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Research Article

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Engineering The Perfect Strike: Lightweight Fiber-Reinforced Concrete for the Aci Bowling Ball Challenge

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Introduction

The ACI Bowling Ball Challenge invites civil engineering students to design a concrete bowling ball that meets strict criteria for weight, size, and mechanical strength. This competition encourages innovative mix designs and the use of sustainable materials, making it a platform to explore the potential of lightweight and fiber-reinforced concretes in a practical, hands-on context.

Objetive

To design a sustainable, lightweight, fiber-reinforced concrete using recycled expanded perlite (polystyrene) and local arenilla (a lightweight aggregate) for the fabrication of a bowling ball that meets ACI Challenge specifications (Ø 20 ± 0.5 cm, ≤ 5.25 ± 0.5 kg). The design aims to minimize environmental impact by incorporating local and recycled materials.

Methods

Material Characterization

Unit weight was measured (loose and compacted). Sand gradation followed ASTM C33.

Unit weight test				
	Aggregate	**Condition**	**Weight (kg)**	**Density (kg/m³)**
Holcim	Coarse	Loose	6,685	665,174
		Compacted	7,635	759,701
	Fine	Loose	911	906,467
		Compacted	10,455	1040. 298
Arenilla	Fine	Loose	-	721. 32
Tezontle	Fine	Loose	-	1200

ASTM C-33 Sands					
Sieve	**% Passing**		**Intermediate Value**	**% Cumulative retained**	**% Retained**
3/8"	100	100	0	25	
#4	95	100	975	25	75
#8	80	100	90	10	225
#16	50	85	675	325	25
#30	25	60	425	575	25
#50	5	30	175	825	125
#100	0	10	5	95	5

Mix Design

Mixes with different proportions of aggregates, fibers, expanded perlite (polystyrene) and additives were prepared

Testing and Final Casting Cubes

(5 × 5 × 5 cm) were cast and cured in water.
Compressive strength was tested at 15 and 28 days.
Final prototype was made in 20 cm plaster molds, chosen for reusability and ease of demolding.

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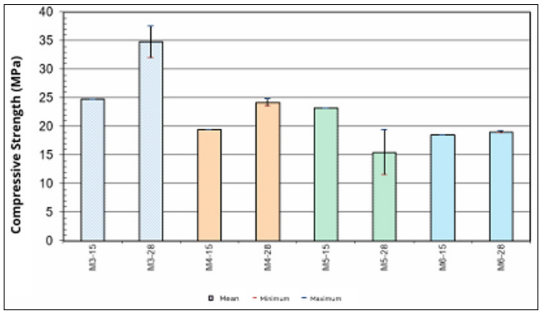
Mix	Type of cement	Cement (kg)	Coarse aggregate (kg)	Sand (kg)	Water (L)	Fiber (g)	Expanded perlite (g)	Silica fume (g)	Admixture (ml)	Ratio w/c	Unit mass (kg/m³)
1	Alumino so	55	Tezontle 1.65	277	25	50	40	385	95	45	147,909
2	CPC 40	55	Tezontle 1.65	277	236	50	40	385	93	43	1674
3	CPC 40	11	Tezontle 0.33	553	66	10	—	77	11	6	1749
4	CPC 40	11	Arenilla #4 – 0.33	553	712	10	—	77	14	65	1608
5	CPC 40	11	Arenilla #4 – 0.33	553	712	10	4	77	12	65	1406
6	CPC 40	11	Arenilla #4 – 0.33	553	712	10	2	77	12	65	149,352

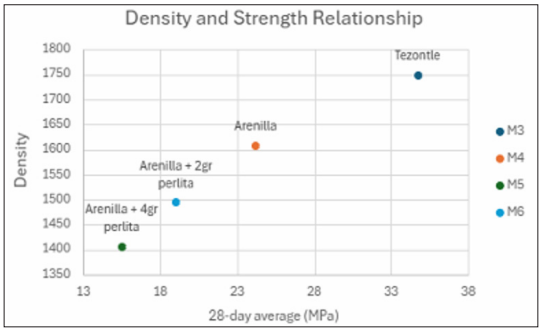
Results

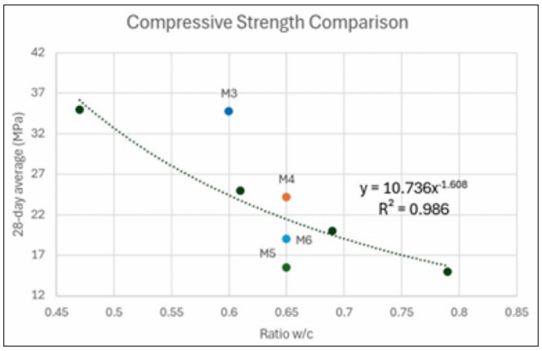
- Arenilla reduced unit weight up to 19.6%.
- All mixes included synthetic fibers to improve fracture toughness

Mix	15-day strength (MPa)	28-day average (MPa)	Ratio w/c	Unit mass (kg/m³)
3	2,474	34,755	6	1749
4	1,948	2,419	65	1608
5	2,322	15,495	65	1406
6	1,849	19,025	65	149,352



Analyses





Conclusions

- Tezontle produced the highest strength (34.75 MPa), but also the highest density (1749 kg/m³). Mixes with arenilla were lighter and reached up to 24.19 MPa.
- Perlite reduced density but lowered strength. Strength was influenced more by aggregate type than by the w/c ratio; a mix with w/c = 0.60 and tezontle exceeded the expected strength typically associated with w/c = 0.61 according to ACI standards.
- The optimal mix must balance weight, strength, and workability. Using local and recycled materials is a viable and sustainable strategy for lightweight concrete.

Acknowledgment

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2. American Concrete Institute. ACI 211.1-91: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete. 2012.