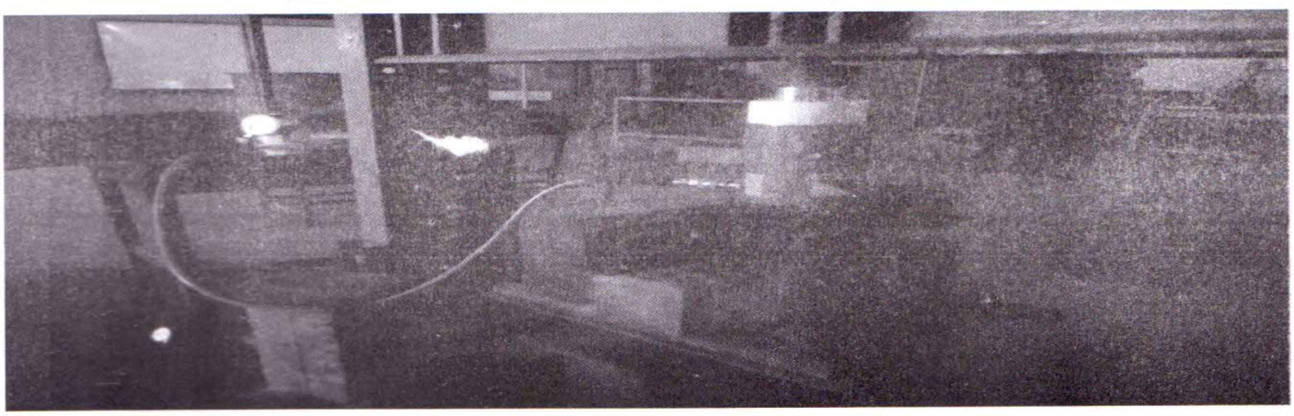
Waste glass was gotten from Agbara town in Ogun State, the waste glass particles from broken bottles are of green and white colour



Experimental Procedure

The waste Glass was collected as equally done for every other material for the test. Waste glass particles were used to replace 0%, 10%, 20% and 30% of the sand by weight. A total of 48 numbers 150x150x500 mm beams were cast and cured in water for 7,14,28,90 days Flexural strength was measured on each of the beam specimen with three beams loaded to failure for each of the mix ratio, and the average strength was recorded in each case.

The beams were loaded in a single point load system at the center as shown below and the deflection were taken with the use of a Dial Gauge.



4.1 Result

The results obtained from the flexural strength test of the Beams for the various percentage replacements are compared with the control to determine the rate at which the strength of the concrete is influenced by the glass particles, below are the results for each of the curing days.

TABLE 4.1 SUMMARY OF COMPRESSIVE STRENGTH RESULT FOR THE 7 DAYS TEST

GLASS CONTENT	COMPRESSIVE STRENGTH			
	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3	AVERAGE
0%	280	300	290	290
10%	280	280	290	283.3333333
20%	250	280	270	266.6666667
30%	240	270	270	260

