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Silica Sand: The Architecture Material of the 21st Century

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Abstract:- Silica sand is a hard, chemically inert mineral composed of one atom of Silicon to two atoms of Oxygen, occurring freely in nature as a result of weathering, erosion or the leaching of rocks, and found in most of the surface of the earth's crust. Silica sand is used in ceramics, chemicals, construction materials, paints, abrasives, glass making, filtration media, etc. Glass is the most visible product of Silica sand formed when subjected to temperatures in excess of 1500ºC, formed from the molten state without crystallisation. Glass is in everyday use, found in every corner of the office or home in utensils such as mirrors, furniture, utensils, crockery, spectacles, and television sets. Glass also finds use in cars, computers, and mobile phones. Glass use in Architecture is very vast and goes back to ancient Egyptian times. This paper features the chemistry of glass, and the historical trajectory of Architectural Glass from the 13th Century to the modern times. Architectural properties of glass, types and uses are also highlighted. Silica sand application in Green Building, a trend that is catching on very fast is reported. Current studies predict a rise in the demand for Architectural Glass in the next decade of the 21st Century. This corresponds to a rise in Silica Sand demand in the 21st Century.

Keywords:- *Silica Sand, Glass, Architectural Glass, Green Building.*

I. INTRODUCTION

Silica sand is the name given to a group of minerals composed of Silicon and Oxygen combined in the ratio of one atom of silicon to two atoms of oxygen (1: 2) resulting in the chemical formula SiO_2. The mineral silica sand occurs naturally in free flowing states as dusts and sands ,etc and in chemical combination in a considerable bulk of earth's crust. Silica sand naturally evolves from the weathering of / erosion of rocks and transportation by rivers and / or the sea. It is a sedimentary material categorized as loose grains leached out from decomposed and disintegrated rocks [SanmoyMitra, 1974]. This silica sand has fine granules withgrain size ranging between 0.06 and 2.0mm in diameter. However, a grain of silica sand is either round or angular in shape, white, milky or brown in color.

Naturally occurring silica sand contains some undesirable impurities like kaolinites, titanium, iron oxides, and heavy element oxides. (Shukla and Pandey, 1977) The term silica sand is used to identify sand that conforms with the specification of main composition of about 95% $SiO_2$with impurities less than 5% (Sarah et al, 2003). Crystalline silica occurs mostly as quartz (SiO_2), that is almost pure Silicon dioxide. Several amorphous varieties are flint, agate, opal etc. Other ceramic minerals like feldspar and clay contain free silica "quartz". In addition, these ceramic minerals also contain silicate: that is SiO_2 chemically combined with other oxides to form crystalline minerals. Other silica sand containing rocks and minerals are anderlusites, barites, beach sand, bentonite, calcites, diatomaceous earth, kaolin, limestone, mica, talc, tripoli, rutile, wollastonite, zeolites, zircon sand, vermiculite, granite and sand stone.

Silica sand is chemically inert and relatively a hard mineral;grading 7 out of 10 in Mohrs Hardness Scale. Sand with particularly high silica content that is used for other purposes other than construction is referred to as silica sand or industrial sand. Industrial use of silica sand depends on its purity, physical characteristics such as grain size, shape, distribution, refractoriness and grain strength.

Silica sand is the primary ingredient for a diversity of products; ceramics, chemicals, construction materials, paints, abrasives, glass making, filtration media, golf courts and sports field etc.

It is the basic requirement for economic solvation. Silica sand is used in the manufacture of glass. Glass is a class of multicomponent inorganic materials that are subjected to high temperature by manufacture. The product is a silicate glass with highly variable mechanical and optical property that solidify from molten state without crystallization. This definition is illustrated in the diagram below. The difference in the relationship between a glass and a crystalline solid is evident when the specific volume of glass is plotted against temperature. The glass solidifies without forming crystals, has higher specific volume and is said to be in a metastable state. [Marshall and White, (1986)]

