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Sustainable Concrete Technology in the Field of Transmission Infrastructure: A Review

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Abstract: ***The increasing demand for energy and the imperative shift towards sustainable infrastructure have propelled research efforts towards developing eco - friendly materials for critical applications such as power transmission projects. This abstract provides a comprehensive overview of the current state of sustainable concrete technologies tailored specifically for power transmission infrastructure. The study delves into the environmental impact of conventional concrete used in such projects and explores innovative approaches to enhance sustainability. The review encompasses various aspects, including the incorporation of alternative binders such as fly ash, slag, and silica fumes, as well as the optimization of mix designs to reduce carbon footprint. Special attention is given to the performance, durability, and long - term resilience of sustainable concrete in comparison to traditional counterparts. Moreover, the document discusses the economic feasibility of implementing sustainable concrete in power transmission projects, considering factors such as material cost, construction practices, and life - cycle analysis. The abstract concludes with insights into ongoing research trends and potential future developments in sustainable concrete technologies, emphasizing the need for collaborative efforts between academia, industry, and policymakers to promote environmentally conscious practices in the realm of power transmission infrastructure, taking into account desired power transmission best performance.***

Keywords: sustainable concrete, power transmission infrastructure, eco - friendly materials, environmental impact, alternative binders

1. Introduction

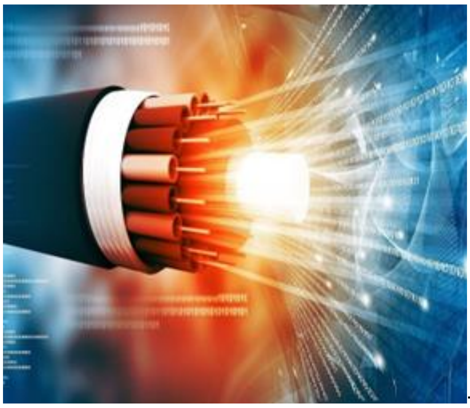
Sustainability lies at the heart of DEWA - Dubai Electricity & Water Authority strategy, stemming from the directives of the leadership of the United Arab Emirates and Dubai.

Sustainability concept, application and adaptation:
Triple - Bottom - Line Perspective" is one of the DEWA's strategic objectives which incorporates sustainability into business decisions through accounting for the three dimensions: financial, social and environmental
Considering the services provided by DEWA - Transmission Power, it is directly and indirectly affecting and affected by economy, environmental and social factors.
Hence it was essential to work out an innovative solution through internal initiatives to enhance and design in line with the main aims and strategies, which eventually comes in virtue of sustainability achievements as follows:

- **Economy:** The proposed initiatives shall have an economic impact to reduce overall cost and maximize DEWA assets values. However, it should maintain the functionality, serviceability requirements and lifetime expectation.
- **Environmental:** The proposed initiatives shall have a positive environmental impact by reducing carbon footprint, gas emissions and associated construction activities.
- **Social:** Considering the importance and preciously of Dubai land, the initiatives outcome shall reduce the affected footprint of dedicated DEWA corridors to allow multiple services installation, integrate with other utilities services and enrich overall Dubai infrastructures.

Major aspects affecting power transmission efficiency in cable projects:
In cable projects for power transmission there are multiple design aspects needs to be assured to achieve power transmission effectiveness which indented originally to accomplish and satisfy high performance of power supply within the network and fulfill the growth of demand.

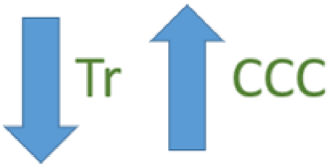
The most important design aspect is the continuous current capacity which assessed by ampacity calculations, and the same is usually limited as 525 Amps in the 132kV network. Considering the actual condition for each proposed circuit in power transmission network.



The common practice in the 132kV network to protect the cable mechanically from any hazard is to use concrete trough and covers mainly along with cable concrete duct banks and/or HDD, this shall be in integration with the electrical components.
The ampacity calculation inputs are mainly listed as follows:

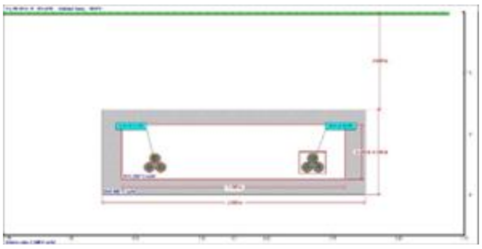
- Thermal resistivity of the components.
- Ambient temperature.
- Cables arrangement.
- Geometrical arrangement.
- Depth of the cable (1.5 m)
- Maximum allowable cable temperature (90°C).

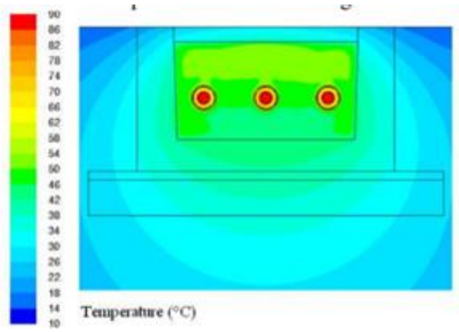
The thermal conductivity of the cables surrounding means, plays a vital rule to enhance the continues carrying capacity of the cable.

