EXPERIMENT ON MECHANICAL BEHAVIOUR OF TRANSLUCENT GEOPOLYMER CONCRETE

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ABSTRACT

About 7% of all human-caused carbon dioxide emissions come from the cement industry. Therefore, in order to promote sustainable material, another material must be found. Geopolymer is a green cementitious material with superior mechanical qualities, low energy requirements during manufacture, and reduced carbon dioxide emissions. A different approach is to use an alternate material, such as fly ash, instead of using cement. Alkaline activators, such as sodium or potassium silicate and sodium or potassium hydroxide, must be additional to fly ash as a binder. Transparent concrete, a contemporary form of concrete, possesses the distinct characteristic of light transmission due to the incorporation of optical fibers. Translucent concrete or light-transmitting concrete are other names for this. Contrarily, translucent concrete that has optical fiber embedded in it makes it possible to see through it to recognize persons and forms.Transparent concrete is used primarily to use sunlight as a light source, which saves or reduces electricity usage for the same reason. It may also be used for architectural purposes to create innovative designs and beautiful partition walls. The focus of the paper is the current demand for transparent concrete for architectural technologies and sunshine use. With its unique Natural qualities, the new form of concrete may meet green energy savings.The objective of this research is to evaluate the compressive strength of transparent geopolymer mortar. The molarity of NaOH used in the study is 10M, and the specimen size measures 70mm. The compressive strength achieved by the transparent geopolymer block was 9% greater than that of the cement mortar block composed of 60% fly ash and 40% silica fumes.

1. INTRODUCTION

GENERAL:

Geopolymers are non-crystalline, long-range covalently linked inorganic materials, usually ceramic. Some geopolymer mixes include obsidian shards. Commercially available geopolymers may be utilized for concrete reinforcement, novel binders for fire-resistant fiber composites, toxic and radioactive waste encapsulation, high-temperature ceramics, medicinal applications, fire- and Geopolymers are being extensively studied and applied in various scientific and industrial disciplines such as inorganic chemistry, physical chemistry, colloid chemistry, mineralogy, geology, and different engineering process technologies. These investigations aim to explore the properties and potential applications of geopolymers in areas such as resistant coatings, adhesives, high-temperature ceramics, and more. Geopolymers are a component of the field of materials science known as polymer science, which includes chemistry, technology, and science. Polymers may either be made of organic material, such as carbon, or inorganic material, like silicon. Natural polymers, synthetic organic polymers, and natural biopolymers are all types of organic polymers. The name "geopolymer" is derived from the utilization of minerals found in rocks on Earth as the main raw materials for creating silicon-based polymers.The two main categories of geopolymers are synthetic copies of naturally existing macromolecules (organic-containing geopolymers) and pure inorganic geopolymers. In the presentation that follows, a geopolymer is basically a mineral chemical compound or combination of chemicals made up of repeating units, such as silico-oxide, silico-aluminate, ferro-silicon-aluminate, or alumino-phosphate. The first symposium presentation of this mineral synthesis.

The primary objective is to utilize natural sunlight as a light source, thereby reducing energy consumption. This study explores the influence of optical plastic fibers on the compressive strength and split tensile strength of concrete. The optical plastic fibers are inserted layer by layer into the concrete, ensuring even dispersion throughout the block. As a result, the translucent geopolymer block exhibits higher compressive strength compared to traditional concrete.To utilize fly ash as a cement substitute in concrete production, beneficiation techniques such as mechanical air classification must be employed to handle the fly ash. This helps achieve the desired particle size distribution. However, unbeneficiated fly ash with a higher LOI can still be used as a filler to replace sand in concrete manufacturing.

Class F fly ash, which is produced from anthracite and bituminous coal burned for a longer duration, contains less than 7% lime (CaO) and exhibits pozzolanic properties. To generate cementitious compounds, Class F fly ash must be combined with a cementing agent like Portland cement, quicklime, or hydrated lime, or mixed with a chemical activator such as sodium silicate (water glass) to create geopolymer. A new kind of material known as geopolymer is typically created by activating an aluminosilicate parent material in a very alkaline solution. Alkaline activator to base ratio, activator, and aluminosilicate supply are the primary factors that affect the characteristics of geopolymer concrete. Previous research have revealed that the Na2SiO3 / NaOH ratio and NaOH molarity impacts the compressive strength of the geopolymer mortar. NaOH and Na2SiO3 are often used to activate the fly ash in geopolymer mortar. For fly ash-based geopolymers, a mass ratio of roughly 2.5 of Na2SiO3 to NaOH was advised. Contrarily, the compressive strength reduced when the ratio of Na2SiO3/NaOH was more than 3, as a result of the excess alkaline component that slows the geo polymerization process.

