IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Durability And Economical Aspects Of SFRC Segments With Conventional Reinforced Segments Used In Construction Of Tunnel.

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Abstract:

Tunnels are part of modern transportation infrastructure systems, varies Tunnelling systems are used in railways, metro transport and even with road transport systems. The most common methods are NATM and TBM tunnelling methods. The durability and economical way of Tunnelling is the demand of today's infrastructure development. TBM tunnelling method with precast segments are used to build the required Tunnel. The precast segments are normally built with reinforced cement concrete at specified casting yards. Studies and research are going on replacing the conventional reinforced segments with steel fiber reinforced segments. SFRC segments offer economic advantages and address durability concerns related to corrosion in traditional reinforced concrete segments.

Introduction

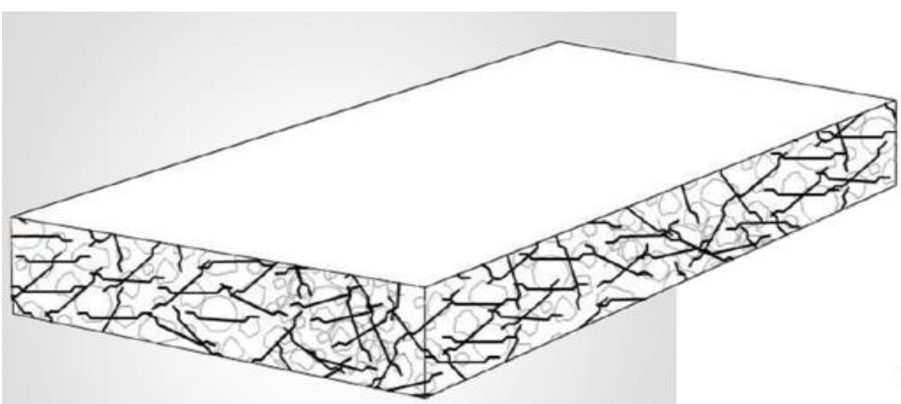

Fig 1: Fiber reinforced concrete

Steel fiber reinforced concrete (SFRC) is a type of concrete that incorporates steel fibers to enhance its structural integrity and durability. These steel fibers are short, discrete strands that are evenly distributed and randomly oriented throughout the concrete mixture. By adding steel fibers to the mix of concrete, the characteristic properties of mix (mechanical), especially flexural and tensile strengths are significantly improved.

The effectiveness of SFRC in enhancing the concrete's properties depends on various factors, including the parameters of size, volume, shape, amount of fiber percentage, and equal distribution of the steel fibers is mandatory, failing of equal distribution invites the probability of cracks. Unlike plain concrete beams that exhibit sudden failure, the inclusion of fibers in SFRC eliminates this characteristic. Additionally, SFRC increases torsional strength, ductile strength, rotational capacity, stiffness and effectively controls cracks with reduced crack width.

Furthermore, the incorporation of fibers in SFRC greatly enhances the shear resistance capacity of RCC beams, often by up to 100 percent. This improvement in shear capacity ensures better structural performance and increases the overall load-bearing capability of the concrete elements.

It is important to note that the information provided is based on general knowledge of SFRC and its benefits.

SFRC finds widespread usage in various construction applications such as tunnel linings, pavements, slabs, shotcrete (including shotcrete with silica fume), airport pavements, and bridge deck slab repairs, among others.

Tunnel segment lining design to be done according to the geotechnical parameters of project location. SFRC segment design to be satisfied all permanent service load cases and construction stage load cases. SFRC Segments to be checked for Stacking load case also Various checks and assessments performed on conventional segments are also applicable to SFRC segments. These include evaluations such as TBM thrust jack forces, tail skin grouting, secondary (localized) grouting, ground embedment, groundwater considerations, and surcharge loads from buildings and vehicles. Tunnel segment lining can also be made using macro synthetic fiber reinforced concrete (MSFRC) for better performance. When a combination of macro and micro fibrous reinforcement is incorporated into the concrete mixture, it demonstrates sufficient residual strength after cracking, thereby enhancing its durability compared to conventional segments.

Fig 2: TBM Tunnel

Fig 3: SFRC Tunnel segments

The design philosophy of the FRC segment generally comprises Material Characterization by performing various tests, Material Behavior, and the Design Check against all acting and design load conditions.

