2016 National Bowling Ball Test Evaluation and Competition Points Assignn

Poster Points Summary Sheet

	University Name	Team Name	Average Points 100	Entry Rank	Poster Winners
1	Universidad San Francisco de Quito	**USFQA**	72.10	10	-
2	Universidad San Francisco de Quito	**USFQB**	65.10	15	-
3	Universidad Autonama de Nuevo Leon	**UANLB**	77.50	1	1st Place
4	Facultad de Estudios Superiores Aragon UNAM	**PUMAA**	60.10	17	-
5	Facultad de Estudios Superiores Aragon UNAM	**PUMAB**	54.00	29	-
6	University of Missouri-Kansas City	**KCROO**	59.40	20	-
7	Arizona State University	**DEVIL**	57.10	25	-
8	University of Wisconsin-Platteville	**PLATT**	72.00	11	-
9	British Columbia Institute of Technology	**BCITA**	49.50	31	-
10	British Columbia Institute of Technology	**BCITB**	8.30	35	-
11	Florida International University	**OHLSC**	76.90	4	-
12	Universidad Autonoma de Nuevo Leon	**UANLA**	67.20	14	-
13	University of Houston-Downtown	**UHDDA**	0.00	37	-
14	Universidad Central del Ecuador	**UCEPV**	74.50	6	-
15	Universidad Central del Ecuador	**LEANX**	59.30	21	-
16	Polytechmic University of Puerto Rico	**PUOPR**	49.10	32	-
17	Fundação Educacional Inaciana Padre Sabóia de Medeiros	**FEIBR**	30.50	34	-
18	Dhaanish Ahmed College of Engineering	**SNRKF**	0.00	37	-
19	University of North Florida	**UNFCE**	68.90	13	-
20	University of Puerto Rico, Mayaguez Campus	**UPRMX**	77.20	3	3rd Place
21	University of Purerto Rico, Mayaguez Campus	**UPRMY**	69.40	12	-
24	University of Missouri-Kansas City	**UMKCS**	64.30	16	-
25	Instituto Tecnologico de La Paz	**ITNDM**	0.00	37	-
26	Instituto Tecnologico de La Paz	**ITLPA**	55.00	28	-
29	San Jose State University	**SJSUT**	77.30	2	2nd Place
30	Faculty of Engineering Cairo University	**Tyche**	0.00	37	-
31	Universidad Nacional De Ingenieria	**unipl**	60.00	18	-
32	University of South Carolina	**STROM**	34.20	33	-
34	University of Minnesota Duluth	**UMNDL**	7.90	36	-
36	University of Illinois at Urbana-Champaign	**UIUCc**	72.30	9	-
37	University of Southern Indiana	**QWERT**	0.00	37	-
38	Universidad Rafael Landivar Quetzaltenango	**URLXE**	57.50	24	-
40	Polytechnic University of Purerto Rico	**PUPUR**	51.40	30	-
43	Embry-Riddle Aeronautical University	**ERNIE**	60.00	18	-
44	Valparaiso University	**VALPO**	73.80	7	-
45	Purdue University Calumet	**ESCBB**	57.10	25	-
46	Southern Illinois University - Edwardsville	**SIUEA**	75.70	5	-
48	Missouri University of Technology	**MSTAA**	0.00	37	-
49	Missouri Universtiy of Technology	**MSTBB**	0.00	37	-
50	Pittsburg State	**PITT1**	57.10	25	-
51	North Carolina State University	**NCSUR**	59.00	23	-
52	North Carolina State University	**NCSUW**	59.30	21	-
53	Auburn University	**AUBIE**	73.60	8	-
55	Texas A&M	**AGGIE**	0.00	37	-
56	City College of New York	**CCNYA**	0.00	37	-
57	New Jersey Institute of Technology	**NJITX**	0.00	37	-


SPEAKER
STUDENT

UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN

FRC Bowling Ball

INTRODUCTION

Fiber Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Concrete reinforced with fibres (which are usually steel, glass or "plastic" fibres) is less expensive than hand-tied rebar, while still increasing the tensile strength many times.