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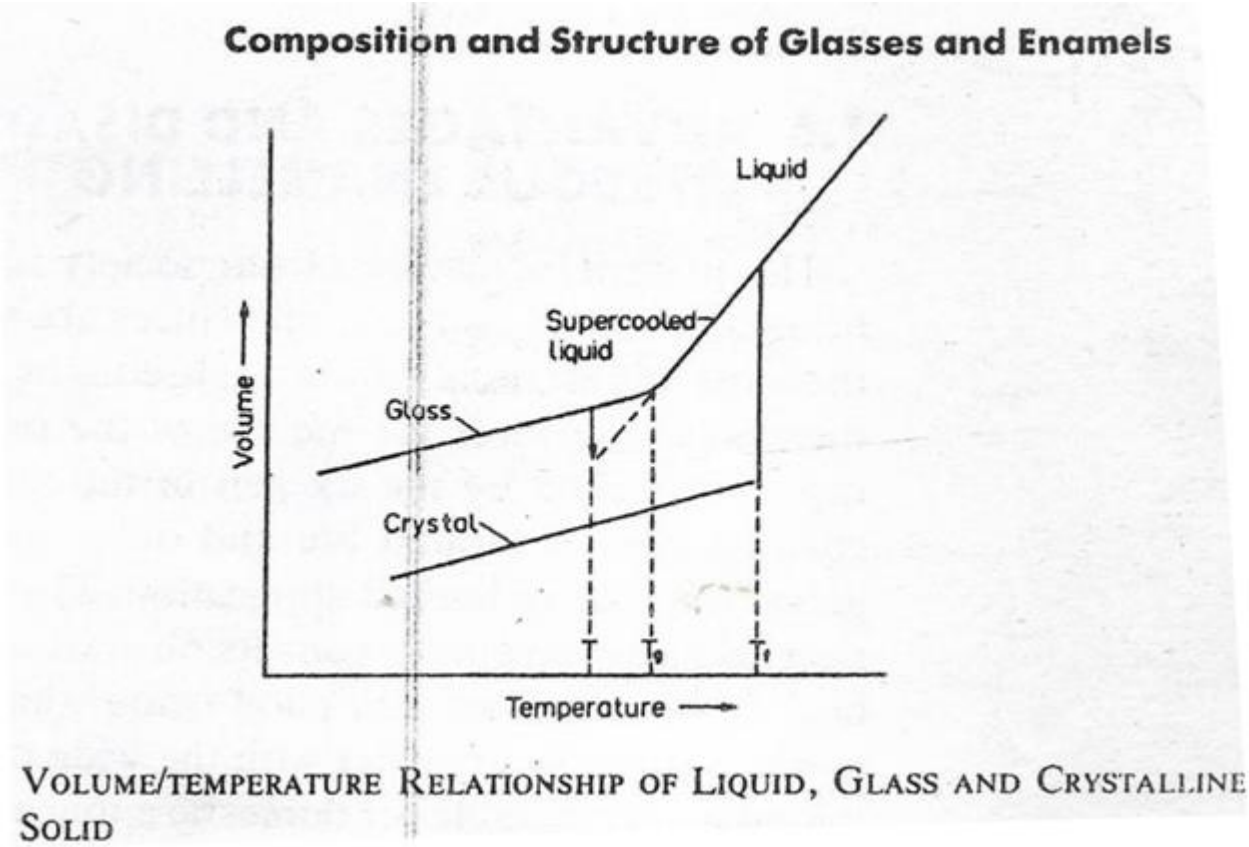


