Recycled Window Glass for Non-Load Bearing Walls

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***Abstract*—This experimental study aimed to investigate the adequacy and advantages of non-load bearing concrete hollow blocks containing recycled window glass, in combination with sand as fine aggregate. The tests conducted were according to Standard Methods of Sampling and Testing Concrete Masonry Units with reference to Standard Specifications for Non-Load Bearing Concrete Masonry Units. Observations from the tests performed were conducted in the laboratory where precise data were gathered and completely attained. Some of the interesting insights of the study are: (a) The highest compressive strength appeared in the hollow blocks with 1:2:4 cement-recycled glass-sand ratios; (b) The mixture with 1:2:4 cement-recycled glass-sand ratios has the least moisture content found among the hollow blocks containing recycled clear flat glass; and (c). The use of clear flat glass in manufacturing hollow non-load bearing concrete masonry blocks would be the capability of finely crushed glass to manifest its pozzolanic effect and its low moisture content characteristics, making it possible for the mixture with 1:2:4 cement-recycled glass-sand ratios to be used as load bearing blocks.**

***Index Terms*—Bearing wall, concrete blocks, partition, recycled glass.**

I. Introduction

The use of recycled glass, as high performance substitute for sand and aggregates is being investigated in many years. Studies that already been conducted by researchers had proven the use of glass as aggregate in concrete mixture. Some examples of the utilization of glass aggregate in construction include its application to asphalt, pipe beddings, backfills, and as filler aggregate.

Previous studies indicate that the main problem confronted in the use of glass as aggregate was the alkali-silica reaction expansion. Several approaches can effectively control the expansion of alkali-silica reaction due to glass aggregate [1]. Moreover, the types and color of glass have significant and important effects in the alkali-silica reaction expansion [2]. They also expounded that very finely ground glass has pozzolonic properties and therefore can serve both as partial cement replacement and filler [2, 3].

The use of recycled glass in concrete opens a vast new market for waste broken glass in a variety of specialty products of specialty products or in local concrete operations. Recent research findings make it possible to utilize glass in regular concrete applications, thereby expanding and developing markets for recycled glass.

In the United States, some of the glass concrete products include paving stone, architectural and decorative application [4].

This research recognizes the potential of recycled glass specifically as a fine aggregate, in combination with sand, in the utilization of hollow non-load bearing concrete masonry units as internal wall partitions. Consequently, the aim of this study is to investigate the adequacy and advantages of hollow non-load bearing concrete masonry units containing recycled glass, in combination with sand as fine aggregate.

II. Literature Review

The National Solid Waste Management Commission categorized glass into two, glass packaging and flat glass [5]. Glass is 100% recyclable and has no waste by products. Glass industry utilizes large amount of energy for its production, glass recycling extends furnace life and reduces energy costs. One of the main wastes generated from glass are the glass cullet or broken glass from windows, and from packaging such as soft drinks, beer liquor, pharmaceutical bottles and packer’s jars [5]. National Solid Waste Management Commission classified cullet into, flint or clear, green, amber, and flint with blue prints [5].

Waste bottles and broken flat glass are sent to cullet traders, wherein condemned cullets were disposed to landfills [5], [6]. Glass cullet are crushed and cleaned and are used to produce recycled flat glass and bottles [5].

In this study, condemned flat glass cullet is the main object in consideration for its possibility as a material for manufacturing hollow non-load bearing concrete masonry units.

In a typical glass manufacturing process, the products are flat glass, container glass and blown glass. The procedures for manufacturing glass are the same for all products except forming and finishing container glass and blown glass, 51 and 25 percent respectively of total soda-lime glass production, use pressing, blowing or pressing and blowing to form the desired product. Flat glass, which is the remainder, is formed by float, drawing, or rolling processes.

Among all concrete block units, the stretcher concrete hollow blocks are the most widely used as non-load bearing partitions, load bearing walls, retaining walls for buildings and other structures, and for fences [6].

Concrete hollow block is classified as load bearing and non- load bearing blocks [7]. Load bearing blocks are those whose thickness ranges from 15 to 20 centimeters and are used to carry a load [6]-[7].

Aside from its own weight, non-bearing blocks on the other hand, are blocks intended for walls, partitions, fences, dividers and the like carrying its own weight whose thickness ranges from 7 to 10 centimeters [7]. The standard hollow blocks has three void cells and two half cells at both ends

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having a total of four [7]. These hollow cells vary in sizes as there are different manufacturers using different types of mold.

