Reuse and Recycle of Debris for Printed Buildings

Aveiro - Innovative Design

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Introduction

The City Hall of Madrid has set the challenge of transforming debris from the demolition of an old, historic building, once emblazoned with the Malta's Order, into 3D printable material. Our team must develop a unique mechanism to repurpose the debris for a 3D building printer, which will be used to rebuild the same structure and preserve its historical significance.

Debris Recycling System

The system is designed to handle building materials in Spain and Portugal, such as bricks, concrete, and various types of natural stones (e.g., limestone and granite). The materials are commonly used in the region and are ideal for repurposing into concrete for 3D printing. By using these we ensure the efficient and sustainable use of region-specific materials.

Ideally concrete can be recycled by grinding it up, then using screens to separate fine and coarse materials, magnets to remove steel, and water floatation to remove other unwanted materials.

Transforming Debris into Concrete

The refined output of the previous step is then combined with cement, water, natural aggregate, recycled aggregate, and additives to create a concrete mixture suitable for 3D printing.

It is crucial to consistently monitor the concrete's quality during the process to guarantee that it meets the standards. This may necessitate evaluating the recycled concrete components for durability. According to prior thesis research, maintaining acceptable durability levels should be feasible as long as the concrete contains no more than 25% recycled content.

Referência	Resistência à compressão (MPa)			% substituição	Relação a/c
	Betão convencional	Betão reciclado	% Δ		
(Fonteboa, 2002) [1]	38,3	40,2	+5%	50% AG	
	41,8	42,9	+3%	50% AG	
(Soberón, 2002) [65]	39	35,8	-8%	60% AG	
	39	34,5	-12%	100% AG	
(S. C. Kou, 2004) [66]	45,9	43,6	-5%	20% AG	
	45,9	40,4	-12%	50% AG	
	45,9	38,3	-17%	100% AG	
(De Juan, 2005) [15]	29,3	26,3	-10%	100% AG	0,60
	40,3	34,4	-15%	100% AG	0,50
	48,5	41,3	-15%	100% AG	0,50
(Jianzhuang Xiao, 2005) [67]	26,9	25,4	-6%	20% AG	
	26,9	23,6	-12%	50% AG	
	26,9	23,8	-12%	100% AG	
(M. Etxeberria, 2007) [38]	29	28	-4%	25% AG	0,55
	29	29	-	50% AG	0,52
	29	28	-4%	100% AG	0,50
(L. Evangelista, 2007) [31]	59,3	57,3	-3,4%	20% AF	
		58,8	-0,8%	50% AF	
		54,8	-7,6%	100% AF	
(A. Turatsinze, 2005) [68]	33,5	33,1	-1%	100% AG	0,40
	24,1	23,6	-2%	100% AG	0,50
	18,1	17,9	-1%	100% AG	0,60
(Chi-Sun Poon, 2007) [34]	48,6	45,3	-7%	20% AG	0,55
		42,5	-13%	50% AG	
		39,2	-19%	80% AG	
		37,1	-24%	100% AG	
(A. Domingo Cabo, 2009) [60]	52,85	52,76	0%	20% AG	0,50
		48,06	-9%	50% AG	
		48,64	-8%	100% AG	
(Mirjana Malešev, 2010) [39]	43,44	45,22	+4%	50% AG	0,569
		45,66	+5%	100% AG	0,62