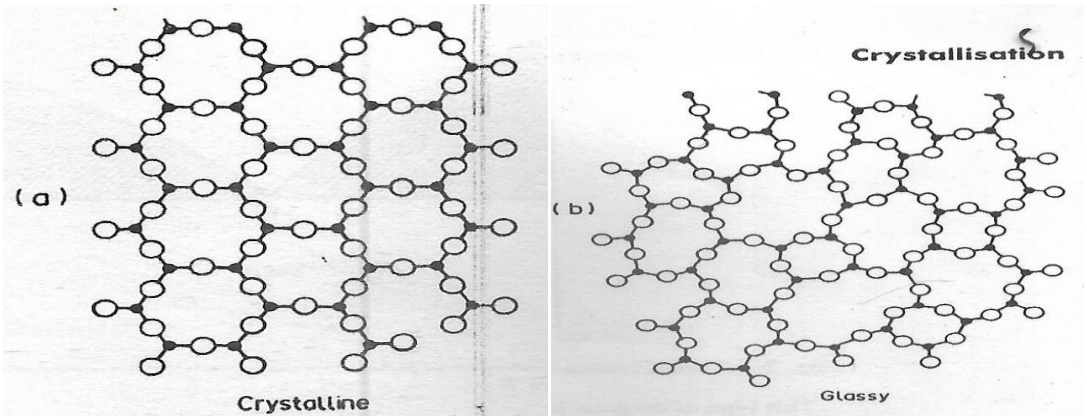
Graph: Volume Temperature Relationship of Liquid, Glass and Crystalline Solid

Not all oxides form glass. Table 1, below shows oxides, their melting points and viscosity at melting points. It is observed from the table that the most critical factor relevant in glass formation is the rate of cooling.

Table 1: Table of Oxides and Salts: Their Viscosity At Melting Point

Oxides	**Melting Point °C**	**Viscosity at M.PtPoises**	**Solid Form**
As_2O_3	300	10^6	
B_2O_3	450	10^5	
GeO_3	1115	10^7	Glass
SiO_2	1170	10^7	Glass
H_2O	0	0.02	

That is the reason SiO_2 though a crystalline quartz, is the best glass forming oxide and used industrially as glass sand. In addition to the glass forming oxides, are glass modifying oxides such as (Sodium Oxide)Na_2O, K_2O, etc. These oxides are capable of weakening the glass-forming network. There is also the intermediate oxides (Aluminum Oxide)Al_2O,that takes part in the glass formation. Glass has a random network formed by the oxygen of the glass forming and intermediate oxides, broken in places by the network modifying ions. It is supposed that this framework is irregular with no repeating pattern as shown in the diagram below. This accounts for the diffused bands found in the X – ray diffraction pattern of a homogenous glass.



A B

(A) Crystalline (B) Glassy

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Glasses are generally hard and brittle. Glass is transparent, and translucent. It reflects, refracts and transmits light. Glass is hygienically safe and recyclable. The pair of lens and googles worn to enhance one's expressive focal point are made of glass. Sleek flashy cars that adorn the streets of most cities in the world have glass components. Glass is an old versatile material found at every corner of a house or an office. Interaction with glass material on day to day is enormous. Some range of household items such as mirrors, cooking utensils, wares for drinking and eating etc, are made from glass.

The use of glass in architecture could be traced from 1330 with Crown glass for artistic work [understandconstruction.com/glass html] till date as bullet-proof glass. Lots of projects on glass are on going aimed at building technologies that are seamless, beautiful and empowering. This paper therefore discusses the chemistry of glass. The use of glass in architecture is reviewed in chronological order and the way forwardin the building industry explored. It is believed that the utilization of the full potentials of glass will influence the future of building industry and impact the quality and quantity of silica sand in use in the 21st century

- *Manufacturing of Glass*

Glass making originated in Egypt in the period 1600 B. C. [http://www.historyofglass.com/The Romans established a few glass factories in their country during the first century B.C. England, France and Germany joined in glass production between 15th and 16th century A. D. The First scientific glass work was produced by Germans, in Jena. England and America followed suit in the manufacture of glass after the First World War,1914 -1916. Glass manufacturing involves the melting and refining the right set of raw materials;basically silica sand (SiO_2) sodium oxide (Na_2O), calcium oxide (CaO) magnesium oxide MgO and Feldspar ($Na_2Al_2O_3$). [Shukla and Pandey, 1977].These ingredients are mixed in the right proportion and processed by the conventional smelting and refining methods at temperature above 1500^{o}C. The molten liquid glass flows into the float bath (a mirror like surface made of tin) and leaves the float bath as solid ribbons at 650^{o}C. Further processing of the solid ribbon glass are tailor made depending on the need or usage of the glass.