A science module prepared by the University of the Philippines Institute for Science and Mathematics Education Development entitled "Making your own Hollow Blocks" supplied the information for the proportion by volume of raw materials for non-load bearing concrete hollow blocks. The module indicated that for non-load bearing concrete hollow blocks the proportion is 1:6 (one part cement and 6 parts sand) [8].

Hollow masonry unit is a masonry unit with cross sectional area in any plane parallel to the surface containing cores, cells or deep frogs, is less than 75 percent of its gross cross-sectional area measured in the same plane [9]. All Masonry units were conform to the requirements specified in Section 702 of National Structural Code of the Philippines in which Concrete Masonry Units shall meet and conform to the following American Society for Testing and Materials (ASTM) standards and requirements: 1) ASTM C55-11, Concrete Building Brick. 2) ASTM C 90-85, Hollow & Solid Load-Bearing Concrete. 3) ASTM C 129, Non-Load Bearing Concrete Masonry Units. 4) ASTM C 140, Sampling & Testing Concrete Masonry Units and, 5) ASTM C 426, Standard Test Method for Drying Shrinkage of Concrete Block [9].

Some physical and chemical properties of glass are the following: 1) Very hard when solid. 2) It has absolutely no crystalline structure. 3) It has no sharp melting point. It melts at 1400 ℃ to 1500 ℃ but the working range of temperature for proper viscosity is 1000 ℃ to 1300 ℃. 4) Generally, it is not affected by air or water, but is affected by alkalies. 5) It has low thermal conductivity and high coefficient of expansion. 6) It is extremely brittle and, 7) It has no effects of ordinary chemical reagents [10].

In this research, recycled glass was incorporated into the production of hollow non-load bearing concrete masonry blocks.

Concrete block wall construction is a fast and economical way to construct buildings [10]. Fewer workers are required, shoring and scaffolding are reduced and finishing operations can be completed quietly and easily in the enclosed building [10]. A six to ten-storey building can be completed easily in six to eight months. Thus, the overhead cost and construction supervision are reduced to a large extent. Maximum job efficiency is achieved by using concrete block. Removal of formworks and large scaffoldings which are unnecessary in this system, cause increases efficiency. The concrete block wall system does not involve the use of columns and beams. Elimination of the beams may permit a reduction in floor to floor height by one foot or more. The walls work as both structural and finish walls and can be painted or left natural, thus reducing the cost of structural and finishing work. The concrete block wall total concrete construction insures minimum maintenance throughout the life of the project.

The studies of Meyer and Lee provided the framework for the eradication of effects of alkali-silica reaction in concrete mixture "unpublished" [11], "unpublished" [12]. To eradicate the effects of alkali-silica reaction, the recycled glass used in this study was passed through American Standard #50 mesh. The researcher focused on the alkali-silica reaction expansion and the pozzolanic effects of finely crushed glass on the concrete mixture of the hollow blocks.

Clear flat window glass was used in this study, as influenced by the concept from Lee's work where the type and color of glass affects the alkali-silica reaction expansion [2], [7].

The literature from University of the Philippines Institute for Science and Mathematics Education Development showed that the quantity of water is critical in the process of manufacturing concrete hollow blocks. Dry mixtures remained on the mold, while wet mixtures, the top side of the hollow block were sag [8].

In addition, water-cement ratio depends on the size of aggregates used to attain a no slump concrete [10]. These two literatures suggest that there is exist of unique range in terms of quantity of water for concrete mixtures depending on the size of aggregates used. The water cement ratio used in glass is different from each try-out mixture used because glass has zero water absorption. It has a significant effect on the compressive strength and moisture content of the try-out hollow block specimens.

This present study is similar to that of Remigio in terms of using substitute materials in manufacturing of hollow concrete masonry units but differs in their uses "unpublished" [13]. The study of Remigio focused on load-bearing masonry units while this study centers on the non-load bearing masonry units 'unpublished" [13].

III. Research Method

Experimental method is used in this study to investigate the adequacy of 4" thick hollow non-load bearing concrete masonry units containing recycled clear flat window glass (in combination with sand as fine aggregate) in its utilization as internal wall partitions.

The researcher attributed the change in compressive strength and absorption/moisture content to the effect of the cement-recycled glass-sand ratio in the concrete mixture.

IV. Experimental Investigation

A. Project Design

Commercial concrete hollow blocks and try-out concrete hollow blocks containing recycled clear flat window glass were used in this research.

Commercial concrete hollow blocks were from three different retailers and sellers of concrete hollow blocks. These commercial specimen samples were sent out for compression, moisture content and absorption tests.

