Conventional Concrete with Recycled Glass

FAB Concrete Mix & Design

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Project Goal

This project is to develop and test a unique concrete mix design utilizing recycled glass and document the results.

The concrete will consist of conventional materials and also include recycled glass.

Cement Recycled Glass Powder

Fig 1

Sand Recycled Glass Coarse

Fig 2

Project Overview

- Research conventional concrete and review recycled glass additive
- Investigate and develop adequate concrete mix designs
- Check American Society for Testing and Materials (ASTM) standards
- Acquire necessary materials
- Create experimental matrix
- Revise experimental matrix
- Mixing and storing
- Testing and analysis

Recycled Glass Experimental Matrix

Materials Required per Pour								
Mix Design	Cement (lb)	Recycled Glass Powder (lb)		Sand (lb)	Recycled Glass Coarse (lb)		Water (lb)	W/C ratio
1	19.87	0%		5.56	0%		6.95	0.35
2	17.88	10%		5.56	0%		6.95	0.35
3	15.89	20%		5.56	0%		6.95	0.35
4	13.91	30%		5.56	0%		6.95	0.35
5	19.87	0%		5.01	10%		6.95	0.35
6	19.87	0%		4.45	20%		6.95	0.35
7	19.87	0%		3.89	30%		6.95	0.35
8	20.86	10%		5.84	10%		6.95	0.35
9	20.86	10%		5.19	20%		6.95	0.35
10	20.86	10%		4.54	30%		6.95	0.35
11	18.54	20%		5.84	10%		6.95	0.35
12	18.54	20%		5.19	20%		6.95	0.35
13	18.54	20%		4.54	30%		6.95	0.35
14	16.22	30%		5.84	10%		6.95	0.35
15	16.22	30%		5.19	20%		6.95	0.35
16	16.22	30%		4.54	30%		6.95	0.35

Table 1 Experimental Matrix (Original)

Recycled Glass Experimental Matrix

Materials Required per Pour								
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4	13.91	30%		5.56	0%		6.95	0.35
5	19.87	0%		5.01	10%		6.95	0.35
6	19.87	0%		4.45	20%		6.95	0.35
7	19.87	0%		3.89	30%		6.95	0.35

Table 2 Experimental Matrix (Final)

Admixtures

- Delvo – Liquid Chemical Stabilizer
  - Increases strength, compressive and flexural
  - Improves workability, increases set time
- P900 – Polymer Plasticizer
  - A mid-range water reducer, increases the strength of the concrete
  - Improves workability, increases set time
- Micro Air – Liquid Chemical Surfactant
  - An air-entraining admixture, creates tiny air bubbles in concrete
  - Used to increase resistance of freeze-thaw cycle damage

Fig 3 Admixtures: Delvo (Top Left), P900 (Right) Micro Air (Bottom Left)

Slump Test

- The slump test shows how much the concrete settles or slumps when compacted in a metal inverted cone.
- Cone Measurements
  - 4” Top diameter
  - 8” Bottom diameter
  - 12” Height of cone
- ASTM C 143 Method followed