2 .LITERATURE REVIEW

SupriyaKulkarani–“GeopolymerConcrete”(2018). This essay examines the use of geopolymer concrete and its structural characteristics. The production of regular Portland cement damages the environment via CO2 emissions, and mining also causes irreparable harm to the ecosystem. Finding a substitute for the current pricey cement concrete is necessary since the quantity of carbon emissions is rising at an alarming rate. An alternative building material called geopolymer concrete is created chemically by the reaction of inorganic molecules. The use of Fly Ash as a substitute for conventional concrete in construction eliminates the need for any Ordinary Portland Cement.

T.Subramani,et.al 2018). Because integrated light-optical components, often optical fibers, have light-transmitting qualities, transparent concrete is a concrete-based construction material. By adding optical fibers to the concrete, it may also be utilized in decorative applications. To improve the strength and durability of concrete, many kinds of fibers are employed. One thing that aids in the transmission of light via fiber is optical fiber.The end-light kind of fiber is used in this project to improve the concrete's visual appeal.

Chithranjali.et.al 2017). This concept showcases translucent concrete as a smart construction material with improved strength, a beautiful look, and the ability to transmit light. Energy conservation and safety assessments are two crucial challenges for buildings. The trials' findings demonstrate that an optical plastic fiber may be readily incorporated into concrete and can also provide a consistent level of light transmission.

Sujay Chetan Nanavati, et.al (2017)". This research examines a number of components utilized in the production of this concrete, including fly ash, aggregates, and super plasticizers. Numerous researchers have documented their experimental studies on the effects of mix design, curing, and other factors on the proportions of geopolymer concrete. At the conclusion, concluding thoughts and recommendations about the uses of geo-polymer concrete are given.

Soumyajit Paul, et.al (2013). This novel kind of construction material combines the idea of renewable energy conservation with the practicality of self-aware materials. Better interaction between the built environment and environment will be possible with transparent concrete. The focus of the research is on how to strengthen this kind of concrete so that it may be used in real-world applications as a load-bearing structure.

K. Srinivasan, et.al(2013)". The goal of the current research is to give a thorough analysis of the numerous manufacturing procedures involved in the creation of a geopolymer binder. Recent studies have shown a strong trend toward expanding the use of geopolymer binders in building practices that are more cost-effective. This also envisions a decrease in global warming brought on by carbon dioxide emissions from cement manufacturing facilities.

M.A.Bhosale,et.al (2012)". This study focuses on the activation mechanism of fly ash using highly alkaline solutions composed of NaOH and Na2SiO3. The aim is to investigate the production of geopolymer by combining fly ash with an alkaline activator through geopolymerization. Geopolymer paste samples were subjected to a bending process at 60 degrees Celsius for one day and then kept at room temperature for the duration of the testing period. Compressive strength tests were conducted after 7 and 28 days to assess the strength of the geopolymer paste.The results indicate that the compressive strength of the geopolymer paste increases as the concentration of NaOH, measured in molarities, increases.

Mohd Mustafa Al Bakri, et.al (2011)". Because of the CO2 emissions from the usage of regular Portland cement, the environment was harmed. As a result, an alternate substance had been added to the concrete to replace OPC. A by-product of the coal industry that is readily accessible worldwide is fly ash. In addition, using fly ash is less expensive and more cost-effective than using OPC. Fly ash interacts with an alkaline solution to create an aluminosilicate gel because it is high in silicate and alumina.

DjwantoroHardjito, et.al(2004)". This study focuses on the compressive strength of fly ash-based geopolymer concrete, examining its relationship with various influencing parameters. The variables considered in the tests include the curing time of the concrete, curing temperature, dosage of superplasticizer, duration of pre-curing resting period, and water content in the concrete mix. The aim is to analyze how these factors impact the compressive strength of the geopolymer concrete.