- *Origin of Glass*

In prehistoric times, "Obsidian" naturally occurring glass was found near volcanic regions, and fulgrurites (glass formed naturally after lightening strikes sand) were used to make weapons. [understandconstruction.com/glass html] Glass blowing was discovered in the 1st century in Europe. This revolutionized the glass making industry. In addition the introduction of manganese dioxide led to the production of "Clear Glass" used for architectural purposes as cast glass windows. Glass making spread through out Europe and Middle East over the next 400 years and in the 7th century, Anglo Saxon Glass was used in the churches and cathedrals. Sheet glass was made by the 11th century. From 11th – 19th century, glass windows were used in gothic renaissance and baroque architecture. There are numerous examples of stunning patterns created by using colorful glass that are immortalized by great artists all over the world. In the 19th century, flat / sheet glass windows were created. Presently, there are nearly infinite varieties of glass.

One data base listed over 350,000 types of currently known glass. [the atlantic.com/technology/archieve/2018/04/humankindmostimportantmaterial/537315/]. Glass is considered to be the humankind most important material. Assuming you are reading this article on a smart phone, you owe a debt to Gorrilla Glass, which dominates the market for mobile devices. Without glass, the world would be unrecognizable. It is in the eyeglasses on your face, the light bulbs in your room and the window panes that let you see the outside. Glass has shaped the world more than any other substance. It is in many ways, the defining materials of the human era.

- *Use of Glass in Architecture*

The glass used in the building industry is called Architectural Glass. It is used as material for insulation, structural element, external glazing, and cladding; it is also used for intricate fenestrations on facades and on conventional windows[Mehran and James (2010)]. The most widespread use of Architectural glass is for transparent glazing of the building envelope, as well as windows in the external walls. Glass can also serve as material for internal partitions. Buildings glass is usually of the safety type, including laminated, toughened and reinforced glass.

- *Timeline of Modern Architectural Glass Development*

- 12226; "Broad Sheet" First produced in Sussex
- 1330: "Crown glass" Produced in Rouen, France produced for artwork
- 1500: Venetian glass makers of Murano, made mirrors by covering the back of plate glass with mercury tin amalgam.
- 1620s "Brown Plate" First Produced in London for mirrors and coach plates
- 1874: Tempered Glass developed in France by Francois Barthelemy Alfred Royer de la Bastie through quenching molten glass in heated bath of oil
- 1888: Invention of machine rolled glass with patterns
- 1898: Pilkington produced Wired cast glass for security issues.
- 1959: Float Glass launched in UK

- *Architectural Properties of Glass*

Glass constructions have become the symbol of development in many countries where people see glassy buildings as a symbol of affluence. Thanks to various properties exhibited by glass. Building glass is usually of safety type, including laminated, toughened and reinforced glass. [Moshen.Abdoulnaga, (2006)] These attributes of glass are achieved by the addition of suitable ingredients for an envisaged feature. Hence glass can also be tailored made to be ECO friendly by improving its green house effect. Glasses exhibit the following properties: [Yan and Shuxia, (2011)]

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- Transparency: A glass material allows an object to be seen through it. Glass can be transparent from one side only as found in mirrors or from both sides as seen in some windows.

- Strength: Glass is known to be brittle but can be enhanced to be strong with some admixtures and laminations.

- Workability: This is the most superior property of glass as it can be formed into different shapes and sizes.

- Transmittance: Transmittance is the light that passes through a material that can be measured by a spectrophotometer. The transmittance of a glass material can be modified by coatings, etching etc.

- Recyclability of Glass: Waste glass materials have the ability to be reclaimed and reused as raw materials for construction works.