OBJECTIVES

- Determine the proportions in order to produce concrete mixture that is lightweight and fiber reinforced which requires, strength, workability, and to be as economically as possible.
- Experiment with fiber dosage to improve the mechanical properties of the concrete bowling ball.
- Produce a concrete sphere with the specified properties.

MATERIALS

STYROFOAM

Expanded polyestirene is used to obtain an aproximate weigth 5.5 kg and to reduce the cost of the mixture.

BOROSILICATE GLASS POWDER

Glass powder is used as a filer and supplementary cementitious material in order to reduce cement dosage and reduce the carbon footprint.

SILICA FUME

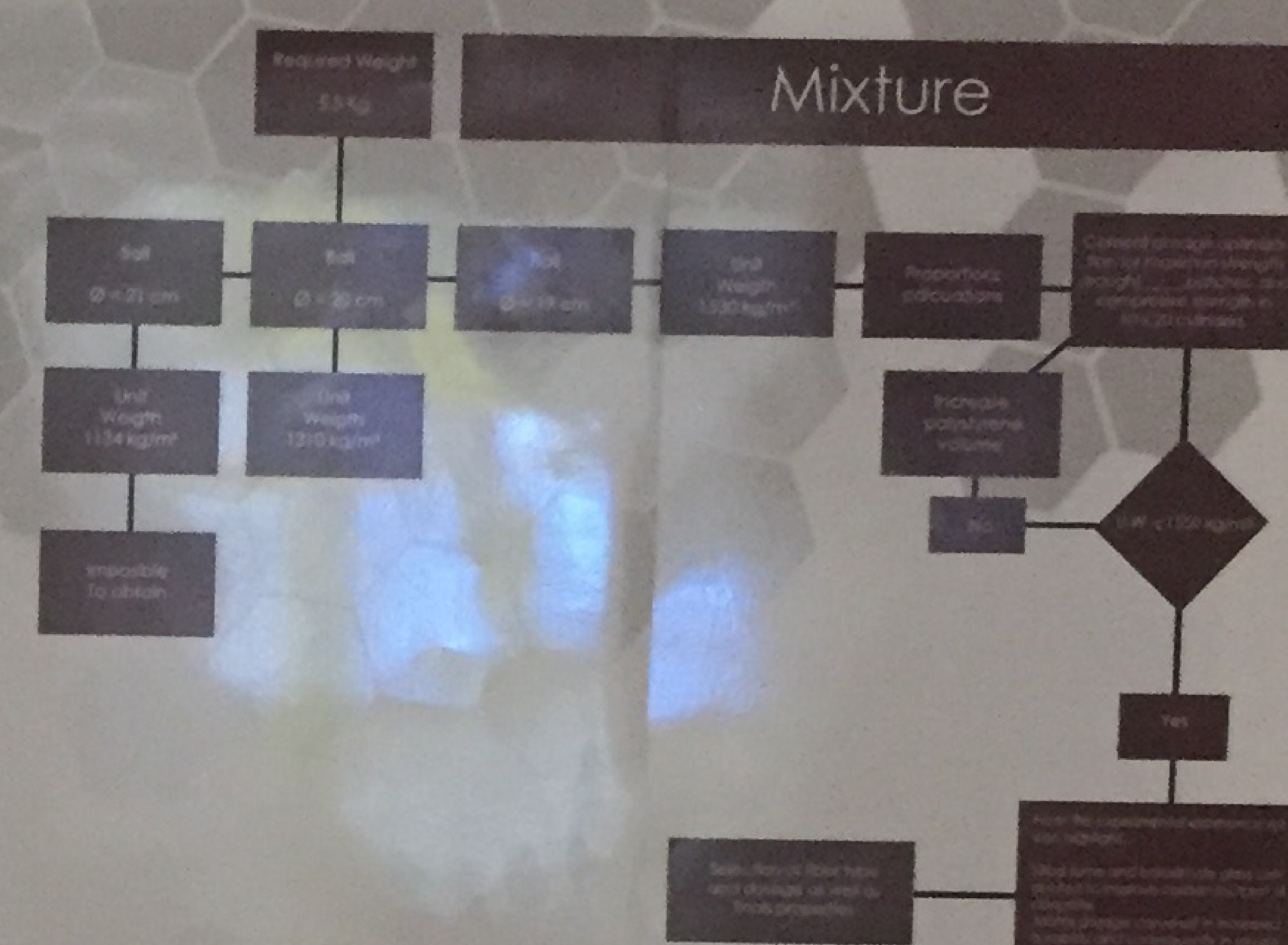
With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