3. METHDOLOGY

3.1 Aim: To measure the compressive strength of a clear geopolymer mortar specimen that had been created and to confirm that it met the necessary strength requirements for the mixed design specified in the IS code.

3.2 Materials Used:

1. Fly Ash
2. Fine Aggregate
3. Silica fumes
4. Optical Fiber
5. Alkaline Activators
6. Sodium Hydroxide
7. Sodium Silicate

Preparation of specimen:

Cubesize= 70mm×70mm×70mm

The optical fibers in the transparent geopolymer block were evenly dispersed down the horizontal axis at a spacing of 5 mm, making up 0.3% of the cube's total volume.

3.2.1 Fly Ash:

ASTM C 618 designates Class F fly ash as being from bituminous and anthracite coals. It is more LOI than Class C fly ash and mostly composed of alumina and silica. Additionally, Class F fly ash has less calcium than Class C fly ash.

Table1:ClassFflyashChemical Composition

Property	ASTMC618 Requirements,%
SiO_2plus Al_2O_3plus Fe_2O_3,min	70
SO_3,max	5
Moisturecontent, max	3
Losson Ignition,max	6

Class F fly ash may replace up to 30% of the mass of cementitious material in Portland cement when employed in that formula.

3.2.2 Fine Aggregate:

A greater capacity to work with a filter of 75 microns, it is sieved. Fine aggregates are simply any unrefined sand that has been take out from the earth through mining. Natural sand or any broken stone fragments that are 14" or smaller make up fine aggregates. Due to the size, or grade, of this specific aggregate, this product is often referred to as 1/4'" minus. Zone-II fine aggregates of good quality were utilized. The following table lists the fineness modulus limitations for different sand zones in accordance with IS 383-1970.

3.2.3 Silica Fumes:

Silica fume, also known as silicon dioxide, is an amorphous form of silica. It is obtained as a fine powder with spherical particles averaging 150 nm in diameter, and it is produced as a byproduct during the manufacturing of silicon and ferrosilicon alloys. Silica fume is commonly used as a pozzolanic component in high-performance concrete. Its particle size is typically around 0.15 µm, making it ultrafine and much smaller than cement particles, about 100 times smaller. The bulk density of silica fume varies from 130 to 600 kg/m3, depending on the level of densification, and its specific gravity ranges from 2.2 to 2.3.

3.2.4 Optical Fiber Types:

Step index single mode fiber is a type of optical fiber that is classified based on the profile of the refractive index and the number of modes it supports. In this type of fiber, the core diameter is typically very small, ranging from 5 to 10 µm. Due to the narrow core diameter, only a single mode of light ray transmission is possible. Step index single mode fibers are widely used and make up approximately 80% of all the fibers produced globally.

Source:Google

Fig 1: Single mode step- index fiber

Step index multimode fiber:

A step index multimode fiber is another type of optical fiber that features a larger core diameter, typically ranging from 50 to 200 µm, and an outer cladding diameter of 125 to 300 µm. In this type of fiber, the refractive index experiences a sudden increase from the cladding to the core due to the core material having a uniform refractive index, while the cladding material has a lower refractive index than the core. The larger core diameter allows for the propagation of numerous modes within the fiber.

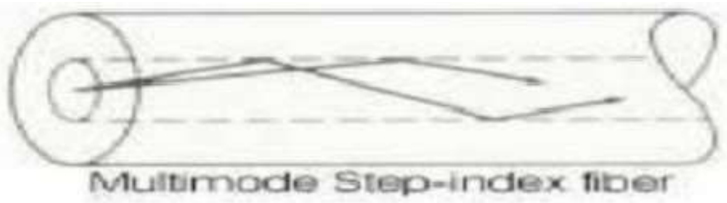

Fig 2:Multi mode step index

Fiber Graded index multimode fiber:

A multimode fiber with a graded index has a core whose refractive index is maximal at the fiber's axis and progressively drops toward the cladding. Modal dispersion may be reduced because the refractive index of the core gradually decreases.

