FLOATING CONCRETE

Using Perlite Aggregate

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Floating concrete

Team No. 1
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INTRODUCTION

The use of Lightweight concrete (LWC) has been a feature in the construction industry for centuries, but like other material the expectations of the performance have raised and now we are expecting a consistent, reliable material and predictable characteristics. Lightweight concretes can either be light weight aggregate concrete, foamed concrete or autoclaved aeriated concrete.
In this project we are using lightweight aggregate concrete i.e. produced using amorphous volcanic glass called Perlite. The perlite aggregate has a wide range of uses generally due to its properties of extremely low bulk density, high brightness, high absorption, low thermal and acoustical conductivity and non-flammability. Owing to its thermal or acoustic insulation, light weight and fire resistance, perlite aggregate is generally used in construction application, especially as concrete and mortar.

Objective:

The main object of this project is to experimentally explore the optimal design of light weight aggregate concrete, considering its compressive strength and density. The objective is achieved by casting five different trial batches of 2-in cube lightweight concrete specimens and compressive strength is determined at 28-days.

DESIGN APPROACH

Since there are no ASTM standards and pre-defined mix ratios for light weight concrete using perlite to attain a specific compressive strength, we used trial and error approach for our project.

Design approach for Trial-1

For our first trial mix, we wanted to know the difference between the strength of normal M20 concrete and the concrete made with the same ratio (1:1.5:3) where perlite was used as the coarse aggregate. Using Table 10.3 from Concrete M.Y.D textbook, selected water cement ratio for 20 MPa non-entrained concrete is 0.69.
Water cement ratio used for trial 1 = 0.56*

*- Refer discussion
[1], [2], [3] – Refer references

Unit weights of materials:

Density of Perlite[2] =8.11 lb/ft^3
Density of Cement =195 lb/ft^3
Density of fine Aggregate[3] =100 lb/ft^3

Five different trials for a specific mix proportions were prepared and casted in a 2 x 2 x 2 in^3 mould, to find the best compressive strength and lightest concrete mix design. A typical mix design of the same is shown in Table 1.

Table 1: Mix design of Trial 1

	Density(pcf)	Mix ratio	Volume (ft^3)	Weight per ft^3 (lb)	Weight per in^3 (lb)	Weight for 3 cubes (lb)
Cement	195	1	**0.272**	**53.181**	0.030	0.738
Sand	100	1.5	0.409	40.909	0.023	0.568
Aggregate	8.11	3	0.818	6.640	0.0038	0.092
	Total =	5.5				

Size of one cube = 2 in x 2 in x 2 in
Assuming 1 unit of dry volume equals 1.5 unit of wet volume
Volume = (mix ratio/5.5)*1.5
Volume of cement = (1/5.5)*1.5 = **0.272 ft^3**
Weight of cement per ft^3 = volume * density = **53.181 lb**

Design approach for Trial 2 to Trial 5

We observed that the density was an issue for our first trial and we could decrease that by increasing the content of perlite and decreasing the fine aggregate content. From Figure 1, we can observe that for the ratio of cement to perlite as 1:4, it shows optimal density and compressive strength. Therefore, we decided to keep the ratio of cement to perlite as constant and vary the sand content in Trials 2 to Trial 5 to study the effect of addition of sand in the mix designs.

*- Refer discussion
[1], [2], [3] – Refer references

MIX DESIGNS										
Cement (ft^3)	Perlite (ft^3)	Expanded Shale (ft^3)	Washed Concrete Sand (ft^3)	Water (gal)	Admix (A&B)	Dry Density (lb/ft^3)	Wet Density (lb/ft^3)	Compressive Strength (lb/in^2)	Thermal Conduct-ivity ("k"*)	Yield (ft^3)
1	8	–	–	16	28[A]	22	37	90-125	0.54	8
1	6	–	–	13	24[A]	27	42	125-200	0.64	6
1	5	–	–	11	20[A]	30	46	230-300	0.71	5
1	4	–	–	10	16[A]	36	50	350-500	0.83	4
1	3	2[1]	–	9	1[A] & 3[B]	54	72	1400-1700	n/a	3.8
1	3	2[2]	–	10	2[A] & 3[B]	62	78	2000-2100	n/a	3.5
1	3	2[2]	–	10	3[B]	65	90	2500-2800	n/a	3.2
1	3	–	–	7.5	7	45	58	800-1100	n/a	3
1	1.6	–	2.5	9.2	3[A]	82	98	1100-1300	n/a	5.1
1	2	–	–	5.5	3[A]	60	74	1600-1900	n/a	2
1	1.1	–	2.1	7.8	3[A]	88	105	2300-2500	n/a	3.5

EXPANDED SHALE [1] 5/16" [2] 1/2"

ADMIXTURE (see Masonary Supplier for Recommendation) [A] Air Entrainment [B] Pozzolith 300-N (fl.oz.)