LIMESTONE SAND

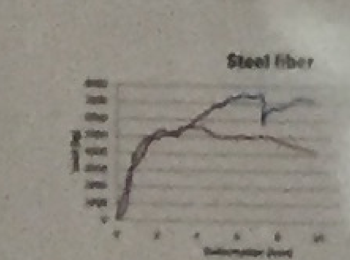
Lime stone is a regional aggregate in Monterrey Mexico, making it the most economic option.

POLICARBOXIALTE SUPERPLASTICIZER

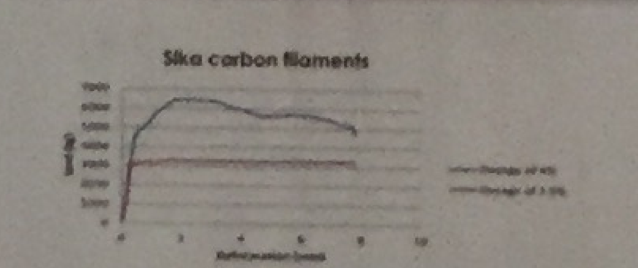
To reduce water and water/binder ratio, as well as to improve strenght, matrix densificacion and cement dosage.



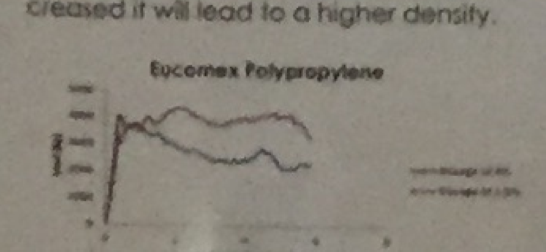
FIBER BEHAVIOR



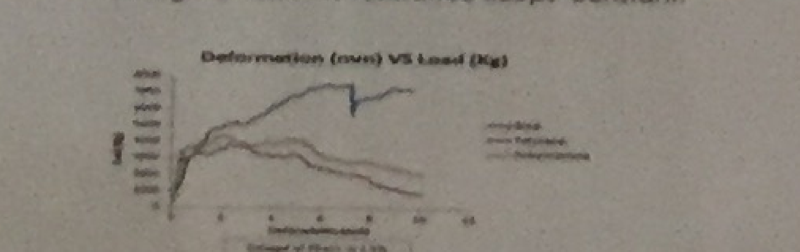
The percentage of fibers added is less than the others due to its workability, at 2% it is deficient. If the dosification is increased it will lead to a higher density.



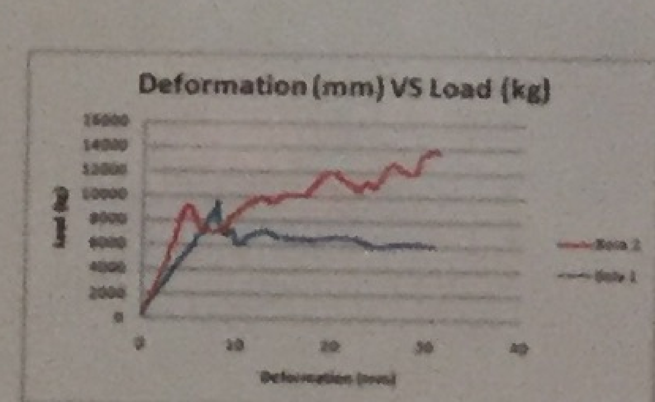
The strength that this fiber provides is considerably greater at higher dosage, however, dosage at 1.5% the resistance keeps constant.