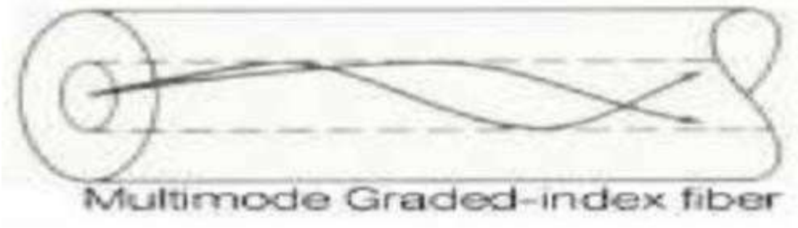

Fig3: Multimode Graded–index fiber

3.2.5 Alkaline Activators:

To reduce carbon dioxide (CO2) emissions and utilize various waste materials, alkali-activated materials (AAM) can be used as a substitute for Ordinary Portland cement (OPC). However, the concentrated aqueous alkali solutions employed in the alkali activation process are corrosive, viscous, and challenging to handle. This has prompted the development of "one-part" or "just add water" AAM, particularly for cast-in-situ applications, where handling convenience is crucial. One-part AAMs are similar to OPC in terms of production, involving a dry combination of solid alumino silicate precursor, solid alkali supply, and potentially other admixtures. High-temperature processing may be employed to enhance the reactivity of certain raw ingredients in the dry mix. Recent studies have focused on investigating one-part AAMs in terms of raw materials, activators, additives, mechanical and physical properties, curing processes, hydration products, and environmental impacts.

3.2.5.1 Sodium Hydroxide

The organic chemical sodium hydroxide, sometimes referred to as lye and caustic soda, has the formula NaOH. It is a white, solid ionic substance made up of the cations sodium (Na+) and the anions hydroxide (OH-).At normal ambient temperatures, sodium hydroxide, a highly caustic base and alkali, breaks down proteins and may result in serious chemical burns. It easily collects moisture and carbon dioxide from the air due to its high water solubility. It produces a string of NaOH-nH2O hydrates. From water solutions, the monohydrate NaOHH2O crystallizes between 12.3 and 61.8 °C. This monohydrate is often the "sodium hydroxide" sold commercially, and it may be used in published data instead of the anhydrous substance. It is one of the simplest hydroxides and is usually used to illustrate the pH scale with neutral water and acidic hydrochloric acid.

3.2.5.2 Silicate of sodium:

White powder or colorless glassy or crystalline solids are sodium silicates. The term "sodium silicate" refers to a group of chemical substances having the formula Na2xSiyO2y+x or (Na2O)x(SiO2)y, including sodium orthosilicate (Na4SiO4) and sodium pyrosilicate (Na6Si2O7). Anions are often polymeric. These substances often come in the form of white powders or colorless translucent solids that are soluble in varying degrees of water.

Design of fly ash mix:

3.3 Fly ash mortar mix design using IS method:

The mix design technique, which is documented in IS 10262-2009, was developed by an Indian standardization organization. Both medium strength and high strength may be used with this technique. Using the IS technique of mix design, the M20 grade of cement mortar mix was created.

3.3.1 Mix design procedure for M20 grade cement mortar:

Mix design ratio = 1:3

Adopting water cement ratio =0.45
Cement content =154.35gm
Fineaggregate =617.4gms
Molarity: 10M–NaOH
Molarity = (weight / molecular weight) × (1000/ volume)10=(weight / 40)× (1000/1000)
Weight= 400 gm for1000 ml

3.3.2 Procedure for Mix Design

For cube compressive strength testing required ingredients as follows for**0%cementmortar block**

Cement quantity=0.3125m^3

- ForM20gradecementmortarCementrequired

$$=0.07^3 \times 0.3125 \times 1440$$

=154.35gm (foronecube)

- ForM20gradeconcrete

Waterrequired=0.45×0.1543kg
=0.069kg (for one cube)

- ForM20gradeconcrete

Fineaggregaterequired=3×0.3125
=0.9375×1920
=1800×0.07^3

=0.617kg (for one cube)

Sand=3×268.75=806.25kg

For60%of flyash&40%of silica fumes in cement mortar block

Fly ash quantity= 268.75kg
=268.75×60%
=161.25kg×0.07^3

=0.0553kg (for one cube)

Silica fumes required =268.75×40%
=107.5kg×0.07^3
Silica fume =0.0553kg (for one cube)

Alkaline solution / Fly ash =0.0368kg (for one cube)

= 0.35Alkalinesolution

=0.35 ×flyash
=0.35×268.75
= 94.0625 kg/m^3Sodium silicate / sodium hydroxide
= 25Sodium Hydroxide
=94.0625 / 1+2.5
= 26.875kg/m^3Sodiumsilicate =94.0625-26.875
=67.18kg/m^3

According to ASTM C618 guidelines, it is recommended that the ratio of sodium silicate to sodium hydroxide in alkali-activated materials (AAM) should not exceed 2.5.