Fig 4 True slump, shear slump and collapse slump ASTM

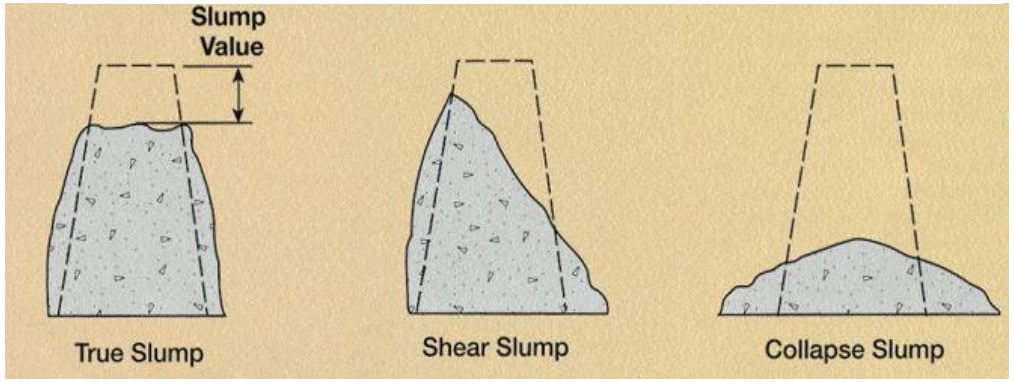

Fig 5 Post Slump Test

Slump Test Results

Degree of workability	Slump		Compacting Factor	Use of concrete considering slump
	mm	in		
Very low	0-25	0-1	0.78	Used in road making
Low	25-50	1-2	0.85	Used for foundations with light reinforcement
Medium	50-100	2-4	0.92	Manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections.
High	100-175	4-7	0.95	For sections with congested reinforcement.

Table 3 Slump Test Application *Civil Engg. Dictionary*

Experiment	Slump (in)
Control	9
10% glass powder	7
20% glass powder	4.25
30% glass powder	2.5
10% glass coarse	9
20% glass coarse	9
30% glass coarse	9

Table 4 Slump Results

The Process: Material Preparation

Fig 6 Clean Equipment/Materials

Fig 7 Sieve Aggregate

Fig 8 Weigh and Measure Concrete Constituents

The Process: Mix and Pour

Fig 9 1.25 cu ft Mixer

Fig 10 Poured Concrete

All mixing and storage methods are all based on standards from ASTM C192

Mold, Store and Cure

Fig 11 Concrete placed in mold

Fig 12 Hardening before removing mold

Fig 13 Samples curing in water

Compression Test

Fig 14 Compression Test Tinius Olsen

Fig 15 Concrete after Compression Test

The Calculation Formula

- The compression testing machine shows force in pounds, to change the force from pounds (lbs) to pounds per sq in. (psi) Equation 1 is used.

$$compression\ strength = \frac{F}{A}$$

Equation 1 Compression (psi)

F: Recorded force from compression testing machine

A: Cross-sectional area of specimen

Compression Test Results

Experiment Number	Experiment Detail	7 Day Average (psi)	28 Day Average (psi)	Standard Deviation (28 Day)
1	Control (0% glass)	6608	8557	503
2	10% glass powder	5865	8090	530
3	20% glass powder	5759	7348	1115
4	30% glass powder	5786	7772	603
5	10% glass coarse	5621	7401	239
6	20% glass coarse	5361	7215	166
7	30% glass coarse	5037	6552	256

Table 5 Compression Test Results *averages based off of three concrete cylinders per experiment