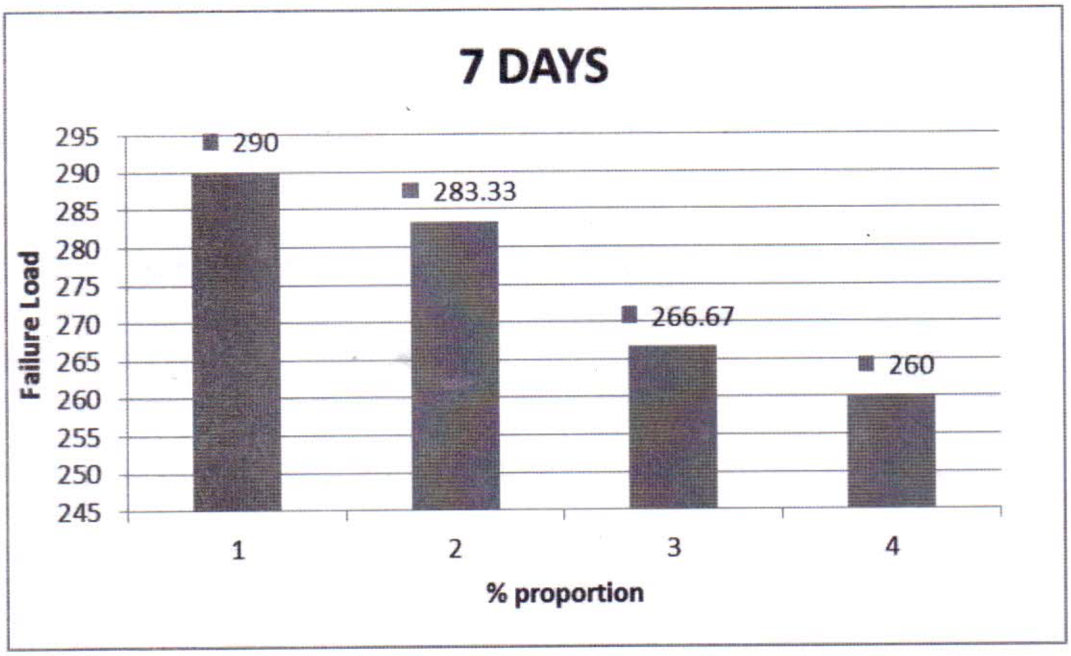


FIGURE 4.1: 7 DAYS COMPRESSIVE STRENGTH CHART

For the 7 days curing, the control beam specimen attained a strength of 290kg/cm^2 and there was a noticeable decrease in the strength as the glass content increases. With a 10 percent increase in the glass content there was a 2.3 percent decrease in the strength to 283.33kg/cm^2, 5.88 percent decrease (266.67kg/cm^2) as the glass content increases to 20% and a final 2.5 percent decrease on the last 10% increase to 260kg/cm^2.

TABLE 4.2 SUMMARY OF COMPRESSIVE STRENGTH RESULT FOR THE 14 DAYS TEST

GLASS CONTENT	COMPRESSIVE STRENGTH			
	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3	AVERAGE
0%	280	324	320	308
10%	316	310	290	305.3333333
20%	300	280	310	296.6666667
30%	290	310	250	283.3333333

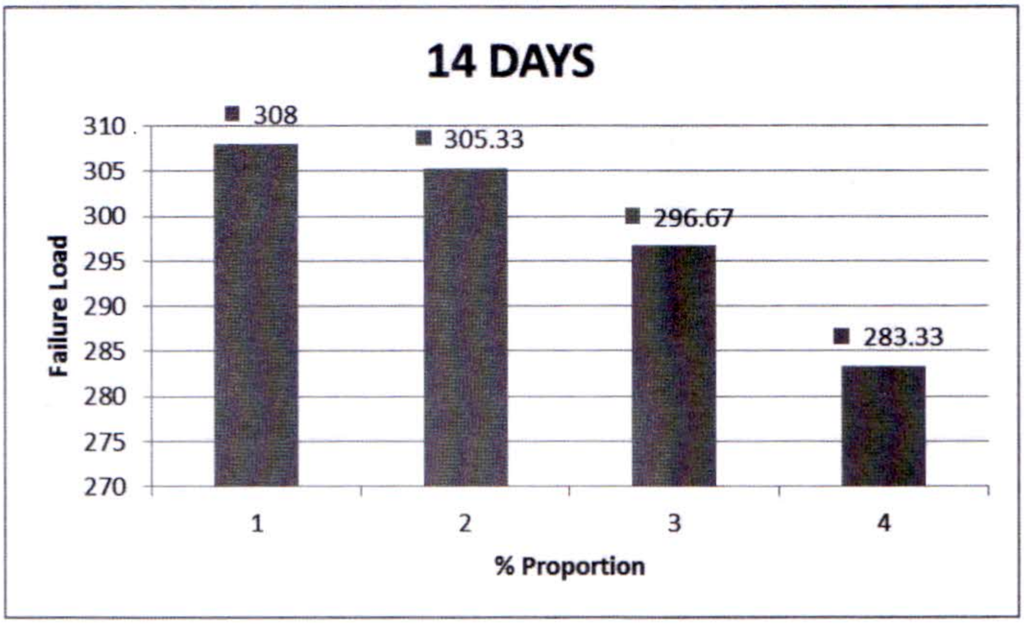


FIGURE 4.2: 14 DAYS COMPRESSIVE STRENGTH CHART

For the 14 days curing, the control beam specimen attained a strength of 308kg/cm^2 and there was also a noticeable decrease in the strength as the glass content increases but with a lesser margine as compared to the 7 days test result. With a 10 percent increase in the glass content there was a 0.9 percent decrease in the strength to 305kg/cm^2, 2.8 percent decrease (296.67kg/cm^2) as the glass content increases to 20% and a final 4.5 percent decrease to 283.33kg/cm^{2}on the last 10% increase.

