Sustainable Concrete with Industrial and Post-Consumer By-Products

By

Rakesh Kumar and Tarun R. Naik

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Center for By-Products Utilization
Why Sustainable Concrete?

• Concrete is the backbone of all construction and development activities and has portland cement as the key ingredient.

• Production of portland cement is not an eco-friendly material:
  
  ➢ It consumes enormous quantities of natural resources;
Why Sustainable Concrete? (cont’d)

- Releases a significant amount of GHGs resulting in adverse environmental impact;
- Responsible for about 7% of total anthropogenic CO$_2$ emissions; and,
- Each construction activity involving cement requires new cement as it does not have significant potential for recycling.
Why Sustainable Concrete? (cont’d)

Global CO$_2$ emissions from fossil fuels use and cement production by the region

Source: EDGAR 4.0 (IEA, 2007; EIA, 2007); BP, 2008; USGS, 2008.
Sustainable Concrete

• It should have a low inherent energy requirement.
• It should be produced with little waste and with recycled materials.
• It should be highly durable.
Sustainable Concrete (cont’d)

• It should have little impact on the environment.
• It should use industrial by-products and other recyclable materials as substitute for natural or manufactured ingredients of the concrete.
Blended Cement

• One of the most common effort to make the concrete more sustainable.

• Involves reducing and replacing of a portion of the portland cement clinker with suitable industrial by-products or other recyclable materials.
Blended Cement (cont’d)

- Can be used for all concrete construction activities.
- Reduce the use of natural or manufactured materials, and emission of greenhouse gases, by using recycled materials.
- The global potential for CO2 reduction through blended cement is between 5 - 20%
Blended Cement (cont’d)

- More environmental friendly than portland cement because it provides energy savings, ecological as well as technical benefits such as increased strength, improved impermeability, increase resistance to chemical attacks, and reduced heat of hydration.
Self Consolidating Concrete (SCC)

- A recent innovation in concrete technology.
- SCC is an advanced step towards development of a sustainable concrete.
- SCC provides benefits beyond conventional concrete in all three aspects of sustainable development (i.e. economical, sociological, and environmental).
Self Consolidating Concrete (Cont’d)

- Enhanced sustainable properties of concrete and permit use of large amount of by-product materials in the manufacture of SCC.
- Reduces electricity needed for compaction and noise at a construction site and increases durability of the concrete construction.
Self Consolidating Concrete (cont’d)

• More environmental friendly than conventional concrete
• It provides opportunity to use one or more industrial by-product materials such as fly ash, blast furnace slag, limestone quarry dust, used foundry sand, and other materials.
Self Consolidating Concrete (cont’d)

• Use of large amount of by-product materials as powder or fines not only avoids landfilling them but also leads to the reduction of the environmental pollution.
Geopolymer Concrete (GPC)

- Proposed by Devidovits (1994) is an upcoming technology for manufacturing of sustainable concrete.
- It is portland cement free concrete.
- This concrete does not require cement or water for curing, and utilizes by-product materials. Therefore, it is more eco-friendly and sustainable.
Geopolymer Concrete (cont’d)

- Industrial by-product materials rich in Silicon (Si) and Aluminum (Al), such as fly ash, rice-husk ash, silica fume, slag, and other similar materials, are added to react with highly alkaline liquid (typically a combination of sodium silicate and sodium hydroxide solution) to produce binders for the geopolymer concrete.
GPC (cont’d)

• Very low CO$_2$ foot print.
• This technology further reduces or eliminates the need for large amounts of raw materials for the manufacture of cement and provides great potential for recycling of Al- and Si-rich by-products materials.
Recycling of Construction & Demolition Debris in Concrete

• Recycling of C & D debris conserves:
  ➢ Raw materials, Energy, Water; and,
  ➢ Reduces the emission of greenhouse gases.
• Most common way of using CD debris is as aggregates.
Recycling of C & D Debris in Concrete (cont’d)

- Use of recycled-aggregates, including the fine fractions, can be used in the manufacturing of sustainable concrete because it not only reduces landfilling but also consumes the recyclable material resulting in the reduction of its environmental impact.
Used Foundry Sand

• A by-product material from the foundry industry.
• Clean silica sand is used and it is recycled & reused multiple times.
• Characteristics of the used foundry sand depend on the type of metal cast and the casting process, types of additives used, etc.
Used Foundry Sand (cont’d)

• Shape of foundry sand is mostly round.
• Fineness modulus ranges from 0.9 to 1.6.
• Depending upon the amount of used foundry sand and dust in the concrete, the color of concrete changes to grayish/black, which may not be desirable. A 15% replacement of fine aggregate of concrete by used foundry dust produces a minimum color change.
Post Consumer Glass

• USA generated 14 million tonnes of waste glass in 2007 and about 25% of the glass was recovered for recycling.

• Glass is known to activate alkali-silica reaction (ASR) in cement-based materials.
Post Consumer Glass (cont’d)

• Commonly used methods is to add pozzolanic material, e.g., fly-ash, silica fume, ground granulated blast slag. etc.

• With a proper mixture proportioning post-consumer glass can be used for manufacturing of sustainable concrete.
Pulp and Paper Mill Residuals

• By-products of the waste-water treatment process used by pulp and paper mills.

• Composed of cellulose fiber, clay, ash-bearing compounds, chemicals, and water.
Pulp and Paper Mill Residuals (cont’d)

• Pulp and paper mill residual solids can be used as additives in CLSM, structural-grade concrete, and bricks/blocks/paving stones, and other types of cast-concrete products.

• It is possible to use pulp and paper mill residuals in the manufacture of sustainable concrete.
Waste Washed-water

• Portable water can be used to make and cure the concrete.

• Ready-mixed concrete plants produce large amount of waste wash-water, the disposal of which has many adverse environmental impact.

• It also has high pH.
Waste Washed-water (cont’d)

• Studies have suggested waste washed-water can be used for a partial replacement of portable water in concrete manufacture and for the curing of concrete.

• Waste wash-water from ready–mix concrete plants could be used in the manufacture of sustainable concrete without adverse effects on concrete properties.
Conclusions

• A sustainable concrete should have a very low inherent energy requirement, could be produced with little waste and with recycled materials, be highly durable, and have a very little impact on the environment.
Conclusions (cont’d)

• The cement industry is held responsible for global warming to some extent. It contributes over 7% of total global CO$_2$ emissions from fuel use and calcinations process.

• Use of the blended cement in place of ordinary portland cement in concrete is one of the most common efforts to make the concrete more sustainable.
Conclusions (cont’d)

• SCC is a very viable step towards sustainable concrete as it provides opportunity to use one or more industrial by-products and enhancing many sustainable properties.

• GPC does not use portland cement
Conclusions (cont’d)

• Use of CD debris is suitable for manufacture of sustainable concrete including SCC.

• Used foundry sand can be used to replace 35% of regular concrete sand for structural concrete; and, even higher amount for use in CLSM.
Conclusions (cont’d)

- Powdered glass along with other pozzolanic materials can be used as a partial replacement cement.

- Pulp and paper mill residual solids can be used as an additive in concrete for enhancing durability properties.
Conclusions (cont’d)

Waste wash-water from ready-mixed concrete plants could be used in the manufacture of sustainable concrete.
Thank you very much.