* Btu-in./ft^2-h-°F

Figure 1: Mix design of Light weight Concrete [1]

Design parameters

The design parameters used to optimally design the lightweight concrete are water to cement (w/c) ratio, sand to cement (s/c) ratio and aggregate to cement (a/c) ratio which are tabulated in Table 2.

Table 2; Design parameters of mix design

Trial	w/c	s/c	a/c
1	0.56	1.5	3
2	0.5	1	4
3	0.5	0	4
4	0.5	0.5	4
5	0.5	0.25	4

*- Refer discussion
[1], [2], [3] – Refer references

Apparatus and materials

- Specimen molds
- Weighing device/scale
- Water
- Ottawa Sand
- Portland cement
- Lightweight aggregate (perlite)
- Oil
- Tamping rod
- Testing machine-INSTRON 1332.

PROCEDURE

1. Make sure the moulds are clean and prepare the mould by oiling them to ensure smooth retrieval of the cubes after casting.

2. Weigh cement, sand, perlite and water as per table 1.

3. Mix cement and sand using trowel in a tray until the mixture is homogenous.

4. Add the water in small amounts to the cement sand mixture and ensure that a smooth paste is formed.

5. Add perlite to the paste prepared and gently mix until a homogeneous mixture is formed.

*- Refer discussion
[1], [2], [3] – Refer references

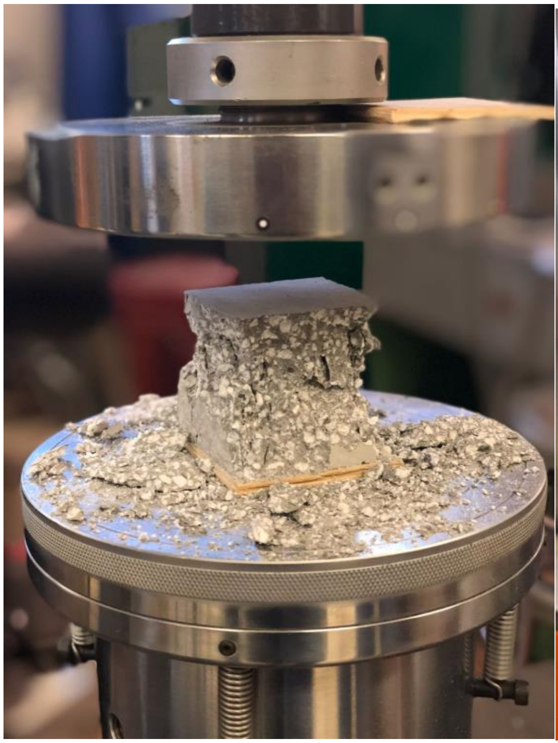
6. Fill each mould in 3 layers and compact each layer by tamping it to reduce the amount of air voids.

7. Leave the mould undisturbed and remove the cubes carefully after 24 hours.

8. Cure the cubes for 28 days to obtain optimum compressive strength.

9. Test the compressive strength of each cube using INSTRON 1332.

Pictures of cracks and Cubes failure.



*- Refer discussion
[1], [2], [3] – Refer references

RESULT AND ANALYSIS

Each trial includes 3 concrete specimens where 2 specimens had been tested. This project consists of 5 trials i.e. C1, C2, C3, C4, C5.

After Testing each specimen, following result has been generated, which includes the 28 days compressive strength f_c' and corresponding compressive strain which is shown in Table 3 and the graph showing stress strain relationship has been generated as shown in Figure 2.

Table 3;INSTRON Test results

Specimen label	Compressive extension at Maximum Compressive load (mm)	Maximum Compressive load (kN)	Compressive strain at Maximum Compressive load (mm/mm)	Compressive stress at Maximum Compressive load (kPa)
C2-1	2.31941	45.06427	0.04566	17462.44049
C3-1	2.03179	30.89099	0.04000	11970.28255
C3-2	2.01440	32.76277	0.03965	12695.59669
C4-1	1.62185	34.06326	0.03193	13199.54014
C4-1 Retest	1.46169	35.49942	0.02877	13756.05297
C4-2	1.82444	38.97374	0.03591	15102.35596
C5-1	2.22263	43.21521	0.04375	16745.92781
C5-2	1.88057	41.16327	0.03702	15950.79708
C1-1	1.70134	45.60772	0.03349	17673.02704
C1-1 Retest	1.49291	52.37755	0.02939	20296.33904