Try-out specimens such as 1:0:6, 1:½:5½, 1:1:5, 1:1½: 4½, and 1:2:4 cement-recycled glass-sand ratios were subjected to compression, absorption and moisture content tests after 28 days of curing. The result of the specimens' tests was then evaluated against ASTM C-129. When the outcome of the test conforms to ASTM C-129, the mixture of the specimen was accepted [12]. If it isn't, the specimen that failed against ASTM C-129 was compared to the first tested commercial concrete hollow blocks "unpublished" [13]. The acceptability of the specimens is now associated to the result of the testing for commercial concrete hollow blocks. When the specimens with recycled glass performed better against at least one of the commercial concrete hollow blocks then its mixture was given a positive response, otherwise the mixture was considered to be a failure "unpublished"[14].

B. Project Development

The recycled clear flat window glass used in this research was taken from junkshops and glass workshops. The collected glass were then cleaned wherein foreign materials were discarded then manually crushed to powder like material before it passed #50 sieve. The experimental specimens were done using parts of cement, recycled flat window glass and sand. Next is to add water gradually after the crushed glass has been mix together with the concrete mixture. The mixture was poured into a pre-fabricated 4" thick concrete hollow block mold. Curing period lasted for 28 days. After curing, the specimens' dimensions and weight were recorded as a preparation for the compression, moisture content and absorption tests with reference to ASTM C-140 [16]. Test results are then evaluated against the required specifications in ASTM C-129 [13].

Other pertinent materials in the manufacturing of concrete hollow blocks such as sand, cement and commercial concrete hollow blocks were bought from commercial hardware in their locality.

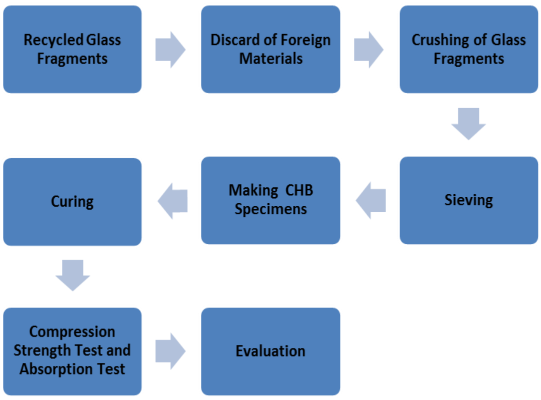

Fig. 1. Project development

C. Proportion by Volume of Raw Materials for Try-out Rectangular Blocks

As shown in Table I, there were a total of five mixtures used from zero part of recycled glass up to 2 parts of recycled glass with increment of half part. Three full size samples for each try-out mixture were made to be subjected for compression test. However, small rectangular blocks are prepared for moisture content and absorption tests.

On the other hand, commercial concrete hollow blocks are obtained from three different retailers or manufacturers (named as Manufacturer A, Manufacturer B and Manufacturer C), six pieces for each. For which, three will be subjected to compression test while other set of three were sawed into small rectangular blocks for moisture content and absorption tests.

TABLE I: PROPORTION BY VOLUME OF RAW MATERIALS FOR TRY-OUT RECTANGULAR BLOCKS

Mixture No.	Cement	Recycled Glass	Sand	Remarks
1	1	0	6	Non- Load Bearing
2	1	½	5 ½	Non--Load Bearing
3	1	1	5	Non--Load Bearing
4	1	1 ½	4 1/2	Non--Load Bearing
5	1	2	4	Non--Load Bearing

D. American Society for Testing and Materials (ASTM) Standard for Concrete Hollow Blocks

Tables II, III & IV were taken from ASTM C-129 which shows the basic requirements for the standard specification of non-load bearing concrete masonry units. Tests results acquired from the conducted tests were compared against these values for the acceptability of the mixture proportions of the try-out rectangular blocks due to the constraint "unpublished" [15]. The validity of the specimens for moisture content will be based on the lowest maximum percentage that is permissible given in Table III which is 35% that falls under categories of humid with linear shrinkage of 0.045 to 0.065, maximum "unpublished" [15], [16].