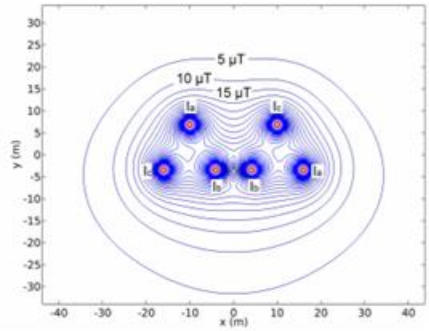


In addition, the spacing between cable groups is also playing other vital rule due to the electromagnetic effect which is significantly affecting the contours carrying capacity.

As this acting actively to dissipate the heat generated in the power transmission process and finally enhance the cable overall performance.







The Case Study:
The study conducted to enhance the civil design aspects to achieve the purpose of the sustainability:
Enhancement Design Objectives:

- Reduce the concrete troughs width and associated civil works using sustainable concrete.
- Optimize the dedicated corridor for power transmission infrastructure to accommodate other utilities services.
- Analyze the impact and outcomes on the sustainability and environmental impact aspects.

The way forward was to assess the proposed enhancement by defining the constrains and possible facilitators:

Constrains	Facilitators
Achievement of desired ampacity - Continuous current capacity as per specifications and functionality requirements	Enhance the concrete characteristics with the virtue of using eco - friendly materials and alternative binders, to have more thermal conductivity capability using advanced additives.
Production of the proposed sizes and related construction works, such as concrete mix design and precast molds	Communicate with stakeholders to assure the requirements for production and find advanced solutions for production.
Cable installation and jointing	Update the pulling procedures and tools in use.

The impact on ampacity outputs due to the congestion and blocking of heat and electromagnetic fields generated. Hence, it was essential to find and alternate innovative approach to enhance the ampacity, and the most effective way recognized was increasing the thermal conductivity of the sounding component starting with the concrete troughs.

Whereas the practice is to use a trough geometry of 2.0m width considering the Concrete Thermal resistivity as 1.0 °C. m/W. However, the proposed solution is to reduce the trough width to 1.20m with a Concrete Thermal resistivity as 0.5 °C. m/W.

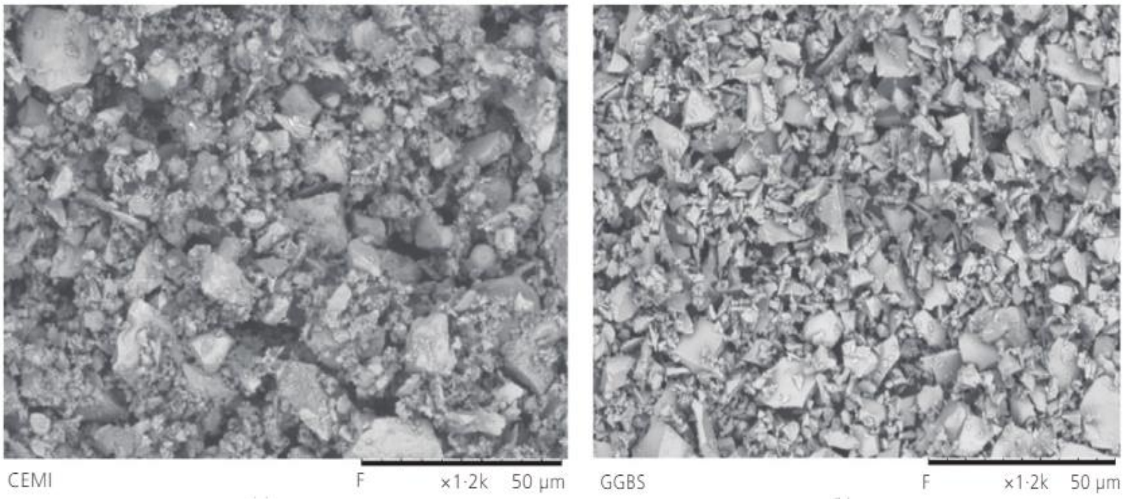
Study Expected outcomes:

- Environmental, the reduction of width will have smaller and optimized concrete section and reinforcement, accordingly, associated materials, cement consumed, and transportation will be reduced and further CO2 emissions.
- Economical, the reduced size will associate lesser amount civil works such as excavation, transpiration and manpower.
- Social, the reduced size will associate lesser size of dedicated corridors which shall allow other serves and/or roads installation, especially con congested infrastructure situations.

Concrete Mix Design Enhancement Key Elements:
In line with the sustainability concept of reduce, reuse and recycle, utilizing Supplemental Cementitious Materials & alternative binders such as Silica Fumes and GGBS (Ground Granulated Blast - furnace Slag) which is effectively enhancing procedure to boost the concrete characteristic in terms of thermal conductivity and reduce the thermal resistivity to achieve the desired purpose, make it more sustainable concrete.