High dosages of Polypropylene fiber weekens the strenght of the mixture.



In order to manufacture the bowling ball carbon, steel and different types of polypropylene fibers were combined. If only the steel fibers are added to the mixture, it gains streght, however, it has no workability and a very high density. Therefore, the polypropylene fibers and tufstrand were used to increase the workability and a provide a more suitable density.



In ball 2, styrofoam beads with a diameter of 2mm were used. In ball 1, beads with a diameter of 4.5mm were used. The ball with smaller styrofoam particles reacted better with the fibers. As we can see on the graph, the ball with larger Styrofoam beads remained constant while the one with smaller beads increased the load resistance.

Dosage:
The percentage of Steel fiber was 0.52% due to the results of poor workability and to the weight of the ball. The percentage of polypropylene fibers was 3% higher than the percentage of steel because of its workability and did not make the ball heavier. The percentage of the Tuf-Strand fibers was 1.5% because if a higher percentage is used, the fibers will not distribute equally through out the mixture,it also helps to achive a smather finishing. The percentage of carbon fiber was 0.24% because it tends to eliminate the workability, so it needs to be added in small dosages. Carbon fiber comes under the very high modulus of elasticity and flexural strength.

MANUFACTURING PROCESS

Cementitious materials are mixed. Reaction water is added and materials are mixed again. Superplastifier is then added.

Absortion water is added to the aggregate.

The cementitious material, aggregate and styrofoam spheres are mixed.

Fibers are added to the mixture

The mold is filled in layers and compacted with a Tamping Rod and a vibrating table.

24 hours later the ball is unmolded

GUIDANCE AND SUGGESTIONS FOR FURTHER STUDY:

1. The casting should be done more carefully in order to have a better finishing surface.
2. Try several sequences for material dosages during mixture.
3. Search for other lightweight material that additionally to its impact in weight, can provide strength to the composite.
4. Improve the granulometry selected for this materials.
5. Consider new trends in fiber materials.
6. Implement a higher control to decrease standard errors and deviations.

ECONOMY

- Silica fume and borosilicate glass were added.
- Use of light weight ingredient and industrial by-products such as the borosilicate glass can reduce the carbon footprint and material cost.
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- Matrix densification can result in increased durability and consequently in service life economy.

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FRC Bowling Ball Competition

aci SJSU Student Chapter

Objective

Design a fiber-reinforced concrete ball to satisfy the following criteria:

- Mass (5.5 kg maximum), Diameter Consistency (200 mm ±15 mm)
- Maximum Load to Deformation (predict the force required to deform 25 mm)
- Toughness Load (highest deformation before failure)

Design Considerations

Finishability, workability and unit weight were factors considered when designing the bowling ball.

In order to achieve good workability and finishability, a superplasticizer and a viscosity modifying admixtures were utilized. W/CM ratio was kept at 0.5.

A target unit weight of 1250 kg/m³ was set based on the desired mass. Poraver aggregates were utilized.

Materials

Poraver Aggregates

0.1-0.3 mm | 0.25-0.5 mm | 0.5-1.0 mm | 1.0-2.0 mm

Cementitious | Fiber | Filler

Type II | VCAS | SLAG | Fibermesh 150 | Styrofoam

Fiber Selection and Justification

Fibermesh 150 was used as based on the following characteristics:

- Resistance against impact and shattering forces.
- Compatible with various cementitious material and admixtures.
- Good finishability.

Please scan for the Fibermesh 150 Product Data Sheet

Experimental Trials

Three mix designs were tested. Summary as follows:

1. The density of the first mix was below the target unit weight (1250 kg/m³) and had poor compaction.
2. The ratio of the 1-2 mm Poraver coarser aggregate to the 0.1-0.3 mm finer aggregate particles was decreased in the second mix to improve unit weight. The compaction method was also modified.
3. Sand was introduced to the third mix design to increase unit weight. Sand didn't bond correctly making it unacceptable.