TABLE II: ASTM REQUIREMENTS FOR COMPRESSIVE STRENGTH

	Compressive Strength (average net area) min. MPa
Average of 3 units	4.14
Individual unit	3.45

TABLE III: ASTM REQUIREMENTS FOR MOISTURE CONTENT

Linear Shrinkage, %	**Moisture Content , max, % of total absorption (average of 3 units)**		
	Humidity conditions at jobsite of point of use		
	Humid	Intermediate	Arid
0.03 or less	45	40	35
From 0.03-0.045	40	35	30
0.045 -0.065, max	35	30	25

TABLE IV: ASTM WEIGHT CLASSIFICATION FOR NON LOAD BEARING CONCRETE MASONRY UNITS

Weight Classification	**Oven Dry Weight of Concrete, kg/m^3**
Lightweight	1680 max.
Medium weight	1680 to 2000
Normal weight	2000 min.

E. Weight Dimensions of Try-out Rectangular Blocks and Commercial Rectangular Blocks

The data in Table V and VI show the deviation of weight and dimensions of full-sized units of try-out and commercial rectangular blocks. These data was utilized in the computations required for compression, absorption and moisture content tests. Because try-out rectangular blocks undergone backyard production, there was a minimal differences in height occurred compared with the commercial rectangular blocks which have uniform height since machine was used in its manufacturing.

Web and face shell thickness for try-out rectangular blocks are much bigger than that of the commercial specimens, having measurements of 23, 22 and 24 mm respectively.

Since the web and face shell thickness for try-out rectangular blocks are much bigger these specimens are also heavier compared to commercial rectangular blocks

TABLE V: WEIGHT AND DIMENSIONS OF TRY-OUT RECTANGULAR BLOCKS

Mixture No.	Length (mm)	Width (mm)	Height (mm)	Web Thickness (mm)	Face Shell Thickness (mm)	Bearing Area (mm^2)	Weight (kg)
1	400	100	190.0	30	30	28800	11.7
2	400	100	194.2	30	30	28800	11.6
3	400	100	188.3	30	30	28800	11.3
4	400	100	190.8	30	30	28800	11.5
5	400	100	186.7	30	30	28800	11.9

TABLE VI: WEIGHT AND DIMENSIONS OF COMMERCIAL RECTANGULAR BLOCKS

Commercial Designation	Length (mm)	Width (mm)	Height (mm)	Web Thickness (mm)	Face Shell Thickness (mm)	Bearing Area (mm^2)	Weight (kg)
A	400	100	190.0	23	23	22250	9.5
B	400	100	190.0	22	22	21500	9.5
C	400	100	190.0	24	24	23225	8.9

F. Weight Classification

As shown in TableVII, mixture 1, 2, 4 and 5 are classified as lightweight while Mixture 3 is classified as medium weight block.

Commercial A and C are classified medium weight blocks while Commercial B is classified as lightweight block shown in Table VIII.

It only shows that the workability of concrete hollow blocks containing recycled glass will not change if rectangular blocks were going to be used.

TABLE VII: WEIGHT CLASSIFICATION OF TRY-OUT RECTANGULAR BLOCKS

Mixture No	Ratios	Volume (mm^3)	Height (mm)	Web Thickness (mm)	Face Shell Thickness (mm)
1	1:0:6	468000	753.33	1609.69	Lightweight
2	1:1/2:5 ½	543450	878.50	1616.79	Lightweight
3	1:1:5	548053	923.83	1687.90	Medium weight
4	1:1 ½:4 ½	573160	949.67	1657.58	Lightweight
5	1:2:4	557510	876.83	1573.56	Lightweight

TABLE VIII: WEIGHT CLASSIFICATION OF COMMERCIAL RECTANGULAR BLOCKS

Commercial Designation	Volume (mm^3)	Height (mm)	Web Thickness (mm)	Face Shell Thickness (mm)
A	339279	586.33	1818.49	Medium weight
B	227450	354.00	1532.24	Lightweight
C	291188	5226.00	1829.00	Medium weight

V. RESULTS AND DISCUSSIONS

A. Absorption and Moisture Content

In Fig. 2, all of the five try-out mixtures' moisture contents were way below the American Society for Testing and Materials (ASTM) limit of 35% for which the highest value is 26.21%. It also shows the minimal differences between absorption percentages of the five mixtures.