For 70% of fly ash & 30%of silica fumes in cement mortar block

Fly ash quantity=268.75kg
=268.75×70%

=188.25kg×0.07^3
=0.0645kg (for one cube)

Silica fumes required =268.75×40%
=80.625kg×0.07^3
=0.027kg (for one cube)

Alkaline solution / Fly ash =0.0645kg (for one cube)
=0.027kg (for one cube)

Sodium silicate / sodium hydroxide = 94.0625 kg/m^3
= 25SodiumHydroxide
=94.0625 / 1+2.5
= 26.875kg/m^3Sodiumsilicate
=94.0625-26.875
=67.18kg/m^3

The ratio of sodium silicate and sodium hydroxide should not exceed 2.5(asperASTMC618page)

For 80% of fly ash & 20% of silica fumes in cement mortar block

Fly ash quantity=268.75k
=268.75×80%
=215kg×0.07^3
=0.0737kg (for one cube)

Silica fumes required =268.75×20%
=553.75kg×0.07^3
=0.018436kg (for one cube)
Alkaline solution / Fly ash =0.35
Alkaline solution =0.35 ×fly ash
=0.35×268.75
= 94.0625 kg/m^3
Sodium silicate / sodium hydroxide = 25
Sodium Hydroxide =94.0625 / 1+2.5
= 26.875kg/m^3Sodiumsilicate
=94.0625-26.875
=67.18kg/m^3

The ratio of sodium silicate and sodium hydroxide should not exceed 2.5(asperASTMC618page)

For 90% of fly ash & 10% of silica fumes in cement mortar block

Fly ash quantity=0.08296kg (for one cube)
=82.96gm
Silica fumes required=0.00921kg (for one cube)
=9.21gm
Alkaline solution / Fly ash =0.35

Alkaline solution =0.35 ×fly ash
=0.35×268.75
= 94.0625 kg/m^3
Sodium silicate / sodium hydroxide = 25
Sodium Hydroxide =94.0625 / 1+2.5
= 26.875kg/m^{3}Sodiumsilicate
=94.0625-26.875
=67.18kg/m^3

The ratio of sodium silicate and sodium hydroxide should not exceed 2.5(asperASTMC618page)

Percentage of Fiber:

Area of circle =$\text{л}r^2$
=$\text{л} \times 0.375^2$
=0.4417mm
The amount of fiber required is 252cm
=$\text{л}\times 0.375^2 \times 2520/ 70\times 70\times 70$
=0.00324
Percentage of fiber =0.00324×100
=0.324%

The fiber percentage should be less than 0.6%

3.3 Casting and Curing: The cubes were formed using molds that were 70mm by 70mm by 70mm.An application of cutting oil is made to the inside surface of the molds. The mold is constructed of thermoplastic fibers or wood. It is not advisable to utilize steel molds

.

Fig. 4 Casted Cubes

4. RESULTS AND DISCUSSION

4.1 Compressive strength:

Here are the rephrased statements regarding the compressive strength of cement mortar and mortar samples containing fly ash and silica fumes:

Table2:Test results for compressive strength

Flyash dosage in%	Silicafumes dosagein%	CompressiveStrength		
		Cube-1	Cube-2	Cube-3
60	40	30.3MPa	29.9MPa	30.1MPa
70	30	21.6MPa	21.4MPa	21.1MPa
80	20	17.0MPa	17.3MPa	17.1MPa