TABLE 4.3 SUMMARY OF COMPRESSIVE STRENGTH RESULT FOR THE 28 DAYS TEST

GLASS CONTENT	COMPRESSIVE STRENGTH			
	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3	AVERAGE
0%	330	320	330	326.6666667
10%	300	320	310	310
20%	300	350	330	326.6666667
30%	345	360	350	351.6666667

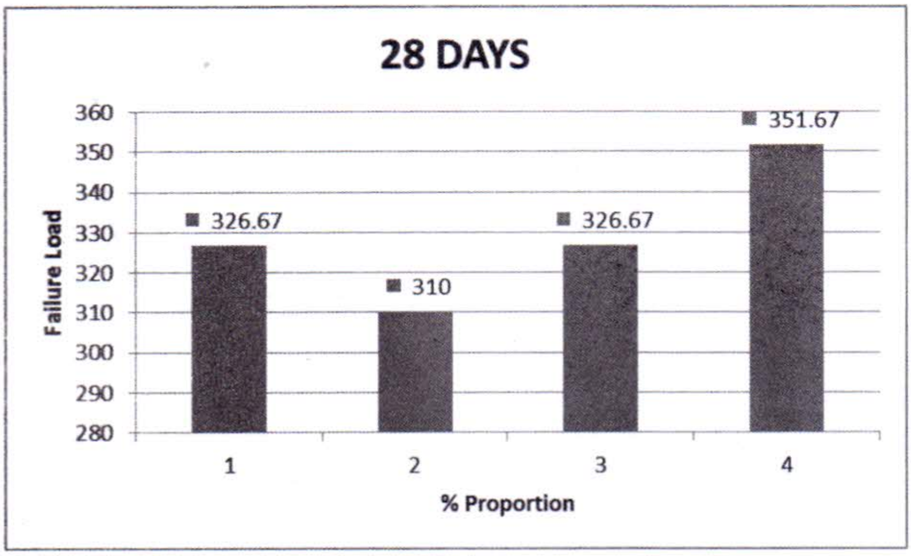


FIGURE 4.3: 28 DAYS COMPRESSIVE STRENGTH CHART

At 28 days, it was observed that the concrete with glass content has gotten strength which was reccomendable with the control beam, though at 10% the beam still experienced a 5 percent decrease to 310kg/cm^2 in strength but there was increase in strength afterwards, the control concrete beam and the 20% glass content beam gained the same average strength of 326.67kg/cm^2 and there was a 7.7 percent increase to 351.67kg/cm^2 for the 30% content glass..

TABLE 4.4 SUMMARY OF COMPRESSIVE STRENGTH RESULT FOR THE 90 DAYS TEST

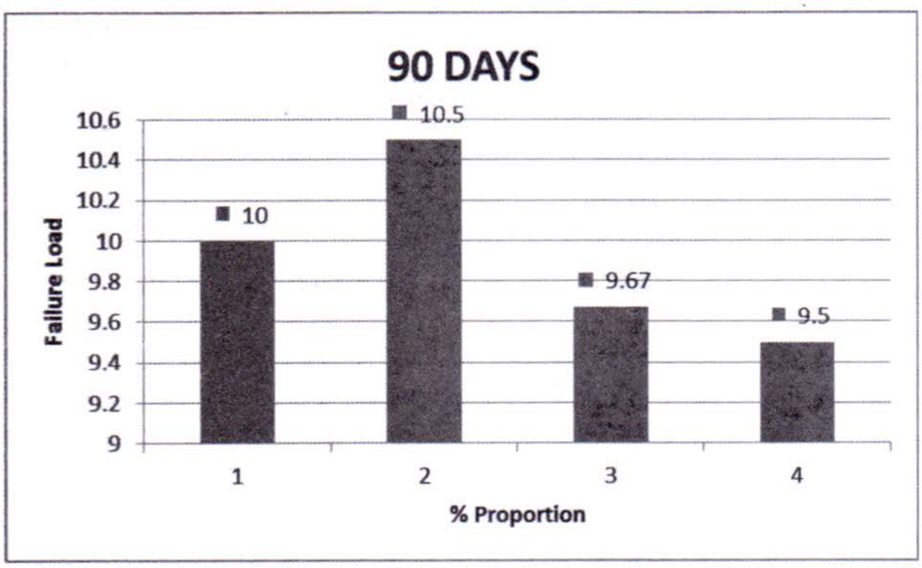


FIGURE 4.3: 28 DAYS COMPRESSIVE STRENGTH CHART

At 90 days, all the concrete beams with the different glass content as attained good compressive strength with a difference of +/-5 percent compared to the control. The 10% glass content beam gained a 5 percent increase in strength to 10.5 tonnes over the 0% glass content beam of 10 tonnes while the 20% and 30% glass content beams had a decrease in strength of 3.3 percent and 5 percent respectively to 9.67 tonnes and 9.5 tonnes.

