Alternative Concrete Masonry Unit

Figure 1: Concrete Masonry Unit (CMU) [1]

UGRADS
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1.0 Project Introduction

1.1 Research Goals

- Develop an insulated, dry-stacked modular block made from local waste materials (e.g small diameter timber, cinders).
- Must have an Insulation value of R-10 while meeting the minimum strength of 1900 psi based upon ASTM C90.

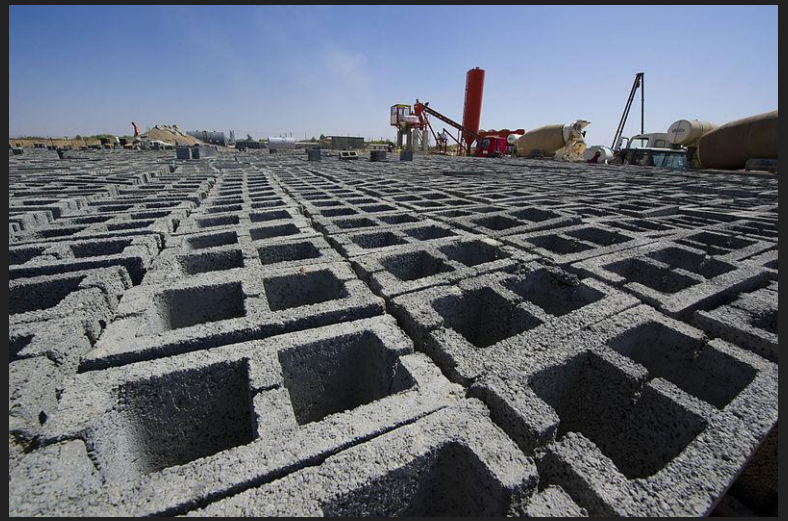

Figure 2: A collection of CMUs[2]

1.0 Project Introduction

1.2 Background Research

- Insulated modular blocks made with wood aggregate are limited.
- Not structural and simply act as formwork intended to support the hydraulic pressure of grout.
- High costs due to unavailability of necessary materials.

Figure 3: FASWALL Green Building Systems [3]

1.0 Project Introduction

1.3 Stakeholders

- Dr. Tuchscherer (client)
- Local brick manufacturing companies
- Local logging companies
- City of Flagstaff

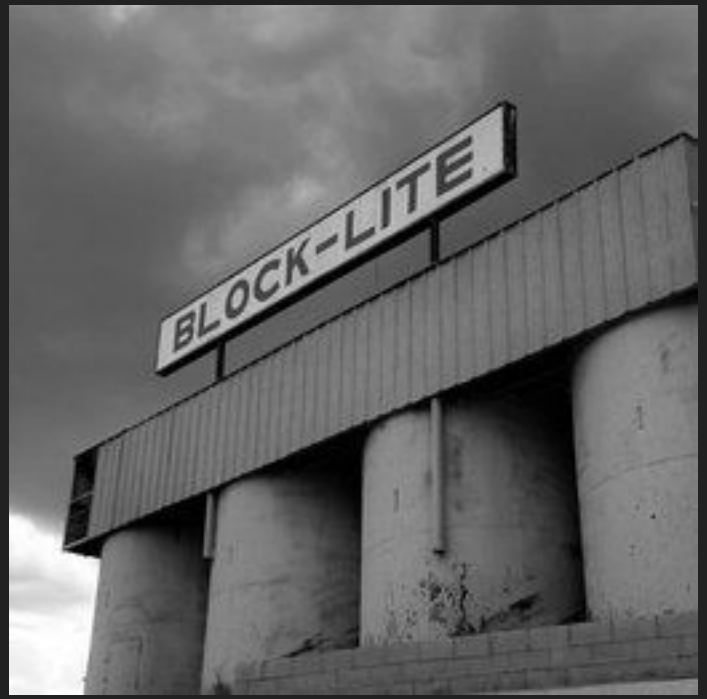

Figure 4: Block-Lite a local brick manufacturer [4]

2.0 Research Methods

2.1 Material Collection

- Cinders were collected on site at Cinder Hills OHV area located in the Coconino National Forest 13 miles northeast of downtown Flagstaff [8].
- Small diameter timber was collected from slash piles located around Mt. Elden.