Table3: Test results for compressive strength for cement mortar

Days	CompressiveStrength
7days	22.43MPa
14days	23.92MPa
28days	27.05MPa

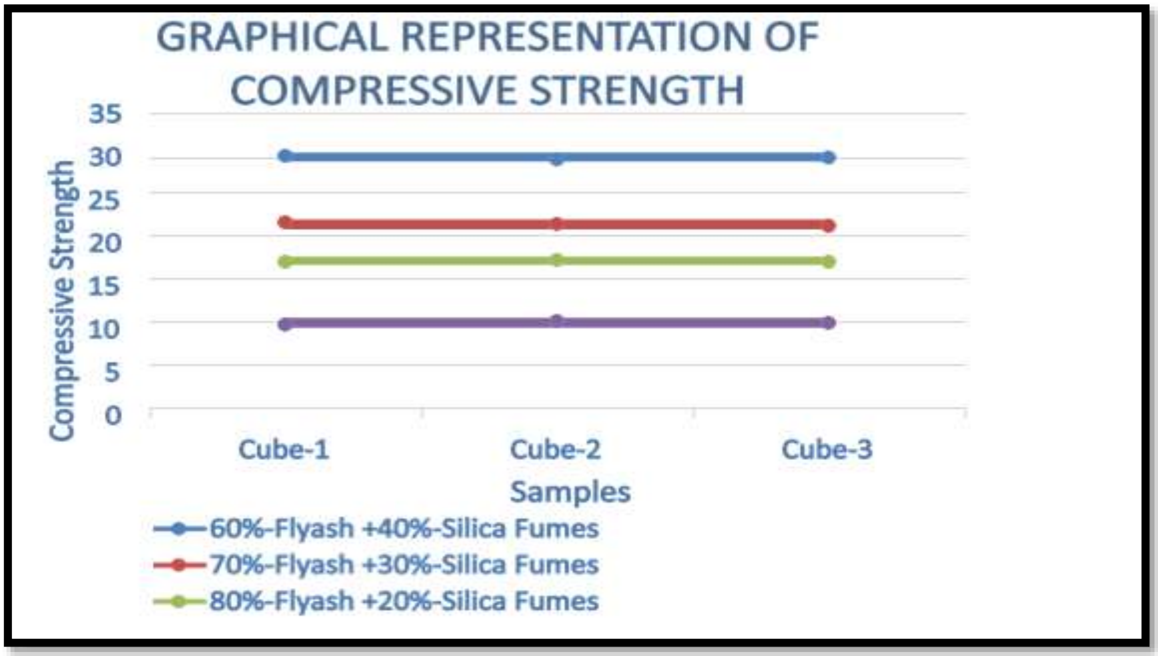

Fig5 Compressive strength of cement mortar block

Here are the rephrased statements regarding the compressive strength of transparent geo-polymer blocks, the Na2SiO3/NaOH ratio, fiber content, and the influence of silica fume percentages:

1. Transparent geo-polymer blocks containing 60% fly ash and 40% silica fumes achieved a compressive strength that was 9% higher compared to cement mortar blocks.
2. Increasing the Na2SiO3/NaOH ratio beyond 3 leads to a reduction in compressive strength due to an excess alkaline component that slows down the geo-polymerization process.
3. Therefore, it is recommended to maintain the Na2SiO3 to NaOH ratio at or below 2.5.
4. If the fiber content exceeds 0.6%, the compressive strength will decrease.
5. The significant presence of silica fumes contributes to the high compressive strength observed in these specific cubes.
6. Decreasing the percentage of silica fumes in different cubes results in a decrease in compressive strength.

4.1 APPLICATIONS

- Interior and external walls may be constructed using transparent geopolymer concrete.
- Transparent geopolymer blocks that may be used for walls, floors, and pavements that support weight.
- It may be used to clothe interior walls and create partitions using thin panels.
- It may also be utilized in places where the sunshine does not reach adequately and as divider walls.
- Lighting up nighttime landmarks and pathways improves visibility in enclosed spaces.

4.2 FURTHERSCOPE

- The research is expanded to examine several additional crucial factors in relation to light-transmitting geopolymer mortar.
- To investigate the various curing times and optical and glass fiber ratios employed in light-transmitting geopolymer mortar.
- To investigate the geopolymer mortar's long-term durability qualities for light transmission.
- To examine the behavior of transmitting geopolymer mortar's shrinkage and creep.

5. CONCLUSION

Transparent geo-polymer blocks with 60% fly ash and 40% silica fumes attained a compressive strength that was 9% higher than cement mortar blocks.By using plastic optical fibers or large diameter glass fiber in the geopolymer mortar, transparent geopolymer may be created.The transparent geopolymer mortar block may be used for the best architectural look of the building and in areas where the light cannot reach the necessary intensity since it has strong light-guiding properties.Routine maintenance is not necessary; however, it could be useful in the long term.

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