Compressive Strength Comparison

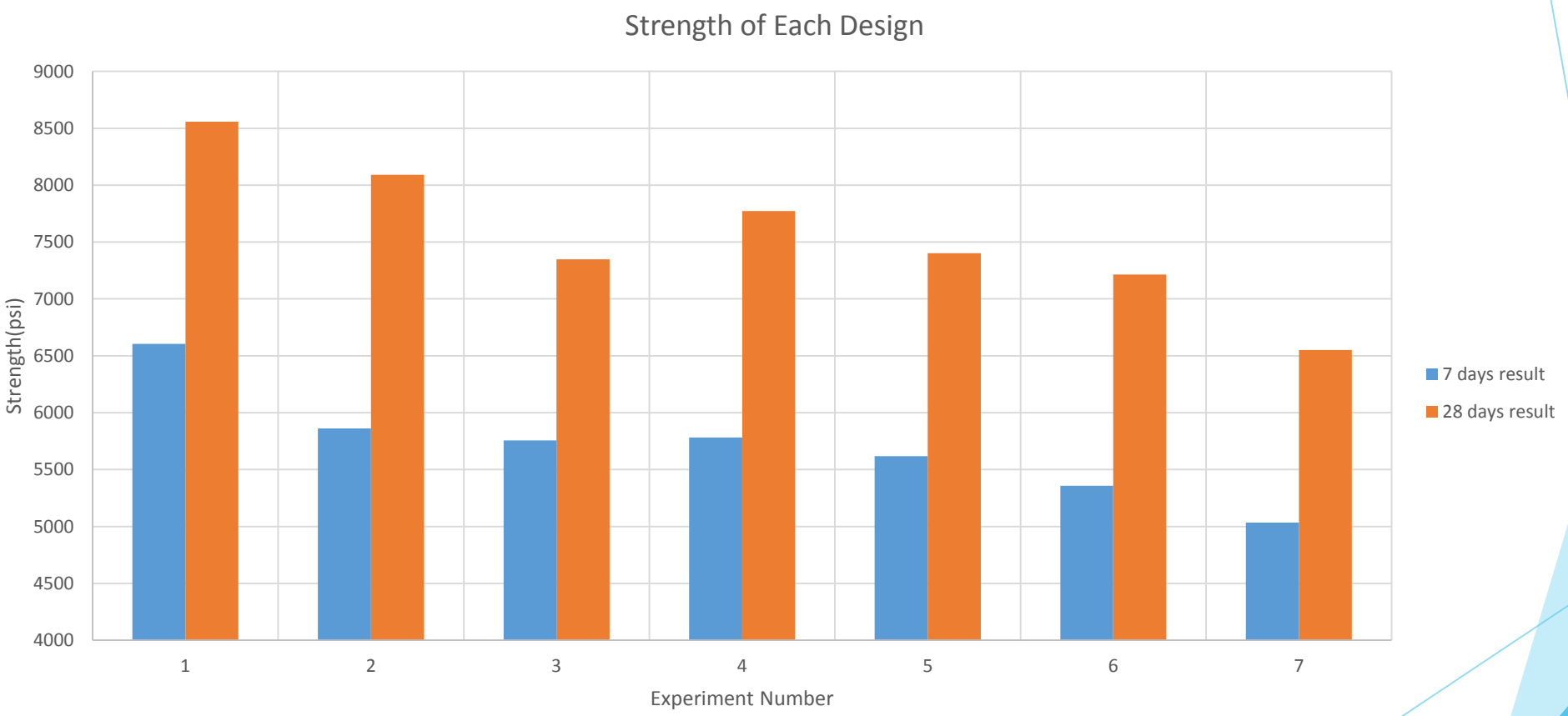

Figure 16 Compressive Strength Comparison

Compressive Strength per Curing Day

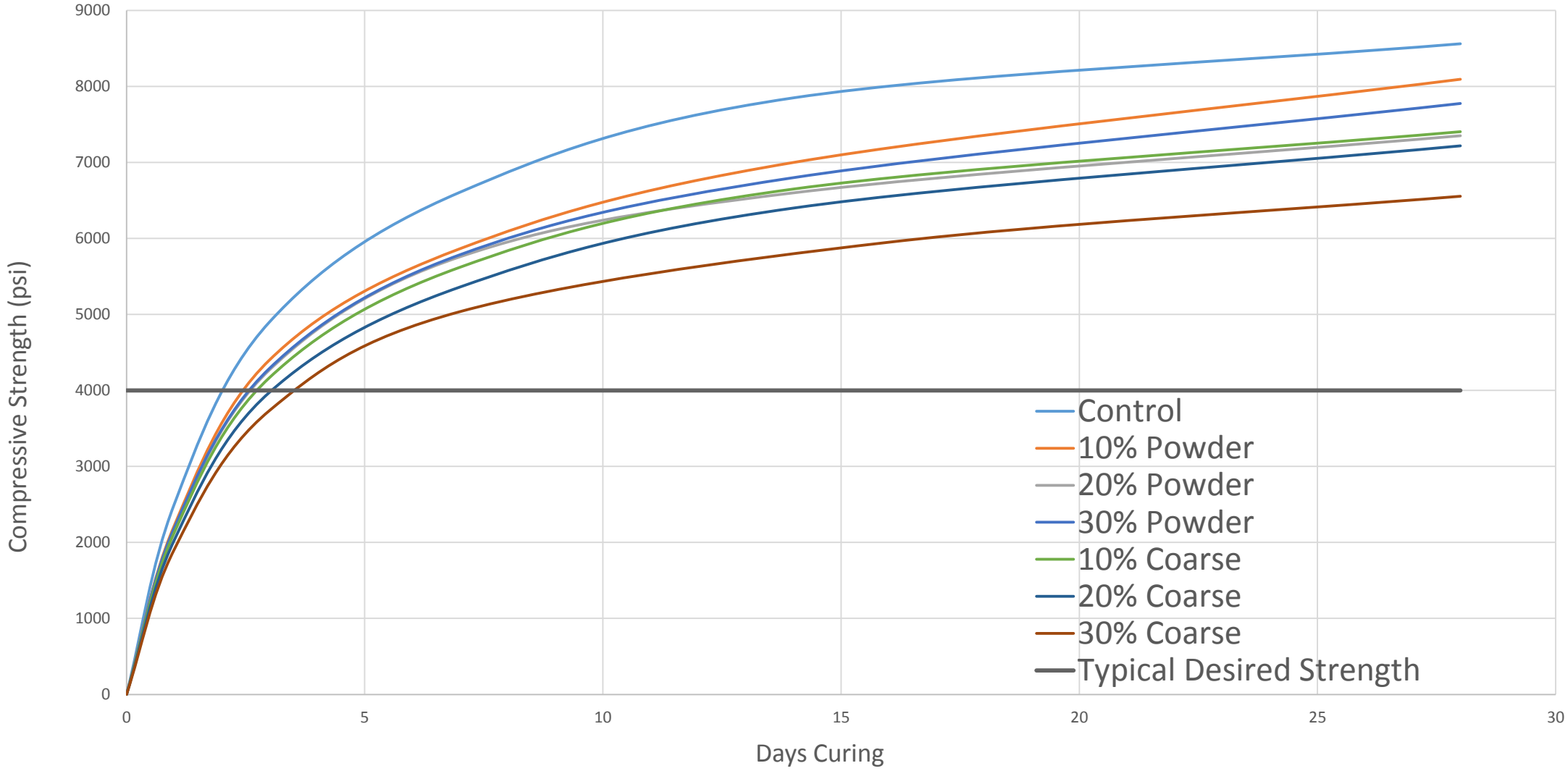

Figure 17 Compressive Strength Per Day

Materials Cost Detail

Total Cost of Materials		
Sieve Machine/ Sieves	Buy	$700
Mixer	Buy	$170
Compressive Strength Machine	60$ /hr. (Rent)	$480
Molds	2.25$ /each mold	$94.5
Cement	0.096$ /lb.	$12.21
Aggregate	0.058$ /lb.	$11.43
Sand	0.1$ /lb.	$3.56
Recycled Glass Powder	0.195$ /lb.	$2.32
Recycled Glass Coarse	0.176$ /lb.	$0.59
Total		$1474.61