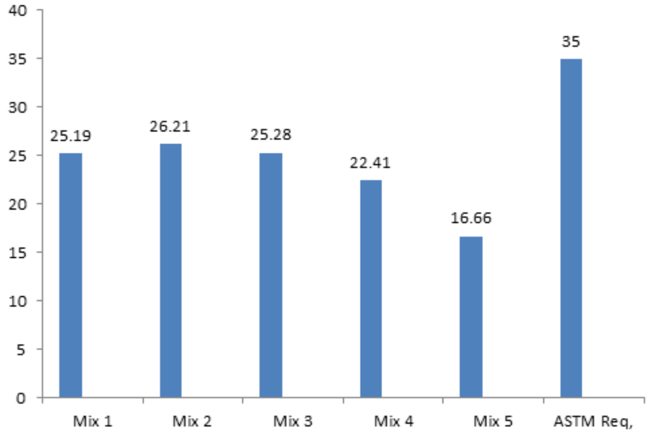

Fig. 2. Absorption and moisture content of try-out rectangular blocks

As shown in Fig. 3, the average moisture content of Commercial B and C are higher than the American Society for Testing and Materials (ASTM) maximum. It also shows the minimal differences in absorption properties of the three commercial specimens.

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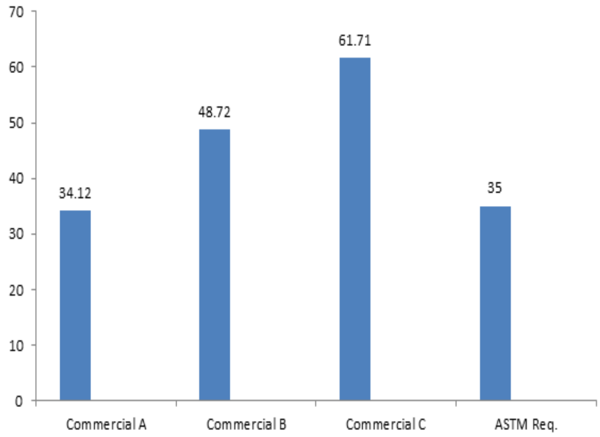

Fig. 3. Absorption and moisture content of commercial rectangular blocks

The moisture content of hollow non-load bearing concrete masonry units containing recycled clear flat glass as fine aggregate with 1:½:5 ½, 1:1:5, 1:1½:4½, and 1:2:4 cement-recycled glass-sand ratios on a 1:6 cement fine aggregate ratio of concrete mix, complied with the American Society for Testing and Materials (ASTM) criteria for moisture content. Hence, all of these mixture proportions are said to be permissible for moisture content.

In terms of moisture content, as a whole, the test results demonstrate a decreasing rate as the quantity of recycled glass is increased. It was showed that the percentage of moisture content of the ratios 1:0:6, and 1:½:5½ have a minimal discrepancy while the ratios 1:½:5½, 1:1:5, 1:1½:4½, and 1:2:4 showed a consistent decrease in percentage. Remarkably, the mixture with 1:2:4 has the least moisture content found among the hollow blocks containing recycled clear flat glass.

Accordingly, besides from its possible economic and environmental benefits, other advantages that could be acquired from using recycled clear flat glass in manufacturing hollow non-load bearing concrete masonry blocks would be the capability of finely crushed glass to manifest its pozzolanic effect and its low moisture content characteristics

B. *Compressive Strength*

Fig. 4 shows that there is a sudden decrease of strength between Mixture 2 and Mixture 3. However, there is a constant increase of strength from Mixture 3 to Mixture 5. This also shows that Mixtures 1, 2 and 3 didn't attain the American Society for Testing and Materials (ASTM) requirement of 4.14 MPa, in contrast with the performance of Mixtures 4 and 5 which achieved to pass this limitation.

Fig. 5 shows that the compressive strengths of commercial rectangular blocks are way behind the American Society for Testing and Materials (ASTM) minimum requirement for compressive strength of non-load bearing concrete masonry units.

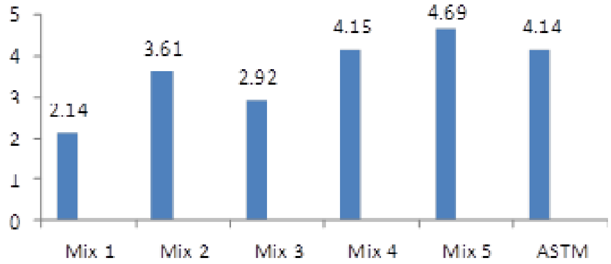

Fig. 4. Compressive strength of try-out rectangular blocks

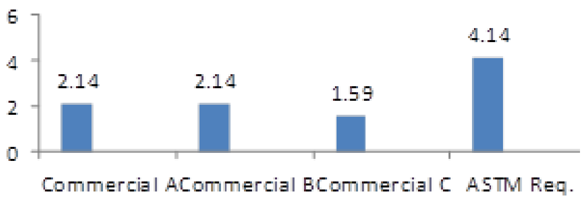

Fig. 5. Compressive strength of rectangular blocks

The compressive strengths of hollow non-load bearing concrete masonry units containing recycled clear flat glass as fine aggregate with 1:1½:4½, and 1:2:4 cement-recycled glass-sand ratios on 1:6 cement-fine aggregate ratio of concrete mix, performed satisfactory against the American Society for Testing and Materials (ASTM) standards on its 28th day of curing. Even though the blocks with 1:½:5½ and 1:1:5 ratios were unable to satisfy this standard, they are still considered permissible since the results gathered were more acceptable than those of the commercial blocks.

