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Transparent shutter: A novel approach to enhance concrete construction efficiency

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Abstract
Shuttering and de-shuttering are integral processes in the field of civil engineering, playing a crucial role in achieving the desired quality and integrity of concrete structures. At most importance is given to the methodology adopted for shuttering and de shuttering concerned with the homogeneity of concrete while placing and compaction. The significance of proper compaction during the concreting process, emphasizing the essential role of needle vibrators in preventing common issues such as honeycombing, air bubbles, cold joints, and cracks. It highlights the challenges faced by construction workers, particularly in situations where the concrete's outer surface is not visible during pouring, leading to uncertainties in the compaction process. To address this issue, a new concept is introduced in this paper - the "Transparent Shutter." This innovative approach aims to provide visibility into the concrete pouring process, enabling construction workers, especially inexperienced engineers, to monitor and understand the compaction process in real-time. The transparent shutter concept has the potential to reduce the occurrence of defects, thereby minimizing the need for extensive repairs and saving both time and costs in construction projects. Also, this paper discusses using Polycarbonate material as a potential candidate for transparent shuttering.

Keywords: Transparent shuttering, concrete construction, polycarbonate material

Introduction
The global construction industry is undergoing a transformative phase, witnessing the continual integration of modern technologies and advanced materials. Over the past decade, there has been a pronounced shift in focus towards leveraging these innovations to streamline construction processes, making them faster, more cost-effective, and of superior quality-all while striving to minimize the environmental impact. However, amidst these advancements, there appears to be a considerable gap in the attention dedicated to lightweight and transparent shuttering solutions within the realm of concrete construction [1]. Recognizing this, our research endeavours to introduce a novel concept that not only addresses the need for introducing transparent shuttering to the domain, but also a potential material it could be made of.

In our exploration for a material that embodies both strength and transparency, we identified polycarbonate as a standout candidate. Polycarbonate boasts remarkable transparency, outstanding toughness, and durability, making it a compelling choice for applications in concrete shuttering [2]. In response to the increasing demand for lightweight and transparent shuttering solutions, we propose a groundbreaking concept of the Transparent Shutter crafted from environmentally friendly polycarbonate materials. Moreover, recognizing the need for practicality and ease of handling, the transparent shutter is envisioned to be lightweight. This characteristic not only facilitates its manipulation during construction but also aligns with the broader goal of enhancing efficiency and reducing physical strain on construction workers.

In essence, the transparent shutter concept represents a paradigm shift in concrete construction methodology. By integrating transparency into the shuttering system, it empowers construction teams to address compaction issues promptly, minimizing the need for post-setting repairs. This not only saves valuable time but also contributes to cost-effectiveness and improved overall quality in civil engineering projects. As the industry continues to embrace innovative solutions, the transparent shutter stands out as a promising development that has the potential to redefine best practices in concrete construction.

This paper delves into the rationale behind the development of the Transparent Shutter, highlighting its potential benefits for the construction industry and the environment. By seamlessly combining strength and transparency, this innovative concept aims to revolutionize traditional concrete construction practices, introducing a sustainable alternative for the future.

Objectives

1. To Explain the advantages of using transparent shuttering for construction practices.
2. To propose Polycarbonate material as a potential option for transparent shuttering.

Transparent shuttering and its components

Transparent shuttering is an innovative concept proposed here in the field of concrete construction that involves the use of materials with high transparency, such as polycarbonate, to create formwork or moulds for pouring and shaping concrete. The primary purpose of transparent shuttering is to provide real-time visibility into the concrete pouring process, enabling construction workers to monitor and control the placement of concrete, as well as detect and address any issues or defects as they occur.

Its components may include

1. **Transparent Panels or Sheets:** The core component of transparent shuttering is the use of transparent panels or sheets made from materials like polycarbonate. These panels serve as the formwork, allowing workers to see through and observe the concrete as it is poured.
2. **Frame Structure:** A supporting frame structure is used to hold the transparent panels securely in place during the concrete pouring process. This frame is typically made from materials like metal or lightweight alloys.
3. **Fastening Mechanisms:** Various fastening mechanisms, such as clips or screws, are employed to secure the transparent panels to the frame structure. These mechanisms ensure that the formwork remains stable and in position during concrete placement.
4. **Sealing Elements:** To prevent leakage of concrete and ensure that it fills the formwork properly, sealing elements are incorporated. These may include gaskets or seals placed at joints and connections between transparent panels and the frame.
5. **Removal Mechanism:** Transparent shuttering should incorporate a mechanism for easy removal after the concrete has been set. This may involve the use of release agents on the transparent surface or a design that allows for the disassembly of the frame without damaging the formwork.

Advantages of using transparent shuttering in Construction practices

The use of transparent shuttering in concrete construction offers several advantages such as it positively impacts the overall quality, efficiency, and sustainability of the construction process. The following can be the key advantages of using transparent shuttering:

Real-time Visibility

Transparent shuttering provides real-time visibility of the concrete pouring process. Construction workers can monitor the placement and compaction of concrete, enabling them to identify and address issues immediately.