Material

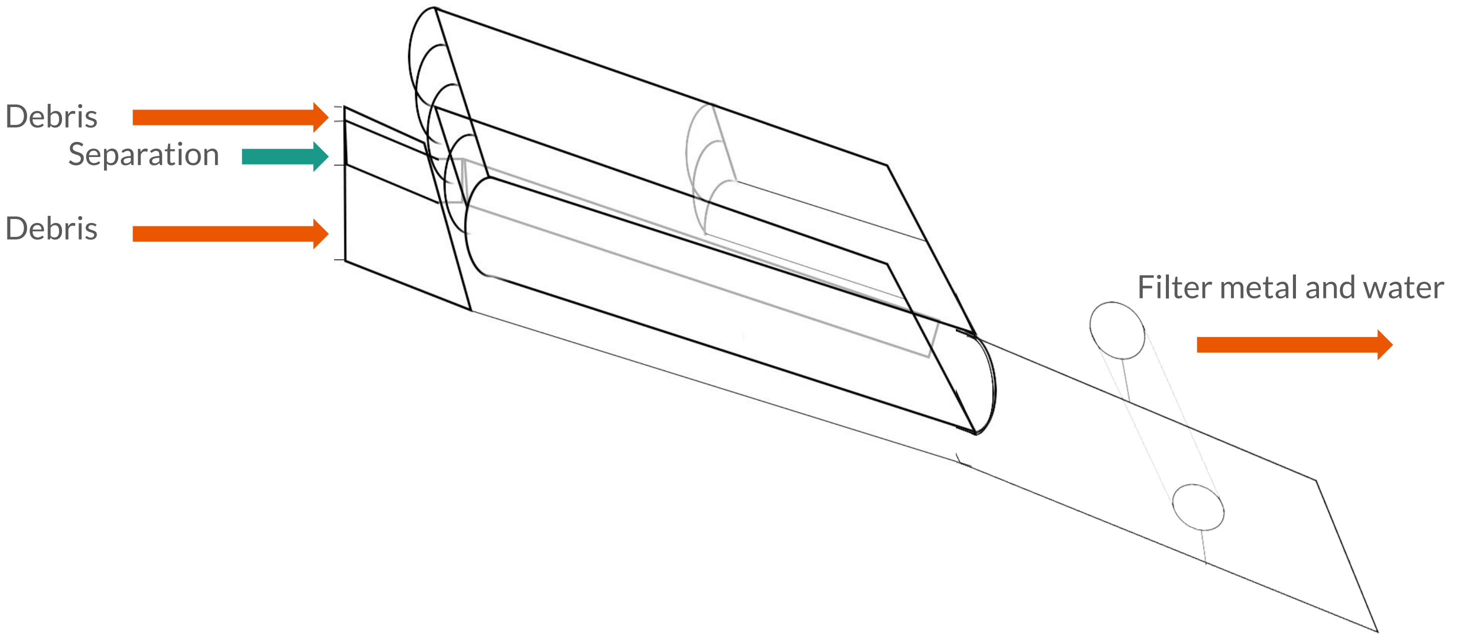
Used for prototype

- Wooden Sticks
- Syringes
- Pulleys
- Hot Glue
- PVC tube
- Foam boards
- Zip ties
- Cardboard
- Plastic tube

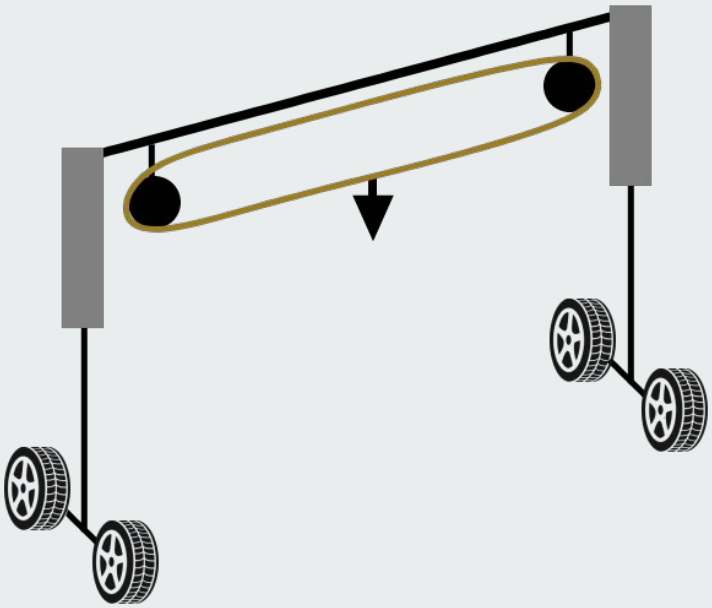
Envisioned for final product

- Recycled steel for the extruder
- Recycled aluminum for the structures
- Salvaged motors the axis displacement and grinding motor
- Used conveyor belts to transport debris to the grinder
- Recycled rollers
- Recycled grinding media (e.g. crushed glass, ceramics)
- Used pipes to transport concrete to the 3D printer

Recycling Machine Design



3D Printer Design



Our design is inspired by the Vulcan 3D printer which features an extruder that comprises both a hot end, responsible for melting the material, and a cold end, which supplies the material. This extruder is attached to a gantry system, enabling movement along the X, Y, and Z axes.