In general, the results gathered present an increasing compressive strength of hollow blocks as the quantity of recycled glass is increased. In fact, the highest compressive strength appeared in the hollow blocks with 1:2:4 ratios while the blocks with 1:0:6 has the least. This scenario may said to be a manifestation of the pozzolonic effect of the finely crushed glass on the concrete mixture or the effect of their water-cement ratio. The water-cement ratio for a mixture that contains more glass is lower than that of less quantity of glass because glass has basically zero water absorption.

VI. Conclusion

The use of recycled clear flat window glass for non-load bearing concrete hollow blocks wall partition decreases the water-cement ratio depending on the amount present in the mixture. As the unit weight of concrete decreases, the utilization of recycled clear flat window glass lowers the value for modulus of elasticity.

The use of recycled clear flat window glass is not recommended for structural members such as columns, beams and suspended slabs.

The advantages using recycled clear flat window glass in manufacturing hollow non-load bearing concrete masonry blocks would be the capability of finely crushed glass to manifest its pozzolanic effect and its low moisture content characteristics, making it possible for the mixture with ratio 1:2:4 to be used as load bearing blocks.

There is a positive projection in the availability of clear flat window glass due for its demands and flexibility in use

Appendix

Fig. 6. Making of concrete hollow blocks with sieved; recycled flat window glass

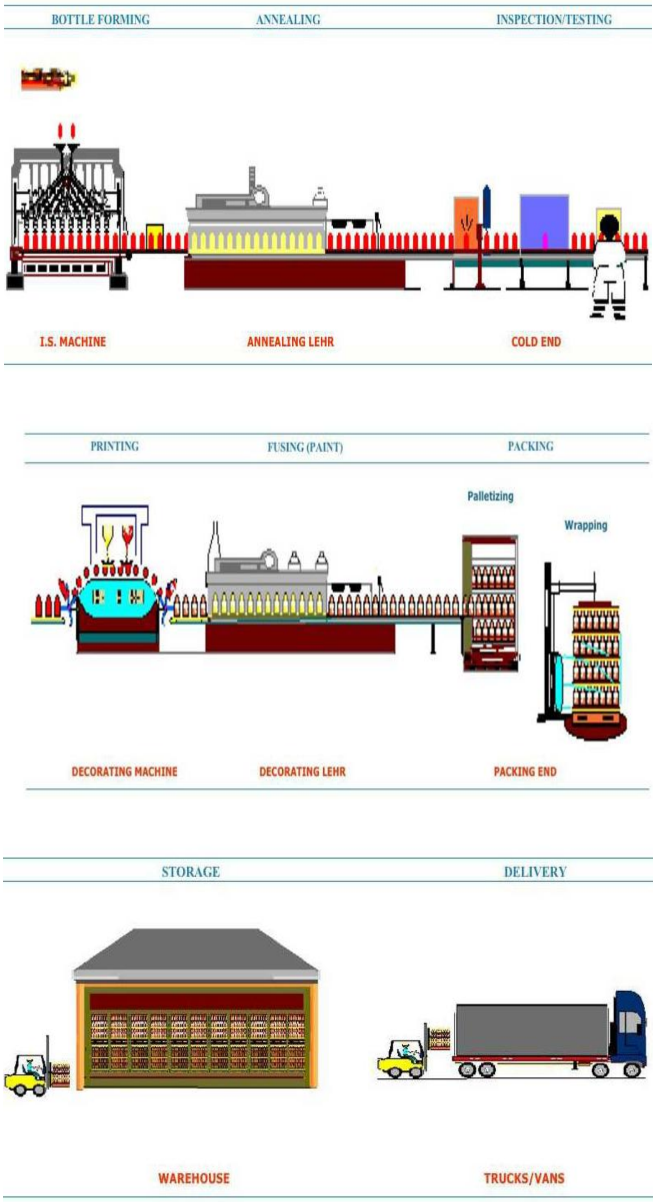

Fig. 7. Glass process flow

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