4.2 Discussion

4.2.1 Effect on Flexural Strength

The Glass content does not have much effect on the flexural strength of the beam, though there are variations in the differences compared to the control beam but the 10% and 20% glass content beam showed better result when compared to the control (0% content) beam. The 10% glass content beam has its greatest difference of less 5 percent strength at 28 days (0% @ 326.67kg/cm^2 and 10% @ 310kg/cm^2) and plus 5 percent strength at 90 days (0% @ 10 tonnes and 10% @ 10.5 tonnes)while the 20% glass content beam has its greatest difference of less 8% decrease at 7 days (0% @ 290kg/cm^2 and 20% @ 266.67kg/cm^2). The strength attained is still very good for light **construction works like lintel beams in small scale buildings.**

The result of the 30% glass content shows that the more the increase in the glass content the greater the effect on the beam strength even though it may later attained strength far above the control beam, the great reduction at the early days of the concrete e.g. 7 days may cause some damages to the structure.

4.2.2 Alkali-Silica Reaction Effect

The alkali-silica reaction effect has been proved in past works to be greatly reduced when low alkali cement is used and majorly when the glass content particle sizes is in the fine aggregate size range. This is the reason for the little effect of this reaction on this work though the ASR effect was pronounced in the early days of the concrete but with time before the 28 days age the concrete attains its full strength.

4.2.3. Effect on Reinforcement

In the entire beam specimen tested, there was no record of the reinforcement being affected by the glass content in the beam. All failure in the beam occurs at the end of the beam especially at places of cover to reinforcement, only cracks were noticed in the beam at places of full reinforcement as shown below.

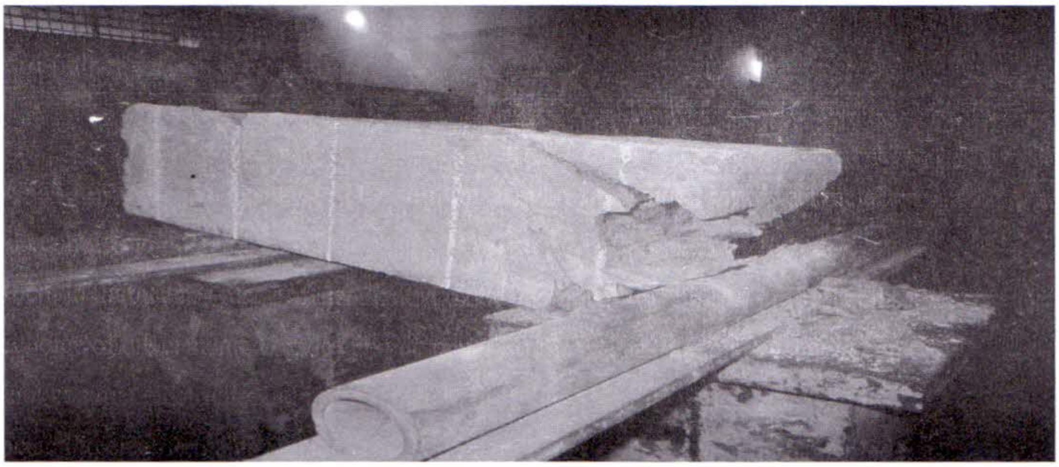


PLATE 6 : FAILURE SAMPLE OF BEAM

No failure was noticed in the reinforcement be it breakage or bending, this shows that the presence of the glass content causes no reduction in the strength of the reinforcement.

4.2.4 Effect on Workability

The percentage proportion of glass content (10%, 20%, 30%) used for the fine aggregate replacement does not affect the workability of the concrete, the concrete was still very workable and does not fail the slump test.

5.0 Conclusion

From the 7days, 14days, 28days and 90days testing of the reinforced sections with glass as replacement for fine aggregate, the following discoveries and conclusion can be drawn:

- The effect of the fine aggregate partial replacement with glass on the concrete strength both positively and negatively is very negligible.
- As much as Glass is a waste readily available in some environment the cost of grinding to fine aggregate sizes is on the high side.
- The presence of glass in the reinforced section does not in any way affect the strength of the steel reinforcement.

5.1 Recommendation

Glass can be used as a replacement for fine aggregate in reinforced sections in situations where sand is not readily available and the cost of processing waste glass to the preferred sizes is cheaper compared to getting sand to the needed area.

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