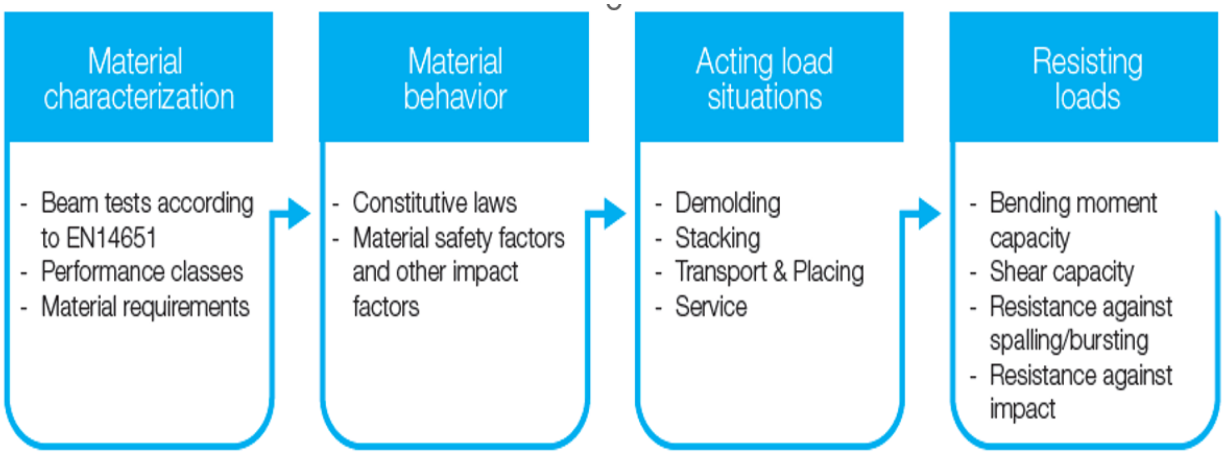

Table 1: **Design Methodology**

In this journal focuses on the utilization of steel fiber reinforced concrete (SFRC) as an alternative to reinforced concrete (conventional method) to produce tunnel segments. All the major functional risks for designing segments for tunneling projects that have been found in case studies by other researchers are looked at. The review starts with a look at general risks, then goes into detail about a major tunneling project with SFRC segments done worldwide.

Keywords: NATM- New Austrian Tunnelling Method, **TBM-** Tunnel boring Machine, **SFRC-** Steel fiber reinforced concrete, **MSFRC-** Macro steel fiber reinforced concrete

1. Pros and Cons of SFRC Segments in Tunnelling.

➢ Advantages of SFRC segments

a) Technical Advantages

- ❖ Better resistance against Cracking and Crack Propagation
- ❖ Reinforcement placed in multidirectional for enhanced structural integrity.
- ❖ Reduce the risk of damages at edges and corners, mitigating spalling forces.
- ❖ Increased durability against corrosion for long-term performance
- ❖ Effective fire protection when combined with micro-polypropylene fiber.
- ❖ High impact resistance

b) Economic Advantages

- ❖ Increase productivity, and timesaving.
- ❖ Reduced expenses associated with repairing damaged segments.
- ❖ Elimination of the need for storing and positioning reinforcement cages
- ❖ Utilization of automatic dosing and dispensing equipment connected to the batching plant's control panel.

- **Disadvantages of SFRC segments**

- Skilled labor required for casting of fiber reinforced segments.
- Exposing both fibers and aggregate during rainfall can result in damage to slabs.
- Accumulation of fibers in certain areas of the mix can lead to crack failure, as other areas may lack fiber reinforcement.
- Aesthetically, it is not desirable.
- The workability of concrete is negatively affected.
- Fiber concrete is heavier compared to non-fiber concrete.
- Improper mixing can cause fiber balling.
- The appropriate selection of steel fiber, including the amount, type, and length, is crucial.
- The use of steel fiber in concrete can be costly.
- Steel fiber can contribute to corrosion-related issues.
- Micro cracks in SFRC segments can lead to sudden crack failure due to their brittle behavior.

2. MAJOR TUNNELLING PROJECTS WITH SFRC SEGMENTS.

With over 200 + Project references, established International Guidance, Codes, and Recommendations are available for fiber reinforced concrete sector.

The Lee Tunnel, located in East London, is a groundbreaking example of an SFRC tunnel. It holds the distinction of being the first SFRC tunnel to be nominated and awarded the prestigious Concrete Society tunnel accolade. The tunnel, with a diameter of 7 meters, plays a vital role in the Thames Tideway Scheme, serving as a conduit for the storage and conveyance of sewage mixed with rainwater cover a distance of approximate 7.0 kilometers**.**

Fig 4: The Lee Tunnel

a) **Proposed Metro line (Line 9)** is currently being built in the Mediterranean city of Barcelona in Spain.

The project is record-breaking, with a tunnel with 12 m diameter and almost 44 km length that will accommodate the tracks and platforms in a double deck configuration. The tunnel is being excavated, at a depth of 30 to 70 m below the ground level, with Tunnel Boring Machine (TBM). As the excavation progresses, a robot arm of the TBM places the prefabricated segments of the tunnel lining to complete it ring by ring. As the excavation progresses, the TBM applies a reaction force through 30 hydraulic jacks as the shield cuts into the rock and/or soil ahead of it. This reaction, which can reach values of up to 140 MN, acts on the lining ring placed last.

Fig. 5: The tunnel for the Barcelona Metro Line 9

5. Conclusion

Ongoing research and continuous advancements in SFRC (Steel Fiber Reinforced Concrete) and macro synthetic fiber reinforced concrete have resulted in the development of a contemporary and cost-effective construction material for tunneling.

The use of durable and corrosion-resistant primary reinforcement offers significant design advantages as it is no longer limited by serviceability constraints. By incorporating fibers, substantial time and cost savings are achieved by reducing the labor-intensive process of preparing reinforcement gauges for conventional rebar segments, especially for complex reinforcement cages. The quality of the material and casting also plays a crucial role in the construction of SFRC segments.

The lifting and stacking of precast tunnel segments are carefully executed according to the design requirements. Additionally, costs associated with maintenance, such as replacing or repairing damaged segments, can be significantly minimized.

From an economic perspective, SFRC segments prove to be more cost-effective compared to conventional methods. Traditional segment designs typically require a conventional steel reinforcement cage weighing approximately 98 kg/m3. On the other hand, SFRC segments typically incorporate steel fibers ranging from 40 to 60 kg/m3. This alternative approach not only saves time but also offers economic benefits.

Overall, SFRC segments provide a time-saving methodology with significant economic advantages.

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