The second mix was selected:
Mass 3.9 kg, Diameter 200 mm, Resists a 45 kN load before deforming 25 mm.

Selected Mix

Poraver Aggregate	Amount	Units
0.1-0.3 mm	277.2	grams
0.25-0.5 mm	406.6	grams
0.5-1.0 mm	462	grams
1-2 mm	702.2	grams
Cementitious	**Amount**	**Units**
Type II Cement	882	grams
Vitrified Calcium Alumino Silicate (VCAS)	504	grams
SLAG Cement	1134	grams
Fiber Type	**Amount**	**Units**
Fibermesh 150	50.8	grams
Filler	**Amount**	**Units**
Styrofoam	6.7	grams
Liquid	**Amount**	**Units**
Water	1259	mL
Admixtures	**Amount**	**Units**
HRWR Superplasticizer (Glenium 7290)	5.8	mL
Viscosity Modifying Additive (VMA 362)	5.8	mL
Air Entrainment (AE 90)	24.6	mL

W/CM Ratio	0.5
Unit Weight (kg/m³)	900

Manufacturing Process

The cementitious material, aggregate, admixtures, and one-fourth of the water were mixed for five minutes in a bowl mixer at 30 rpm.

Fibermesh 150 and the remaining water were added slowly and mixed for additional three minutes.

The concrete was placed in a 203 mm diameter half-sphere mold. The concrete was placed in three layers. Each layer was vibrated for half a minute and compacted 15 times using standard tamping rod. The other half sphere mold was placed on top and a hole was cut to insert the remaining concrete.

The bowling ball was cured in the lab for 24 hours (21° C).

The mold was removed and the bowling ball was placed in a 100% humidity curing room for an additional 27 days.

The ball was sanded, painted ready for bowling.

Conclusion

An attempt was made to construct a concrete bowling ball to meet given design specifications.

The Final product has a Mass 3.9 kg, Diameter 200 mm, and can resists approximately a 45 kN load before deforming 25 mm.

Future Suggested Research

Conduct tests comparing Fibermesh 150 to other types of fiber to improve ball load capacity to allowable deformation. Reduce fiber-content to improve ball finishability and use higher density aggregates to increase unit weight.

Final Product

Team Picture

Team Information

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Use of Bamboo and Steel in Fiber Reinforced Concrete

Abstract

In Fiber Reinforced Concrete, small fibers are dispersed and distributed randomly in the concrete during mixing. The fibers improve important concrete properties, specially tensile strength and cracking resistance. Different materials including, cement, metakaolin, limestone powder, expanded glass, superplasticizer, water, steel, and bamboo fibers were used to create a ball having restrictions in weight, toughness and deformation. An iterative procedure was used to arrive at a right mix that comply with this restrictions.

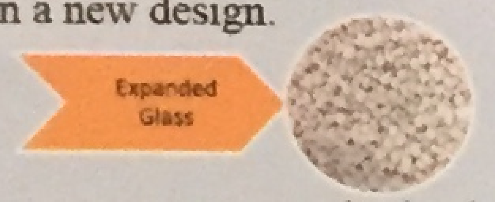
Objectives

1. To design and construct a fiber reinforced concrete bowling ball. [1]
2. To achieve a maximum weight of 5.5kg in a sphere with a diameter not larger than 200mm ± 15mm.
3. To develop a ball perfectly spherical
4. To create a mixture that provides the ball the ability to deform while exhibiting high resistance when force is applied.
5. To study and find the necessary materials in order to achieve the desired mixture.

Manufacturing Process

The manufacturing process was iterative because of the different constraints imposed in the objectives. The breach of one of the objectives led to a regression in the procedure.