Early Detection of Defects

Defects such as honeycombing, blow holes, cold joints, and inadequate compaction become visible during the pouring process. This early detection allows for prompt corrective actions, minimizing the need for extensive repairs after de-shuttering.

Improved Compaction

Visibility into the concrete placement allows for better control over the compaction processes. Construction workers can ensure that concrete is evenly distributed, reducing the likelihood of voids, and improving overall compaction.

Quality Enhancement

The ability to observe and manage the concrete pouring in real-time contributes to the overall quality enhancement of the concrete structure. Transparent shuttering helps achieve a smoother and more uniform finish.

Cost Savings

Early defect detection and reduced repair needs lead to significant cost savings. Transparent shuttering minimizes the expenses associated with post-construction repairs, leading to overall project cost efficiency.

Time Efficiency

The proactive approach enabled by transparent shuttering reduces the time required for inspections and repairs. Construction processes become more streamlined, allowing for faster project completion.

Environmental Sustainability

The use of transparent shuttering, particularly if made from recyclable materials, aligns with environmental sustainability goals. Additionally, the reduction in repair needs contributes to minimizing construction-related waste.

Ease of Learning for Construction Workers

Transparent shuttering provides a valuable educational tool for construction workers, especially those new to the field. Workers can visually understand the effects of concrete placement and compaction, facilitating knowledge transfer and skill development.

Reduced Dependency on Heavy Machinery

Transparent shuttering can reduce the reliance on heavy machinery such as cranes and hydraulics during the shuttering process. This not only minimizes operational costs but also enhances the portability and flexibility of the construction site.

Versatility in Design

The use of transparent materials allows for versatile and innovative design possibilities. Architects and engineers can explore new aesthetic and functional options while maintaining structural integrity.

Resistance to Environmental Factors

Transparent materials like polycarbonate are resistant to environmental factors, including rusting in marine environments. This eliminates the need for periodic maintenance tasks such as painting.

In summary, transparent shuttering introduces a range of benefits that span from enhanced construction quality and cost savings to environmental sustainability and improved learning opportunities for construction workers. Its adoption represents a forward-thinking approach to modernizing concrete construction practices.

Poly Carbonate as Material for Transparent Shuttering

What is Polycarbonate?

Polycarbonate is a thermoplastic polymer containing carbonate groups in their chemical structures. It belongs to a class of polymers known as polyesters and is derived from bisphenol A (BPA). The representation of chemical

composition of a Polycarbonate molecule is shown as in Fig. 1

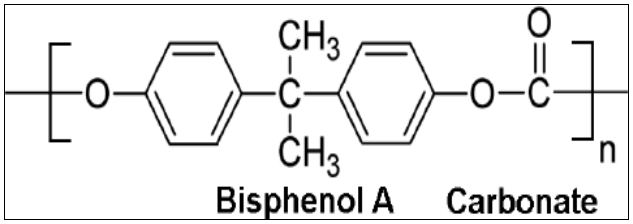

Fig 1: Molecular structure of Polycarbonate

Polycarbonate is a versatile and durable thermoplastic polymer known for its exceptional transparency, strength, and impact resistance. It is widely used in various industries, including construction, due to its unique combination of properties [3]. Polycarbonate is a polyester made by the condensation of carbonic acid and Bisphenol A. Polycarbonates are strong, stiff, hard, tough, transparent engineering thermoplastics that can maintain rigidity up to 140 °C and toughness down to – 20 °C [4]. Here are some key characteristics and applications of polycarbonate material which can be advantageous for the transparent shuttering concept:

Transparency
Polycarbonate possesses high optical clarity, allowing for excellent light transmission. This transparency is a crucial attribute in applications where visibility or aesthetics is essential, such as in the Transparent Shutter concept. The transmittance of polycarbonate is more than 90% light which is excellent considering the scope and objective of this research. The guidelines and protocol have been considered as per ASTM D 1003-21 standards.

Strength and Impact Resistance
Polycarbonate is renowned for its high impact resistance, making it significantly stronger than other transparent materials like glass [5]. This property is vital in construction applications where the material may be subjected to physical stress or potential impact. As per IS14443:1997, Dart drop Impact strength is considered to be the criteria for impact resistance in polycarbonate sheets.

Lightweight
Despite its strength, polycarbonate is a lightweight material. This makes it advantageous in construction scenarios where reducing the overall weight of structures or components is desirable. The fabrication of lightweight formwork can be done as well as the handling, installation becomes easier.

Durability
Polycarbonate is highly durable and resistant to weathering, chemicals, and UV radiation. This durability ensures a longer lifespan of structures or components made from polycarbonate, contributing to sustainability in construction.

Flexibility
Polycarbonate can be easily molded into various shapes and forms, offering flexibility in design. This characteristic is beneficial when crafting innovative solutions, such as the Transparent Shutter, which requires a specific combination of strength and transparency. Polycarbonate is a thermoplastic material that can be easily molded into complex shapes and forms. This flexibility allows for the creation of customized transparent shuttering components to suit.