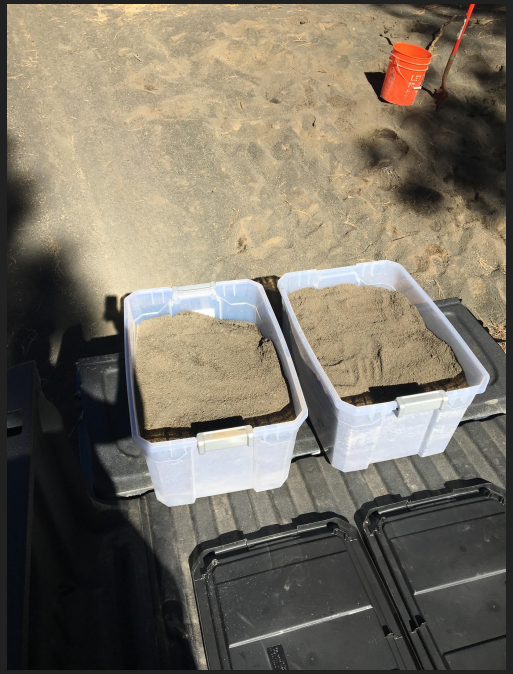

Figure 5: Collected cinder from the field [Photo taken by: Sam Carnes]

2.0 Research Methods

2.2 Small Diameter Timber Analysis

- K-X Treatment Process by FASWALL Green Building Systems.
- The K-X Treatment makes swelling, shrinking and decaying of the wood particle impossible due to mineralization [3].

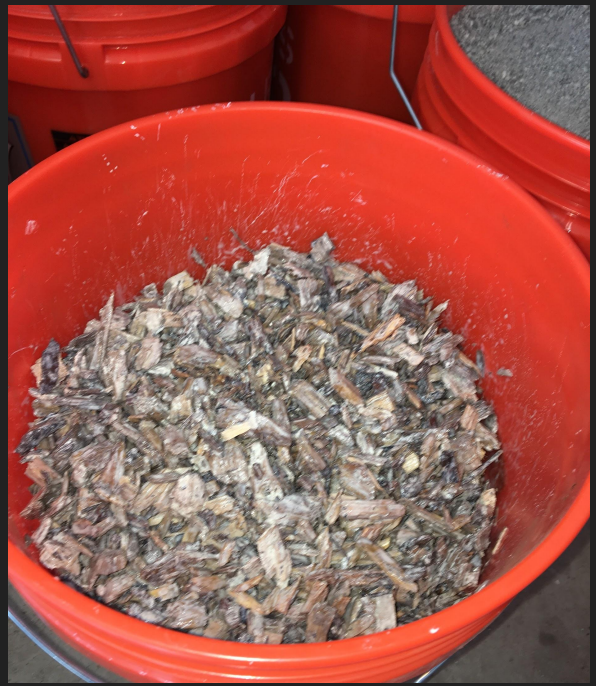

Figure 6: K-X Treated Wood Chips [Photo taken by: Sam Carnes]

2.0 Research Methods

2.2 Small Diameter Timber Analysis

- The K-X Treatment is conducted in two stages
  - First the wood chips are soaked in an aluminum-sulphate and water solution.
  - Second the surface area of the wood chips are evenly coated in kaolin powder.
- Wood chips must rest for 48 hours prior to being used in a concrete mix.