Initially, a fiber glass spherical mold was built with a 198mm diameter to comply with the competition requirements. After this, the first challenge was to obtain the correct mass of the ball. To accomplish this, a compaction and accommodation method was implemented complying the ASTM C192.[2] If the mass exceeded 5.5 kg, expanded glass was added to the mixture resulting in a new design.



After the correct mass was obtained, deformation was considered. For deformation, different types of fiber, such as steel and bamboo, were analyzed and monitored by varying proportions and dimensions. Different mixtures with variations in the size and type of the fiber were incorporated without compromising workability and ductility.

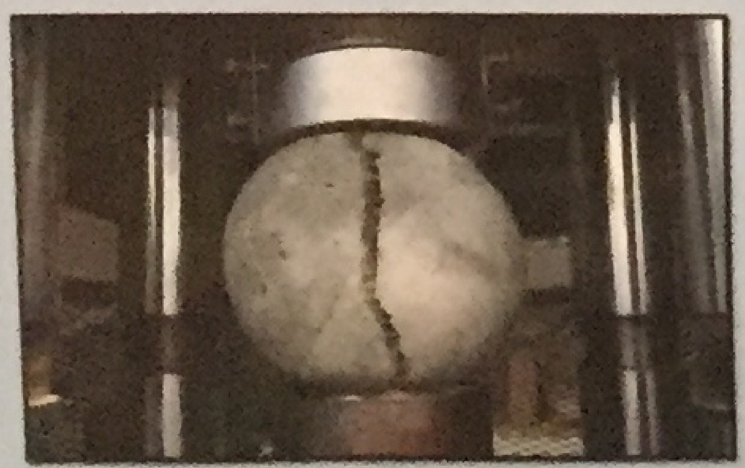


Figure 1: Specimen under deformation test

When the new mixture comply with the required deformation as shown in Figure 1, the next property, toughness, was pursued. To improve the toughness of the mixture, pouzzolan materials were added. The goal was achieved when all the challenges were overcome. If not a new mixture was designed. This iterative process is shown in the Figure 2.

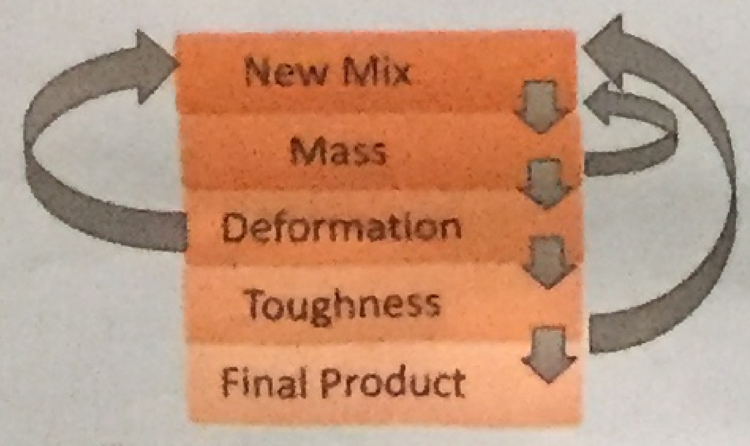


Figure 2: Mixture qualification chart

Mixture Design

Preliminary mixtures, were cast, cured and tested at 24 hours and 7 days. Six 2" by 4" cylinders were obtained from the mixture after the ball mold was filled. The addition of expanded glass was a key element for achieving the desired mass. In order to achieve the required mass of 5.5kg, replacement of the total volume by 30-50% of expanded glass was necessary. After testing, it was noticed that the addition of expanded glass reduced concrete strength in both tension and compression. In order to minimize the effect of strength loss, metakaolin was added. Figure 3 shows that metakaolin addition to the mix enhances the tensile and compressive strength. With metakaolin strength that was usually obtained after 7 days of curing are now obtained in 24 hours without curing.