Table 6 Materials Cost

Materials Cost Observation

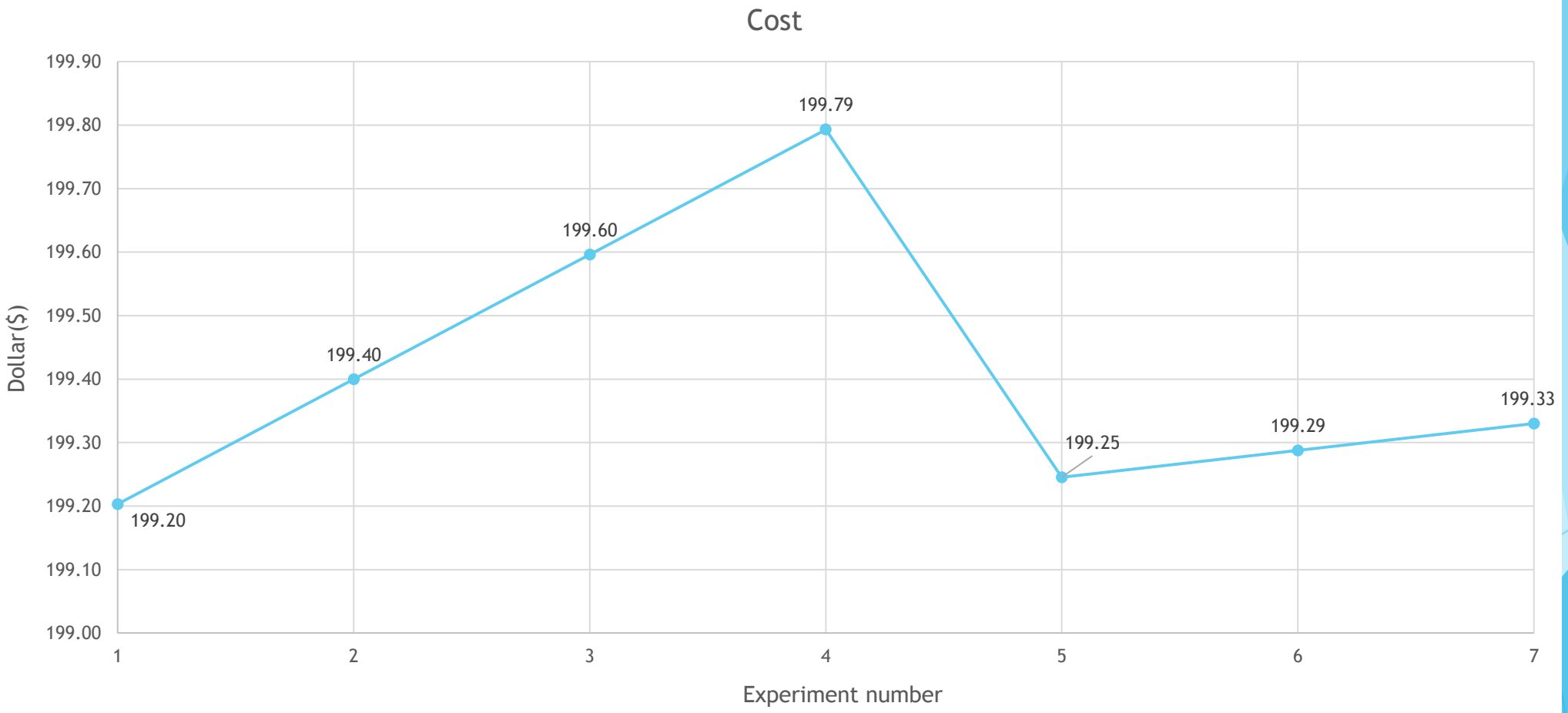

Figure 18 Cost Observation

Hours Log

Total Time Spent Working						
Major Task	Task	Hours				
		SENG	ENG	LAB	INT	AA
1.0 Research	1.1 Pavement	3	3	3	3	3
	1.2 Concrete Design	3	6	6	3	3
	1.3 Recycle glass additive	3	3	6	3	3
	1.4 Standards and Codes	3	3	0	6	6
2.0 Acquire Materials	2.1 Typical Concrete Materials	3	0	0	6	0
	2.2 Recycled Glass Powder	0	0	0	0	0
	2.3 Concrete Support Materials	0	0	0	0	0
3.0 Design and Experimentation	3.1 Experimental Design	0	0	11	0	0
	3.2 Prepare for mixing	0	0	20	0	0
	3.3 Concrete sample pouring	0	0	21	0	0
	3.4 Testing and Analysis	0	0	12	11	0
4.0 Project Management	4.1 Project Schedule	3	8	0	0	0
	4.2 50% Design	8	10	3	3	9
	4.3 Final Design Report	15	20	5	15	20
	4.4 Final Presentation	6	6	5	6	5
	4.5 Website	4	8	0	6	14
	Hours per Worker	51	67	92	62	63
	Total Hours	335				