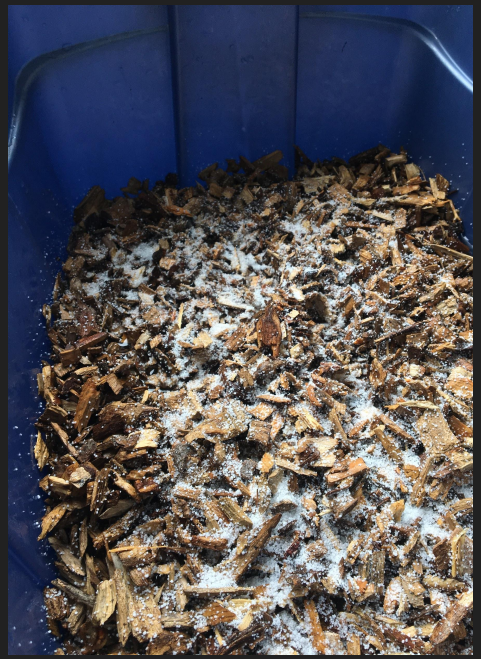

Figure 7: Wood Chips soaking in aluminum-sulphate and water solution [Photo taken by: Sam Carnes]

2.0 Research Methods

2.3 Established a Baseline

- All baseline materials were donated by Block-Lite a local brick manufacturing company.
- Baseline Mix
  - 3 parts Sand
  - 1 part Cement
  - 3 part Aggregate
    - ➢ 2 part Fine Cinder
    - ➢ 1 part Coarse Cinder
- 0.50 Water-Cement Ratio

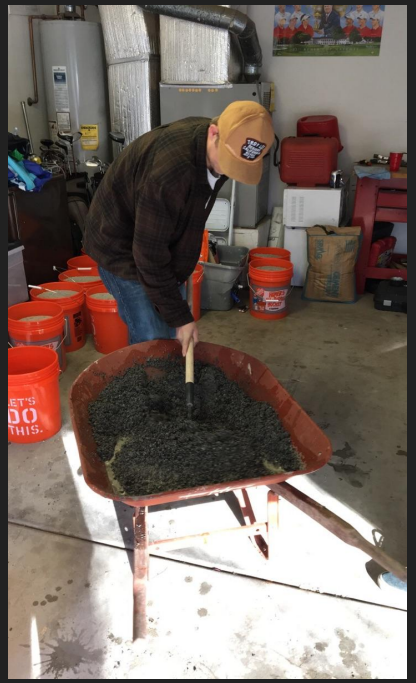

Figure 8: Teo mixing the baseline design mix [Photo taken by: Sam Carnes]

2.0 Research Methods

2.4 Mix Design

- 3 design mixes
  - 10% Wood aggregate replacement
  - 15% Wood aggregate replacement
  - 20% Wood aggregate replacement
- Wood aggregate will replace the coarse cinder following the same mix proportions as the baseline mix.

Figure 9: Mix Designs (Pictured from left to right: Mix Design #1, Mix Design #2, Mix Design #3) [Photo taken by: Teo Albers]

2.0 Research Methods

2.5 Compressive Strength Test

- ASTM C39
- The test method consists of applying a compressive axial load to molded cylinders until failure occurs [5].
- 10 test specimens per design mix.
- 40 total specimens tested.

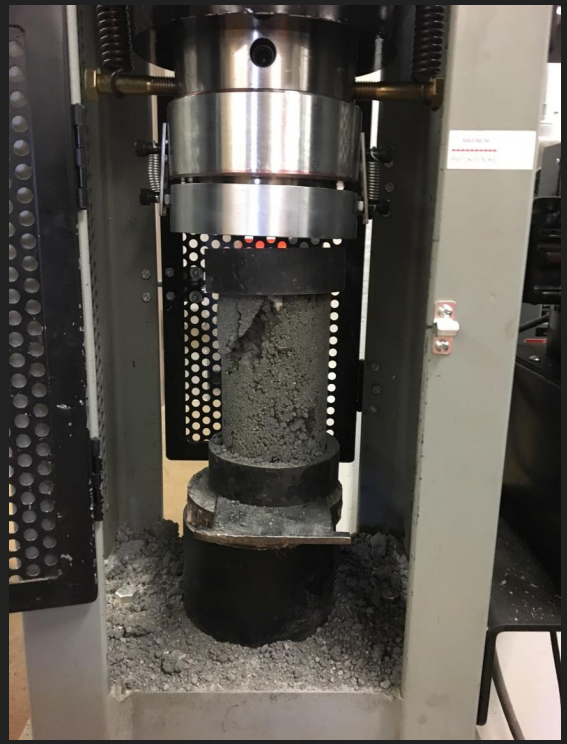

Figure 10: Compressive Strength Test [Photo taken by: Teo Albers]

2.0 Research Methods

2.6 Tensile Strength Test

- ASTM C496
- Performed by applying a diametral compressive force along the length of the specimen at a constant loading rate until specimen failure [6].
- 10 specimens per design mix.
- 40 total specimens tested.