To control the X-axis, we use a pulley system, while the Y-axis is guided by a set of wheels. Meanwhile, the Z-axis relies on a hydraulic mechanism to raise and lower the extruder as needed.

Social Impact

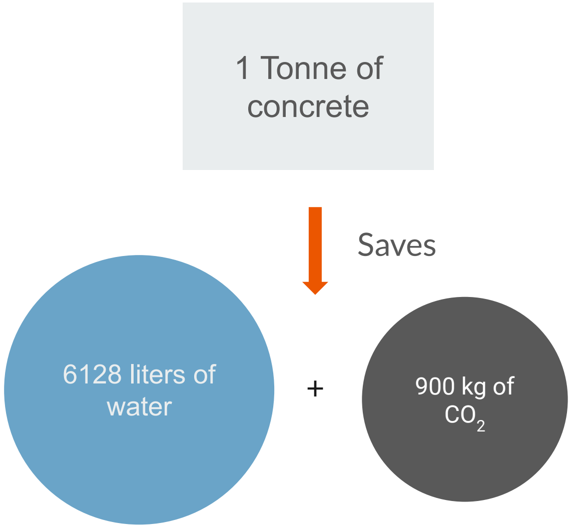
The social impact of our debris-to-concrete 3D printing technology offers multiple benefits. It enables the accurate recreation of historic buildings and preserving cultural significance. By utilizing debris as the primary material source, construction costs are reduced, which allows for better resource allocation in other urban development areas. This technology also minimizes landfill waste and promotes sustainable construction practices, aligning with green city initiatives.

In times of natural disasters or conflicts, this technology can aid in the rapid reconstruction of damaged infrastructure and buildings, using the generated debris for rebuilding efforts.

Environmental and Economic Considerations

By recycling debris into new building, waste sent to landfills is significantly reduced. In reality it is hard to recycle concrete because it contains contaminants, but it's really worth trying. Recycling one tonne of concrete could save 6182 litres of water and 900 Kg of CO_2. Sometimes only about 30% of the materials in concrete can be recycled, because its performance may otherwise be reduced.

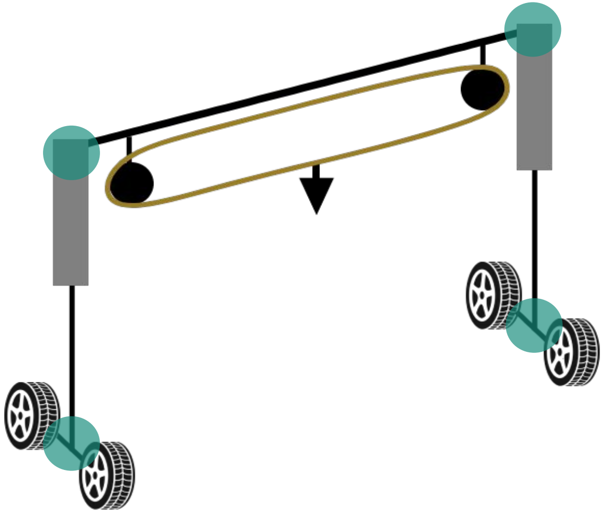
Additionally, in times of natural disasters, this can aid in the rapid reconstruction of damaged infrastructure, utilizing debris for rebuilding, resulting in faster recovery times and lower overall reconstruction costs.



Scalability and Modularity

Since the design of our 3D printer is minimalist and straightforward, making it easy to disassemble and scale to meet the requirements of various projects. To adjust the machine for taller or shorter buildings, simply replace the vertical poles with ones of different heights. For wider buildings, substitute the existing pulley system.

The printer consists of 3 components connected by a single point, allowing for quick disassembly and convenient transportation as needed.



- Represents a disassembled joint

Conclusion

We have presented a successful approach to a debris-to-concrete 3D printing machine that can be used in construction and urban development and most importantly rebuild historic buildings.

As we move forward, our system will not only raise awareness about the importance of preserving cultural heritage but also inspire environmentally conscious practices in the construction industry.

References

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