

Geopolymer Concrete for Sustainable Developments: Opportunities, Limitations, and Future Needs

By

**Tarun R. Naik, Ph. D., P. E., and
Rakesh Kumar, Ph. D.**

**Presented at the Third International Conference on Sustainable
Construction Materials and Technologies, Kyoto, Japan, 18-21 Aug. 2013**



In last two decades, considerable interest have been generated in Geopolymer concrete, particularly in light of hot-topics of today:

- **Sustainability and**
- **Reduction of green house gas emissions from cement-based industries, leading to potential for global warming.**

GEOPOLYMER CONCRETE

- **Pozzolans combined with suitable alkaline activators**
 - **Geopolymerization technology is not new.**
 - **It is believed to have been used in the construction of the Pyramids at Giza, Egypt (circa 2550 B.C.) .**
 - **Significant claims for the reduction of carbon footprint of the GPC are made, compared to the conventional concrete.**

REQUIREMENTS FOR GPC

- **Materials rich in Silicon (Si) and Aluminium (Al)**
- **Activators, highly alkaline liquids (typically a combination of sodium silicate and sodium hydroxide solution)**
- **Heat curing either in the form of steam curing or dry curing**

REQUIREMENTS FOR GPC (CONT'D)

- **Aggregates suitable for making conventional concrete**
- **A high-range water reducing agent and some water. In addition to the water present in the activator solution**

A Typical Low-calcium Fly Ash Based GPC Mixture

Constituent Materials	Quantity (kg/m³)
Coarse aggregates	1295
Sand	555
ASTM Class F fly ash	406
Sodium silicate solution (Na₂O = 14.7%, SiO₂ = 29.4%, and water = 55.9% by mass)	103
NaOH solution (8 M), made by mixing 11 kg of NaOH solids with 98% purity in 30 kg of water	41
Super plasticizer	6

OPPORTUNITIES FOR APPLICATIONS OF FLY ASH-BASED GPC

- **High-volumes of recycling of fly ash in cement-based construction industry.**
- **Geopolymer concrete gives a glossy appearance.**
- **Manufacturing of more durable concrete due to absence of transition zone in GPC.**

OPPORTUNITIES FOR APPLICATIONS OF FLY ASH-BASED GPC (CONT'D)

- **Very suitable for precast concrete products such as RCC box culverts .**
- **Manufacturing of precast segmental units .**



- **Ratio of compressive to tensile strength is very high.**

OPPORTUNITIES FOR APPLICATIONS OF FLY ASH BASED GPC (CONT'D)

- **Strength is almost independent of age**
- **GPC is very suitable for the construction of underwater structures where early strength and rapid setting is desired**

LIMITATIONS OF GPC TECHNOLOGY

- Requirement of heat curing for setting of GPC is a notable limitation for its utilization in similar ways to that of the conventional concrete.
- Production of GPC requires greater care in contrast to portland cement concrete .
- Limited availability of widely accepted specifications and guidelines.

LIMITATIONS OF GPC TECHNOLOGY (Cont'd)

- **Development of strengths and other key properties of GPC are dependent on the purity of the materials used.**
- **Maintaining homogeneity in the materials and purity of alkaline materials obtained from different suppliers for preparing activator solutions make the design of GPC mixture proportions difficult, to meet the requirements for GPC production based on a recipe .**

LIMITATIONS OF GPC TECHNOLOGY (CONT'D)

- **Cost of alkaline solution is high depending on the purity of its alkalis.**
- **It is necessary to prepare the alkaline liquid by mixing both the solutions together 24 hours prior to use.**

LIMITATIONS OF GPC TECHNOLOGY (CONT'D)

- **High alkalinity environment possess health hazards to the workers.**
- **Higher alkalinity of the materials requires more processing resulting in more energy.**

FUTURE RESEARCH NEEDS

- **GPC curing under ambient conditions without requiring additional heat for curing.**
- **Make GPC more user friendly; i.e. capable of being mixed with a relatively lower alkaline solutions.**
- **GPC requiring less expertise in its design and handling during construction.**

FUTURE RESEARCH NEEDS (CONT'D)

- **Cost effective and low-carbon footprint geopolymer cement which could be easily mixed and hardened.**
- **Corrosion aspect study of geopolymer concrete is needed for its utilization in the construction of the reinforced structures.**

CONCLUSIONS

- **GPC technology is still not being readily used. It is more confined at proto-type production.**
- **The choice of the resource materials for making GPC depends on their availability locally and cost.**
- **To make this technology for manufacturing of concrete more cost effective, low embodied energy product, and user-friendly practical uses like that of ordinary portland cement concrete, more research are needed .**

CONCLUSIONS (CONT'D)

- **Dry or steam curing requirements has restricted its application to precast concrete products.**
- **Making portland cement free and reduced water requirement for manufacturing of GPC, while heat requirement for curing and higher energy requirement for processing of alkaline salts raise questions about concerns for its lower carbon footprint.**

**Thank you very
much for your
interest.**