Also, limestone powder was used as a substitute for Portland cement. Preliminary mixtures showed that the properties of limestone powder increased the early strength of concrete. Afterwards bamboo fibers were included to the mix since it provides great deformation capabilities. So they were added to the mixture because it provided a fast deformation rate that diminished the final toughness capacity of the ball. Using bamboo fiber alone, deformations of 43.8mm were achieved. In order to increase toughness capacity of the ball, steel fiber was added. Addition of steel fibers increased the toughness resistance of the ball by 63.4% as shown in Figure 4. Finally a superplasticizer was also added to improve workability since the fibers reduced it.

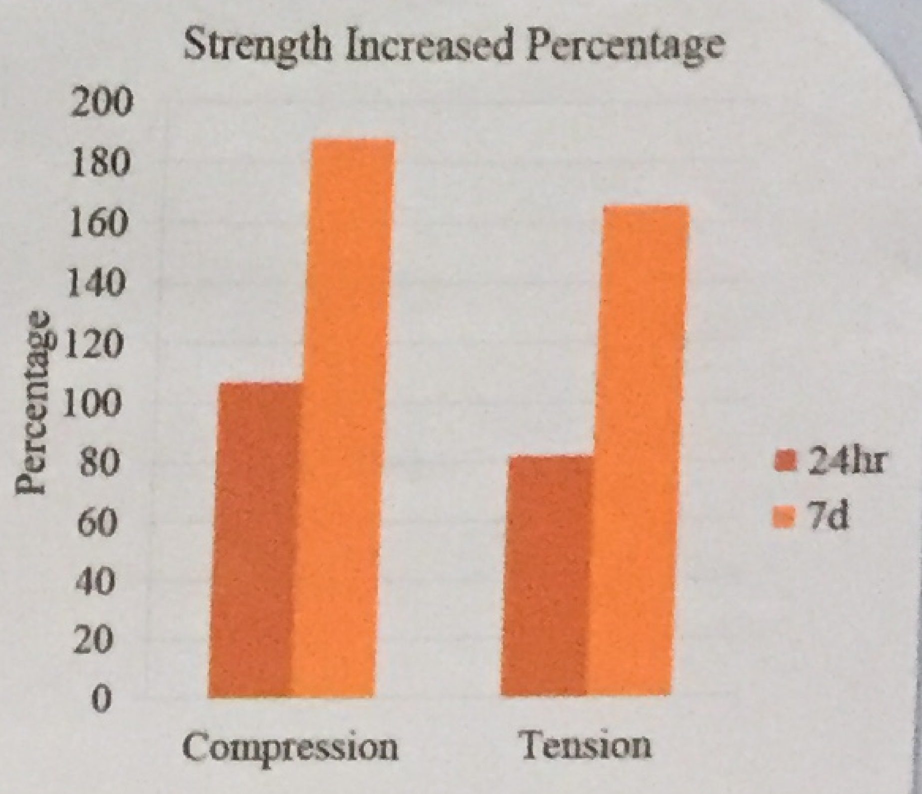


Figure 3: Effect of metakaolin addition

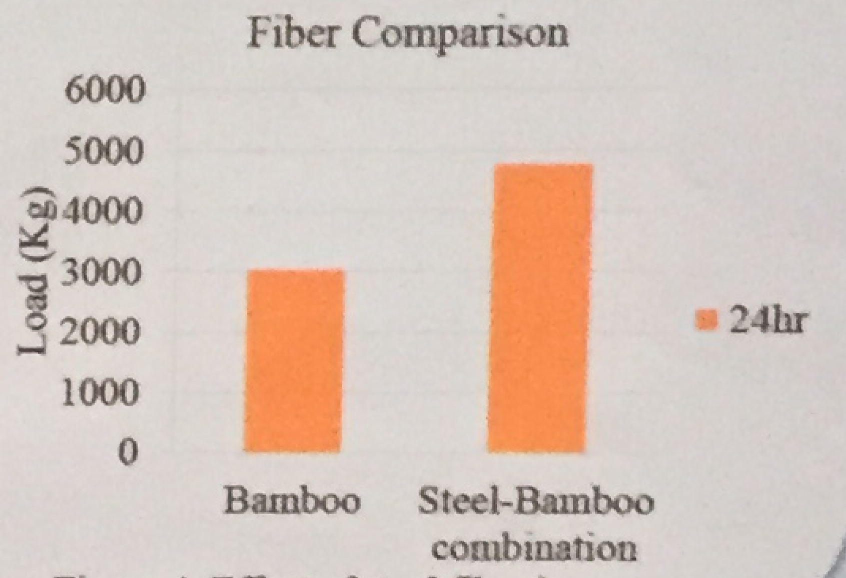


Figure 4: Effect of steel fiber in toughness capacity

Results

After testing many possible combinations and methods of placing and compaction, the final mixture design was:

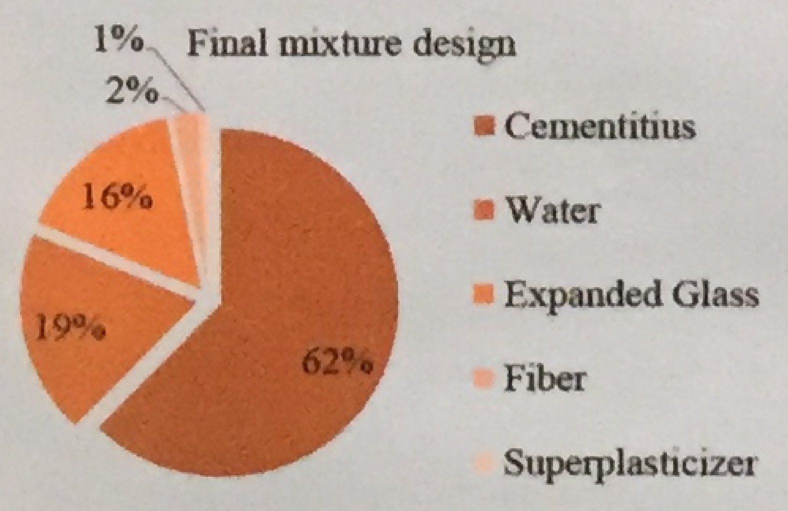


Figure 5: Mix design chart by mass

As shown in Figure 5, the mixture finally had the following proportions by mass: cementitious materials is 62% and included: 47.5% Type 1 cement, 5.5% limestone powder and 9.3% metakaolin. Expanded glass was incorporated in two standard granulometric sizes, 9.3% of 2-4mm and 6.2% of 1-2mm. Fiber composition is 1.4% steel fiber and 0.9% bamboo.

Conclusion