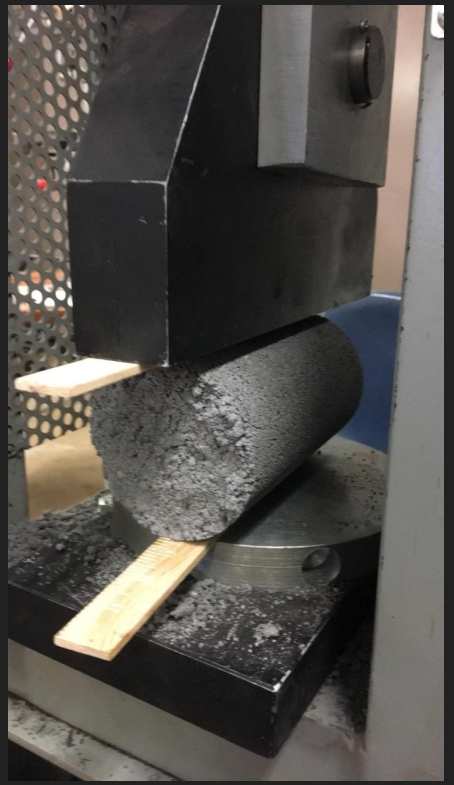

Figure 11: Tensile Strength Test [Photo taken by: Teo Albers]

2.0 Research Methods

2.7 Freeze-Thaw Test

- ASTM C666
- Alternately lowering the temperature from 4 to -18℃ and raising it from -18 to 4℃. [7]
- A total of 300 cycles completed. [7]
- The compressive strength was tested at the conclusion of the 300 cycles.

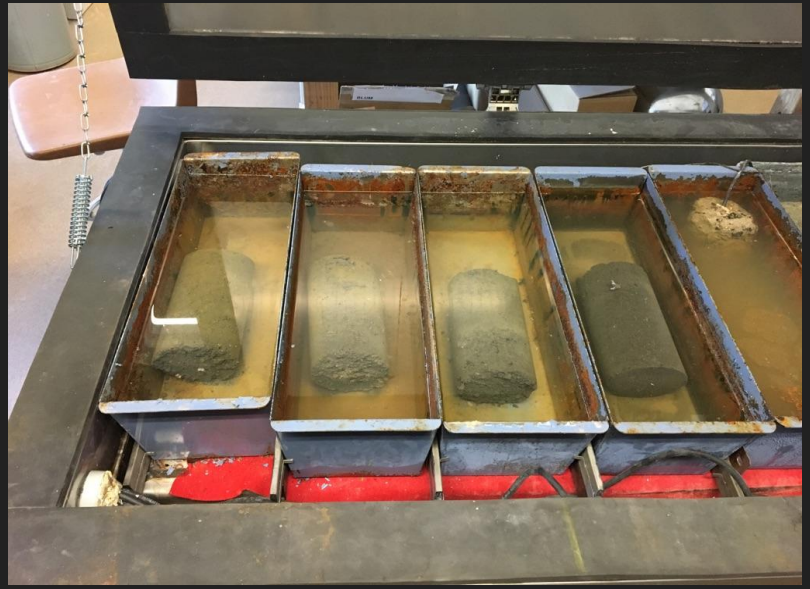

Figure 12: Freeze-Thaw Test [Photo taken by: Sam Carnes]

2.0 Research Methods

2.8 Embodied Energy Study

- Due to the CMUs comparatively high density & specific heat values, they offer highly effective thermal storage properties [9] .
- A thermal advantage that is seen by CMU over light framing systems is applicable in all climate types although the benefits of their thermal mass is more evident in warmer climates [10].