➢ *Architectural Glasses, Properties and Uses*

Glass	Properties	Uses
Chromatic	Controls interior spaces from daylight. It can be electrochromic, photochromic and thermoschromic	Used in Intensive Care Units (ICU) as well as meeting rooms
Extra Clean Glass Stain Proof	Has High aesthetic value due to photocatalytic and hydrophilic properties	Ease of maintenance
Float Glass Soda lime Glass	It is clear and Flat Weighs about 6 – 36kg/m2 and thickness of about 2mm – 20mm	Used for shop fronts and public places
Glass Block	Made from different half of glass that are pressed and annealed together	Used for walls and staircases where lights are needed without openings
Glass Wool	Insulating Glass material	It is fire resistant
Insulated Glazed Units: Double Glazed Glass Units	Comprises of two or three layers of glass separated by spaces filled with gases such as (noble gas argon, krypton) or vacuum	Good Insulators. Insulating glass retains heat during cold weather thereby saving energy, reduces noise penetration and increases comfort.
Laminated Glass	Laminated glass is created by coating resin glue film between two or more pieces of glass sheet, followed by heating, pressing and bonding together of the glass sheets to form flat or curved glass products. Hence it is heavier than normal glass.Laminated glass screens off Sound, Ultra Violet Rays. It can be made to screen offBullets. It has good transparency, and very good impact resistance. It remains intact when broken.	For Aquarium, Bridges etc
Shatterproof Glass	Made of plastic polyvinyl butyral between two sheets of glass preventing it from shattering sharp edged into pieces when broken	Used in windows, skylights, floors and car windshields
Tinted Glass Colored Glass	Produced by mixing ingredients during normal glass production that yields colored glass	Normal glass properties are not affected by the tinting
Tempered Glass	Strong glass with low visibility. Tempered is made by heat treatment of normal glass and quickly quenching the heat treated glass quickly in cold water thereby altering the micro structure of the glass hence, hence conferring the tempered glass with heat, shock and scratch resistance. It breaks and shatters into pieces without any sharp edges. This makes it safe for use as window panes and shower doors.	Used for fire resistant doors Mobile screen protectors Window panes shower doors etc

Table 2

➢ *Glass in Green Building*

A building with environmentally friendly features appearing the same as other buildings,[Yan, and Shuxia, 2011] but with environmental friendly aspects is termed Green Building. They have lower operating energy, enhanced asset value, increased productivity, and some health and safety benefit.

A Green Building has the following features:

- Minimal disturbance to the landscape and site
- Recycled and environment friendly materials.
- Non-toxic materials.
- Efficient use of water.
- Energy efficient and eco-friendly equipments.
- Renewable energy.
- Ideal indoor air quality for human safety and comfort.
- Effective control and building management systems.
- Effectively reduces the Carbon footprint on the environment

➢ *Role of glass in green buildings*

- Glass reduces the need for artificial lighting and lets in

day-light into the interior of the building.

- Glass reflects heat or UV rays and maintains optimal temperature inside the building.
- Glass is aesthetically pleasing to the eyes and affords better panoramic views from interiors by blending interiors with exteriors.
- Glass is recyclable.
- Glass can enhance acoustic comfort by reducing outside noise.
- Glass being comparatively weightless can considerably reduce the weight of the structure.
- Glass can be coated to achieve advanced thermal insulation
- Additionally, some glasses have self-cleaning properties that automatically bring out the shine instantly.

➢ *Future Prospects of Architectural Glass in the 21st Century*

The use of glass in architecture is getting more popular, and the drive to improve sustainability in buildings and energy efficiency poses a serious challenge to architects, manufactures and other practitioners in the built environment. Today there are bridges made of glass, entire building envelopes, and even entire building can now be made of glass. In the USA over 400 Apple stores are made of glass, and still counting. The global market for various types of Architectural Glass are expanding rapidly. By 2025 the market is expected to a growth rate of 7% according to Grand View Research. Glass is growing in popularity due to its energy efficiency[Zuo. (2014)], light weight, availability, flexibility of use and sustainability.

II. CONCLUSION

Silica Sand is a common raw material, universally available. It is very useful in the production of many goods. Its usage has kept increasing through the ages, and still increasing. Its use as an Architectural material is quite widespread and is particularly important in achieving sustainable environment. New uses of silica sand are cropping up. Further research is going on to extend the applications in the Built Environment; better, higher processing methods are needed to ensure availability of purer forms of silica sand. This will in turn result in the development of more products from silica sand for Architecture in the 21st Century.

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