Comparing the Properties of Polyethylene Terephthalate (PET) Plastic Bricks to Conventional Concrete Masonry Units

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Abstract

The research investigates the viability of recycled polyethylene terephthalate (PET) bricks as a replacement for concrete masonry units as a building material. The underlying goal is to validate the pursuit of production and testing of recycled PET bricks. Recycled plastic bricks have the potential to divert valuable post-consumer plastic waste from landfills, locking up this plastic for decades to come. A comparison of the material properties, as well as the greater societal impacts, of PET and concrete comprise this study. The compressive strengths of the two materials are compared using both published data and computational analysis. The toxic substances released during the production and post-production of concrete and PET are examined, to gain a deeper understanding of the overall impact these materials have on human and planetary health.

Background & Motivation

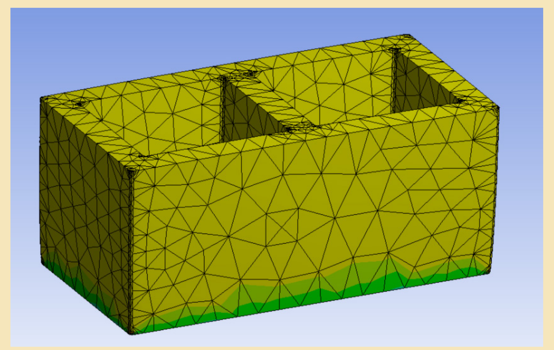
- ***Motivation*** - The ever-increasing volume of solid plastic waste produced globally has created a need for upcycling plastic into a profitable product to divert a large quantity from landfills and maximize plastics' lifespan for as long as possible. Building materials molded from recycled plastic, specifically bricks, meet both of these criteria.
- ***Background*** - Some organizations have started to use plastic waste as building materials. Existing academic research indicates that plastic-concrete composite made from plastic aggregate (PA) or plastic fiber (FB) is typically weaker compared to conventional concrete due to poor bonding between cement and plastic.
- ***Purpose*** - Investigate the potential of making bricks entirely out of plastic to eliminate the shortcomings of the plastic-concrete composite. Companies producing plastic bricks suggest that they are viable alternatives, but there is limited published research on this topic and this investigation serves to bridge the knowledge gap.

Experiment

<u>Investigation:</u>

1. Structural integrity of PET vs concrete from material properties standpoint (compressive strength, density, water absorptivity, linear coefficient of thermal expansion, and thermal conductivity).
2. Societal impact of manufacturing both materials to understand their effect on human health and the environment.

<u>Method:</u>



- Compile data from existing research.
- Finite element analysis (FEA) following ASTM standard C90-16a minimum required load of 12.4 MPa:
  - A standard concrete masonry unit of dimensions 20.32 cm x 20.32 cm x 40.64 cm (8 in x 8 in x 16 in) was modeled in SolidWorks.
  - The model was imported into Ansys Workbench for loading application on the top face with the bottom face statically secured.
  - Recorded the compressive stresses from the simulation.

* Study compares pure PET and concrete. The material properties may vary slightly between recycled and pure PET, as well as between variations of concrete that use different aggregate.

Results

<u>Mechanical & Thermal Properties:</u>

	PET	Concrete
Compressive Strength	45.2 – 80 MPa	12.4 MPa
Density	1.35 g/cm^3	2.4 g/cm^3
Water Absorption	0.304%	240 – 320 kg/m^3
Linear CTE	117 x 10^{-6} °C^{-1}	13.6 x 10^{-6} °C^{-1}
Thermal Conductivity	0.15 Wm^{-1}K^{-1}	1.25 – 1.75 Wm^{-1}K^{-1}

- Compressive strength: Bricks have to bear the compressive load of other bricks and the roof.
- Density: Lower density reduce the compressive load on other bricks in a structure. Lower density also decreases the work required to lift and assemble the blocks for a wall due to the decrease in brick weight.

Results (Cont.)

<u>Mechanical & Thermal Properties (Cont.):</u>

- Water absorption: Predicts the durability of concrete because water facilitates the penetration of the material by aggressive substances. Water in concrete can also induce cracking due to thermal expansion and contraction with temperature change.
- Linear coefficient of thermal expansion (CTE): CTE value indicates the degree to which the material will expand or contract with temperature changes. PET's higher CTE value could result in regions of stress if the bricks are in contact with a material of lower CTE, posing a problem in regions that experience a freeze-thaw cycle.
- Thermal conductivity: Lower thermal conductivity corresponds to enhanced insulation capability which can lead to reduced heating and cooling costs.

<u>Finite Element Analysis:</u>

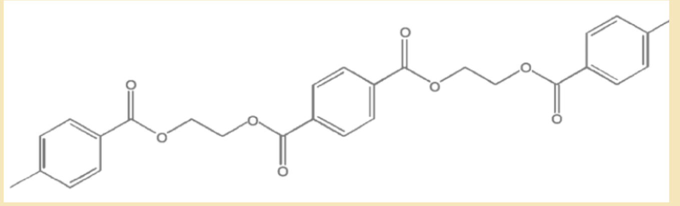
- The concrete and PET bricks passed the required minimum ASTM standard of 12.4 MPa.

Material	Maximum Compressive Strength (MPa)	Maximum Principal Compressive Stress (MPa)
Concrete	18	7.11
PET	45.2	21.9

<u>Health Hazards:</u>

- Occupational Safety and Health Administration (OSHA) estimates that approximately 10% of concrete manufacturing workers experience job-related injuries and illnesses over a one-year period. OSHA does not classify PET as hazardous and has not found it to be carcinogenic.
- PET is highly stable and resistant to photo-oxidation due to the presence of structural aromatic rings which leads to a negligible amount of volatile organic compounds released in exposure to environmental conditions.

<u>Green House Gas Emission:</u>



- 1900 kg of CO_2/ton of virgin plastic produced.
- 880 kg of CO_2/ton of concrete produced.
- 200 kg of CO_2/ton of produced from recycling plastic.

Conclusion

Recycled PET (rPET) bricks are adequate substitutes for conventional concrete masonry units due to their superior strength, lower density, insulation capability, lower health hazards in production, and lower environmental impact. A single hollow plastic brick can divert 986 water bottles from the landfill. Recycled PET will likely behave differently than pure PET hence future work on this pursuit will focus on laboratory testing.