Material (per inch)	K Value	R Value
Wood	0.76	1.25
Aluminum	15.5	N/A
Vinyl	0.97	N/A
Fiberglass Batts	0.3	3..33
Rockwool	0.3	3.33
EPS	0.03	4.00
Air Space	0.7	1.43
Drywall (gypsum)	1	1.00
Cement board	1.92	.052
Sand and Gravel	1.7	0.59
Poured Concrete	3.9	0.08
CMU (hollow)	1	1
Common Brick	5	0.11
Ceramic Tile	12.5	0.08
Marble	11	0.09

Figure 13: R-values of common building materials [8]

3.0 Results & Analysis

3.1 Compressive Strength Test

Table 1: Compressive Strength Testing Results

	Density (lb/ft^3)	Pmax (lbf)	f_{cm} (psi)	% Error
ASTM C90		23876.10	1900.00	0.00
Baseline (No Replacement)	84.78	26452.21	2105.00	10.79
Mix #1 (10% Replacement)	91.72	13383.18	1065.00	43.95
Mix #2 (15% Replacement)	86.97	16084.95	1280.00	32.63
Mix #3 (20% Replacement)	87.44	11284.60	898.00	52.74

3.0 Results & Analysis

3.2 Tensile Strength Test

Table 2: Tensile Strength Testing Results

	Density (lb/ft^3)	Pmax (lbf)	T *(psi)*	% Error
ASTM C90		2388.00	190.00	0.00
Baseline (No Replacement)	85.10	2205.00	188.00	1.05
Mix #1 (10% Replacement)	90.08	1065.00	131.00	31.05
Mix #2 (15% Replacement)	85.52	1280.00	143.00	24.74
Mix #3 (20% Replacement)	85.82	898.00	120.00	36.84

3.0 Results & Analysis

3.3 Freeze-Thaw Test

Table 3: Freeze-Thaw Test Results

	Density (lb/ft^3)	Pmax (lbf)	f_{cm} (psi)	% Error
ASTM C90		23876.10	1900.00	0.00
Baseline (No Replacement)	91.80	10005.34	796.20	58.09
Mix #1 (10% Replacement)	97.12	10103.36	804.00	57.68
Mix #2 (15% Replacement)	97.23	10599.98	843.52	55.60
Mix #3 (20% Replacement)	97.86	FAIL	FAIL	FAIL

Figure 14: Freeze-Thaw Test failed specimen [Photo taken by Teo Albers]

3.0 Results & Analysis

3.4 Embodied Energy Study

Table 4: Embodied Energy Study Results

	R-Value
Baseline (No Replacement)	12.00
Mix #1 (10% Replacement)	12.81
Mix #2 (15% Replacement)	12.95
Mix #3 (20% Replacement)	13.01

4.0 Conclusion

- The compressive strength of the test specimens decreased as the percentage of wood aggregate replacement increased.
- Thermal properties of the test specimens increased as the percentage of wood aggregate replacement increased.
- Incorporating mineralized wood chips into a CMU mix has significant impacts on its strength and thermal properties.
- While the design mixes did not meet load bearing standards they could still be used as formwork.

5.0 Future Recommendations

- Further analysis of the K-X treatment
  - Minimizing the wood chips size
    - Increased bond within the concrete mix
- Using other waste materials within a concrete mix
  - Plastic

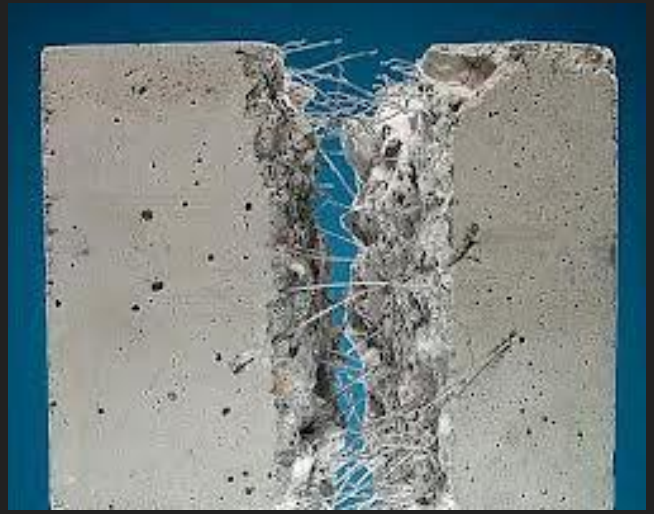

Figure 14: Concrete modular block utilizing plastic fiber reinforcement [11]