Table 7 Hours Log

Total Cost

Total Cost of Project					
Type of Worker	SENG	ENG	LAB	INT	AA
Hours per Worker	39	55	88	49	48
Rate$/hour	148	75	57	27	50
Cost for position	5772	4125	5016	1323	2400
Total Labor Cost	**$18,635**				
Total Equipment Cost	**$1,475**				
Total Project Price	**$20,110**				

Table 8 Total Project Cost

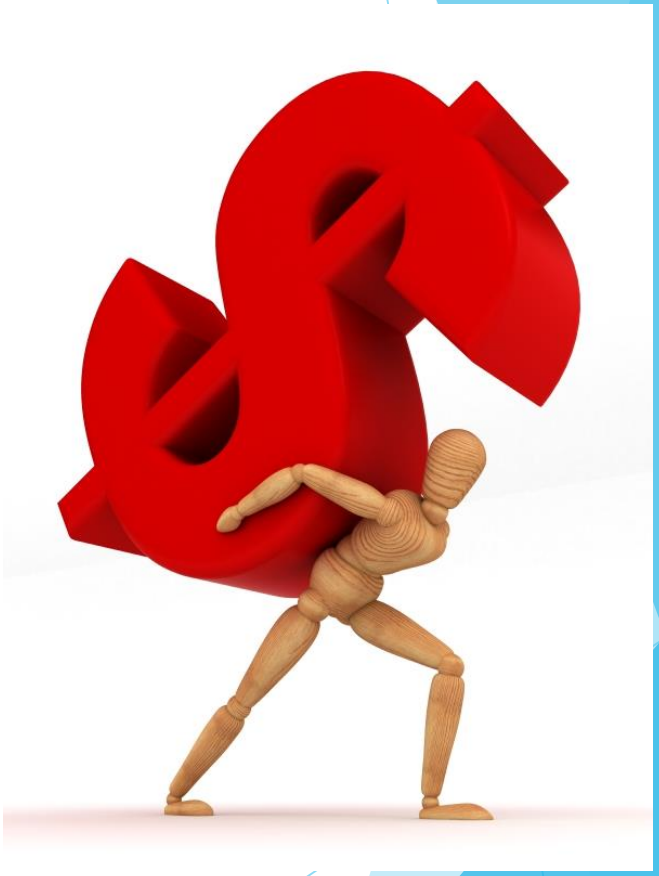

Figure 19

Recommendations

- Create samples to be broken periodically through the 28 day curing process
- Collect data on how recycled glass concrete reacts in a long term analyses
- Continue research and produce the designs which have not been done yet
- Develop relationship to the amount of powder and coarse glass to strength

Figure 20 Concrete Cylinder

Conclusion

- Glass aggregate is an effective alternative to traditional mixing materials
- Recycled glass concrete can have a compression strength over 4000 psi, a traditional number used in calculations
- Recycled glass powder concrete cost slightly higher than conventional concrete
- Research needs to continue to develop concrete that can be used in structural applications

Questions?

ASTM Standards

ASTM STANDARDS	
C 31-00	Standard Practice for Making and Curing Concrete Test Specimens in the Field
C 33-01	Standard Specification for Concrete Aggregates
C 39-01	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 125-00	Standard Terminology Relating to Concrete and Concrete Aggregates
C 136-01	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
C 143-00	Standard Test Method for Slump of Hydraulic Cement Concrete
C 150-00	Standard Specification for Portland Cement
C 172-99	Standard Practice for Sampling Freshly Mixed Concrete
C 192-00	Standards for Mixing and Storing

Table 9 Considered ASTM Standards