Diverse construction requirements
Thermal Insulation
Polycarbonate exhibits good thermal insulation properties, contributing to energy efficiency in buildings. This can be advantageous in construction applications where maintaining a stable indoor temperature is important.

Recyclability
Polycarbonate is recyclable, supporting environmentally friendly practices in construction. The ability to recycle polycarbonate aligns with sustainability goals, reducing the environmental impact of construction materials.

Fire Resistance
Depending on the specific formulation, polycarbonate can offer varying degrees of fire resistance. This property is crucial for meeting safety standards in construction applications. It also possesses a good heat resistant capacity. Polycarbonate is physically stable up to 135 °C.

Chemical Stability
The chemical resistance of polycarbonate is a significant factor contributing to its versatility in various applications. Polycarbonate has good resistance to chemicals, refined acids, and alcohol. It is also chemical resistant against oil and grease.

Applications in Construction
Polycarbonate is used in a variety of construction applications, including but not limited to:

- Greenhouses and conservatories
- Architectural panels and facades
- Transparent barriers and safety glazing
- Skylights and roofing materials
- Transparent shutters and formwork (as proposed in this research)

Fig 2: Polycarbonate Sheet Sample

A sample of 1.2m X 1.2m and 6 mm thickness has been tested for different properties to substantiate the potential of the material which can be used for shuttering purposes. A polycarbonate sheet sample used at the construction site is shown in Fig. 2.
Table 1 shows results of the tests conducted on the polycarbonate sample for impact resistance, light transmissibility, and chemical resistance.

Table 1: Properties of Polycarbonate

Sl No.	Test	Result	Guidelines/Criteria
1	Dart Drop Impact strength – Applied impact energy. resistance	124 J	As per IS 14443: 1997
2	Light Transmission	90%	ASTM D 1003-21
3	Chemical Testing (Resistance to chemicals for any visible changes)	No visible changes	ASTM D 1693-21

In the context of the Transparent Shutter concept, the choice of polycarbonate as the material is driven by its ability to provide the necessary transparency, strength, and durability required for efficient concrete construction processes while being environmentally conscious. The lightweight nature and the flexibility in molding it to any different shape and kind of shuttering can also be advantageous to our objective.

Limitations

Scratch Susceptibility: Polycarbonate can be prone to scratches, which may occur during handling, transportation, or construction activities [6]. Scratches can impact the transparency of the material. While pouring concrete in the transparent shutter, the concrete slurry may spread on shutter and its transparency may decrease.

Cost: Polycarbonate is more expensive than traditional shuttering materials like plywood or metal. The higher cost of polycarbonate may impact the overall budget of a construction project, especially for larger-scale applications. Therefore, it is mostly suggested for small scale construction activities.

Flammability: While polycarbonate is flame-resistant, it is not entirely fireproof. It can burn under certain conditions, and the combustion process may release toxic gases. Fire safety considerations are crucial when using polycarbonate in construction.

It is essential to carefully assess these disadvantages in the context of the specific requirements and conditions of a construction project before deciding to use polycarbonate for transparent shuttering. Additionally, ongoing advancements in material technology may address some of these limitations in the future.

Conclusion

Polycarbonate proves that it is one of the most advanced building materials in today's time and due to its lightweight and portability which is easy to handle. Since it can be made from reused and recycled plastic, which is recyclable also, the polycarbonate transparent shutter will reduce environmental damage. In marine environments, there is no chance of damage due to rusting in polycarbonate transparent shutter as compared to steel shutter. It will not accommodate the cost of shutter painting.

It can also be concluded that the usage of transparent shuttering for construction practices can reduce the overall cost of construction by accounting the lesser requirement of repair and rectification works post the concreting. Since there is no available code for design of structures using the materials such as polycarbonate, with in the limitations, this research paper proposes the idea of transparent shuttering using polycarbonate as a landmark concept which can be put open for further detailed studies and investigations. Nowadays, plastic shutters with socketing are already gaining popularity in the construction sector for their versatility and ease of use, introducing transparency to these shutters can offer several benefits as discussed in this paper.

Way Forward

Using transparent materials for plastic shuttering opens exciting possibilities for innovation in the construction sector. To move forward in this area and capitalize on the benefits of transparent shuttering, several key steps and considerations can be taken on research and development. This includes investigatingnew transparent materials, optimizing their properties, and developing cost-effective solutions. Conducting comprehensive testing of transparent materials to ensure they meet industry standards and performance requirements for structural applications. Establish clear design codes and standards for the use of transparent materials in shuttering. Emphasize the sustainability aspects of transparent shuttering, especially if the chosen materials are recyclable. Highlighting the environmental benefits can contribute to the adoption of more sustainable construction practices. By addressing these aspects, the construction industry can forge a path towards the widespread adoption and integration of transparent shuttering, fostering a more efficient, transparent, and sustainable approach to concrete construction.

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