6.0 Research Schedule

Table 5: Team Schedule

Task Number	Task Name	Proposed Start Date	Proposed End Date	Actual Start Date	Actual End Date
2.1	Material Collection	8-Jan	20-Jan	8-Jan	20-Jan
2.2	Small Diameter Timber Analysis	8-Jan	20-Jan	8-Jan	24-Feb
2.3	Establish a Baseline	25-Jan	23-Mar	17-Feb	13-Apr
2.4	Mix Design	25-Jan	10-Feb	24-Feb	15-Mar
2.5	Compressive Strength Testing	11-Feb	23-Mar	16-Mar	13-Apr
2.6	Tensile Strength Testing	11-Feb	23-Mar	16-Mar	14-Apr
2.7	Freeze-Thaw Testing	11-Feb	23-Mar	16-Mar	24-Apr
2.8	Embodied Energy Study	11-Feb	23-Mar	28-Mar	20-Apr

*Red highlight represents tasks that were completed late

7.0 Staffing

Table 6: Project Staffing

	Proposed			Actual		
	Research Manager (RM)	Research Engineer (RE)	Lab Technician (LT)	Research Manager (RM)	Research Engineer (RE)	Lab Technician (LT)
Task	Time (hrs)			Time (hrs)		
2.1 Material Collection	4	16	0	4	16	0
2.2 Small Diameter Timber	8	16	8	16	32	8
2.3 Establish a Baseline	16	28	0	16	24	0
2.4 Mix Design	24	16	24	8	16	16
2.5 Compressive Strength Testing	8	16	40	8	16	24
2.6 Tensile Strength Testing	10	16	40	8	16	24
2.7 Freeze-Thaw Testing	10	30	60	8	24	40
2.8 Embodied Energy Study	8	8	0	8	16	0
Total Hours:	88	146	172	76	160	112
		Total:	406		Total:	348

8.0 Cost of Engineering Services

Table 7: Cost of Research Services

Cost of Engineering Services	Proposed				Actual			
	Personnel	Hours (hrs)	Base Pay* ($/hr)	Cost ($)	Personnel	Hours (hrs)	Base Pay* ($/hr)	Cost ($)
	RM	88	$150.00	$13,200.00	RM	76	$150.00	$11,400.00
	RE	146	$90.00	$13,140.00	RE	160	$90.00	$14,400.00
	LT	172	$60.00	$10,320.00	LT	112	$60.00	$6,720.00
			Total:	$36,660.00			Total:	$32,520.00
Equipment:			Total:	$300.00			Total:	$300.00
			Total:	$36,960.00			Total:	$32,820.00
*All base pay rates include overhead and benefits								

9.0 References

[1] “Concrete Masonary Units ,” *Fredrick Block Brick & Stone* . [Online]. Available: http://frederickblock.com/product-list/masonry-supplies/concrete-masonry-units/ened-concrete.html. [Accessed: 24-Apr-2018].

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[3] Faswall Green Building System, http://faswall.com/faswall-green-building-system/. [Accessed: 24-Apr-2017]

[4] *Block-Lite Masonary & Hardscape Products Forever* . [Online]. Available: https://www.block-lite.com/. [Accessed: 23-Apr-2018].

[5] ASTM C39 / C39M-17b, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International, West Conshohocken, PA, 2017, www.astm.org

[6] ASTM C496 / C496M-17, Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, ASTM International, West Conshohocken, PA, 2017, www.astm.org

[7] ASTM C666 / C666M-15, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing, ASTM International, West Conshohocken, PA, 2015, www.astm.org

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