GGBS Content:

The concrete mix design for the troughs precast element is having at least 36% of GGBS which is in line with DM's Green Buildings regulations. However, increasing the same will have positive impact on the thermal conductivity, since Ground Granulated Blast - furnace Slag is a by - product from the blast - furnaces used to make iron so it has a high thermal conductivity material. Moreover, the densification of the concrete particle using the same is directly enhancing the thermal conductivity as well.

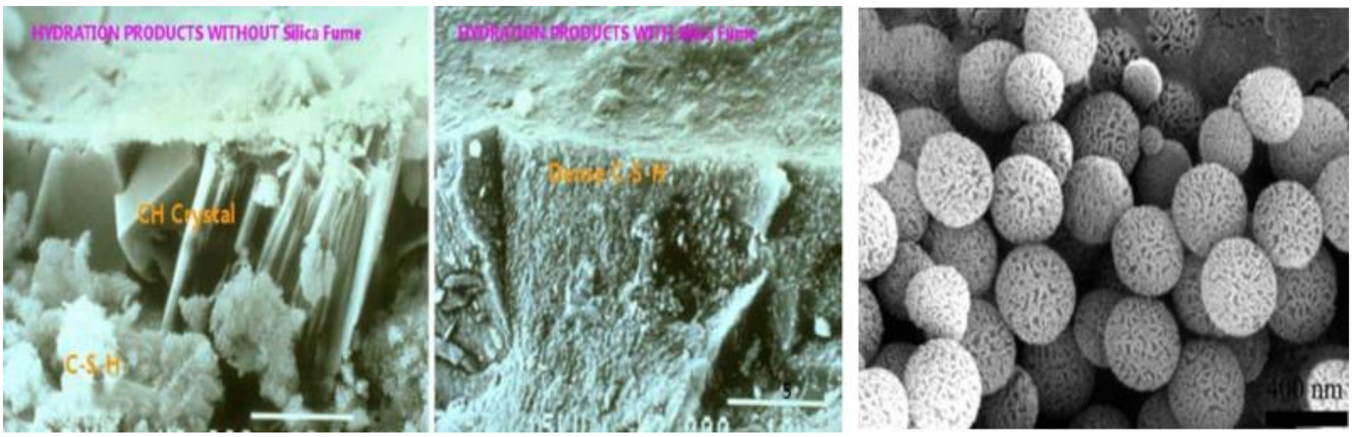


Microscopic view of concrete without and with GGBS

Micro Silica (Silica Fumes):

Currently the concrete mix design for the troughs precast element having no amount of silica fumes / Micro silica. Utilizing MS gives a significant advantage to densify the concert partials by reducing porosity and increasing overall concrete strength / durability.

Adding at least 7% of MS. This will have a promising potential to chive the target.



Microscopic view of concrete without and with Micro - Silica

Industry Stakeholders feedback:

The feedback from the stakeholders were very supportive to utilize the Micro Silica instead of GGBS, as the raises of GGBS content of more than 36% will have a negative impact on the production rates of precast concrete due to more setting time required and subsequent curing time.

Where, the setting time for 36% GGBS concrete is around 14 Hrs. for demolding. However, increasing GGBS up to 50% will at least duplicate the time.

Case study final outcomes and conclusion:

The study outcomes from the laboratory tests conducted in line with respective code shows that after adding the proposed amount of 7% of Micro Silica to the concrete mix design for Concrete troughs production represented a significant change in the earlier presumed concrete thermal resistivity, whereas several tests conducted on the hardened concrete in an approved and authorized laboratories in line with ASTM D 5334 - 14. Some of the results shows as follows:

Table 1: Set of specimens tested in Agency A, with 7%MS.

Specimen No.	Thermal Conductivity (watt/m-°K)	Thermal Resistivity (m-°K/watt)	Temperature(°C)	Mass of cube(Kg)
1	2.258	0.443	21.74	8.315
2	3.677	0.272	21.92	8.193
3	2.440	0.410	22.20	8.136

Table 2: Set of specimens tested in Agency B, with 7%MS

	24.11	°C				
Thermal Conductivity==>	3.821	W/m.K	3.821	W/m.C	0.038	W/cm.C
Thermal Resistivity====>	0.262	m.K/W	0.262	m.C/W	26.171	cm.C/W

By converting the achieved results for the design input, the ampacity – Continuous current Capacity of the cables have been enhanced and the following benefits could be gained:

- Adding 7% of Micro Silica to the design mix will achieve the (Tr) of 0.50 m. °C/W, conservatively.
- Potentially 48% of the concrete amount could be saved, subsequently more than 5% of CO_2 gas emission would be reduced.
- Potentially 38% of overall civil works could be saved with associated transportation, handling and manpower.
- The cited results found in line with the guidance provided vide ACI 122R - 02 recommendations.

It would be concluded that the imperative to develop sustainable concrete solutions for power transmission projects cannot be overstated. By embracing eco - friendly materials and alternative binders, the construction industry can significantly mitigate the environmental impact of power transmission infrastructure. These innovations not only enhance the longevity and durability of structures but also uphold our responsibility towards environmental stewardship. Moving forward, continued research and implementation of sustainable concrete technologies will be crucial in fostering a greener, more resilient future for infrastructure development for DEWA - TP and worldwide applications.

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