



Uses of Recycled Materials for Remote 3D Printing

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June 2, 2021

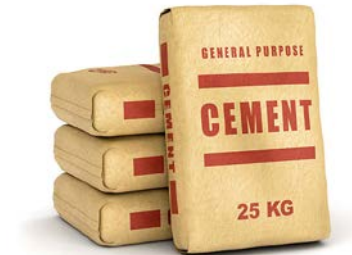
Concrete Structures for Remote Military Operation

- Concrete is the most widely used construction material.
 - Pavements
 - Bridges
 - Foundations
 - Dams
 - Utilities, and other infrastructures would not be possible without concrete
- Construction using 3D printing technology has a lot of advantages for remote military operation.
- Concrete is made of portland cement, sand, aggregate, and other optional admixtures. These materials might not always be available in remote area.
- Shipping of concrete to remote area, pre-packaged or their components, are cost prohibitive and logistically challenging.



Portland Cement Containing Recycled Materials

- Portland cement is about 15-25% by mass of the dry mixture.
- Addition of industrial by-products/recycled materials (5-50% by weight) is a common practice worldwide.
- Typical industrial by-products/recycled materials used are:
 - Fly ash from power industry
 - Slag cement from steel industry
 - Silica fume from alloy industry
 - Other pozzolans, such as calcined clay, volcanic ashes, rice husk ash, etc.
 - Pulverized glass powder
 - Pulverized limestone
- However, during remote military operation, making cement containing recycled materials is NOT an easy task.
 - Grinding and blending processes are necessary.
 - Quality control is difficult.



Aggregates Made of Recycled Materials

- The main ingredients of concrete by mass are aggregates, up to 80% of the dry mixture. They might be better sourced locally, from indigenous materials or recycled materials.
- Aggregates made of Recycled/Reused Materials
 - Recycled Concrete Aggregate (RCA)
 - Recycled Scrap Tire Aggregate
 - Recycled Asphalt Pavement (RAP) Aggregate
 - Blast Furnace Slag
 - Crushed Returned Concrete Aggregate (CCA)
 - Crushed Glass Aggregate
 - Recycled Plastic Aggregates
 - Others

Recycled Concrete Aggregate (RCA)



- In-service concrete can be demolished, processed and recycled as aggregate for fresh concrete
- Fresh concrete made of RCA can be batched, mixed, transported, placed, and compacted in the same measure as conventional concrete.
- Contamination from building components, such as reinforcing bar, plaster, wood, and other debris should be removed as much as possible.

- Recycled concrete aggregates have densities less than the original aggregates used, due to the low density of hardened cement mortar remained on aggregates.
- Poor quality and inconsistency of recycled concrete aggregate will lead to low performance fresh concrete.
- Mix design for structural concrete made of RCA should be adjusted to account for differences between RCA and virgin aggregates.



Recycled Scrap Tire & Recycled Asphalt Pavement (RAP) as Aggregates



- Scrap tires in the form of crumb rubber could be used as fine aggregate for concrete
- RAP could be used as a replacement of the coarse and fine aggregate in concrete on an equal weight basis
- Both recycled aggregates have negative effects
 - Workability as measured by slump decreases
 - Entrained air content increases
 - Compressive strength, flexural strength, and modulus of elasticity decreases with increase of replacement
 - Permeability increases
- Use of these in concrete would only be in construction such as walkways, cycling tracks, or pavements subjected to low loads.

Ideal Solution for Remote 3D Printing

- **Preblended 3D printing admixture/concentrate (<5%) + local cement + local aggregates**
- The admixture could be one combo or several kinds with specific functions, such as:
 - Flow agent/pumping agent
 - Set controller
 - Rheological modifier
- Use local dry-mix facilities for proper blending to ensure consistency of the mixed materials.
- Collaboration between 3D printer engineers and material scientist is critical.