Extensive testing provided enough information to determine the best fiber proportions with the desired workability. Adjustments were made for the final proportions of the mix. Reductions by 48.2% by mass in bamboo fiber along with an increase of 57.3% by mass of steel fiber provided better deformation capacity to the ball. Lastly, the analysis of the final product reveals that team met the initial objectives.

Future Work

Engineering should be always advancing. In a near future, optimization of mixture design will be addressed. Trial batches will be done to add colloidal nano-silica in order to improve the strength in transition zones. Admixtures as viscosity modifiers will be part of the study. This admixture will improve the workability of mix along with the colocation and compaction process inside non-conventional formwork.

Special focus to the behavior of the bamboo fiber will be placed. Being bamboo an organic compound, its mechanical properties can decrease with the pass of time. Investigation focused in the degradation of the bamboo fiber in concrete will be executed.

This future work will be addressed step by step in order to obtain useful data that can be used to usher in a new era of stronger, more durable and eco-friendly construction.

References

1- FRC Bowling Ball Competition Rules- American Concrete Institute (ACI). Web <https://www.concrete.org/Students/studentcompetitions/frcbowlingballcompetition.aspx> (Jan.20, 2016)

2- ASTM C192 / C192M-15, Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory, ASTM International, West Conshohocken, PA, 2015, <www.astm.org> (Jan.29, 2016)

UPRM-X

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