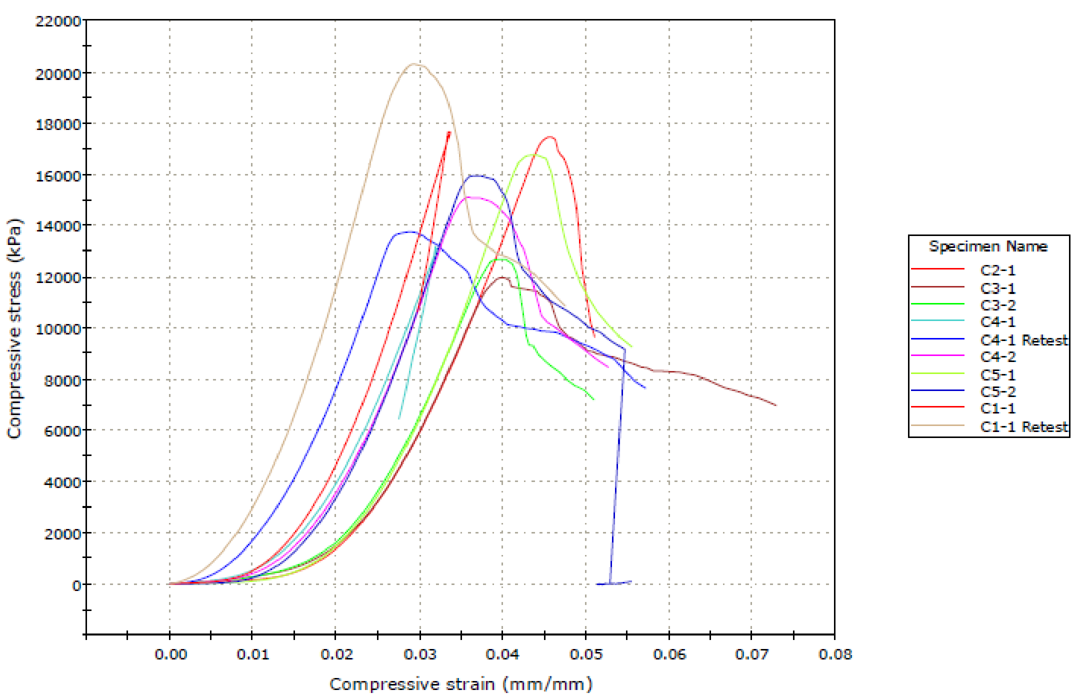


Figure 2; Compressive strength vs compressive strain

*- Refer discussion
[1], [2], [3] – Refer references

The average of compressive strengths and weights of each trials are shown below in Table 4.

Table 4;Average Values

Specimen label	Weight(lb)	Average weight(lb)	Compressive strength(kpa)	Average Comp. Strength(kpa)	Average Comp. Strength(psi)
C1-1	0.430	0.430	20296.339	20296.339	2942.969
C2-1	0.394	0.394	17462.440	17462.440	2532.054
C3-1	0.338	0.337	11970.282	12332.939	1788.276
C3-2	0.335		12695.596		
C4-1	0.381	0.381	13756.052	14429.204	2092.235
C4-2	0.381		15102.355		
C5-1	0.395	0.389	16745.927	16348.362	2370.512
C5-2	0.383		15950.797		

<u>Calculation of Performance criterion 'p' are as below</u>:

Volume of one cube V =2in x 2in x 2in = 8 in^3

$$f_c{}' = \frac{P}{A}$$

where $f_c{}'$= compressive strength (psi), P= load (lb) and A= surface area (in^2).

$$\rho = \frac{m}{V}$$

where $\rho =$ cube density (pci), m= cube mass (lb), V= volume of the cube (in^3).

$$p = \frac{f_c{}'}{\rho}$$

Where $p =$ Performance criterion (in).

Using the formulas mentioned above, performance criterion is calculated for all the trials and are tabulated as shown in Table 5. Figure 3 shows the graphical representation of the same.

*- Refer discussion
[1], [2], [3] – Refer references

Table 5;Performance Criterion

Specimen	Mix Proportion	weight (lb)	Density ρ (pci)	Compressive strength f_c'(psi)	Performance Criterion (P)
C1-1	1: 1.5: 3	0.43	0.053	2942.96	55542.13
C2-1/2	1 : 1 :4	0.394	0.049	2532.05	51687.96
C3-1/2	1 : 0 : 4	0.33	0.041	1788.27	43627.8
C4-1/2	1:0.5:4	0.38	0.047	2092.23	44527.02
C5-1/2	1:0.25:4	0.38	0.047	2370.51	50449.57

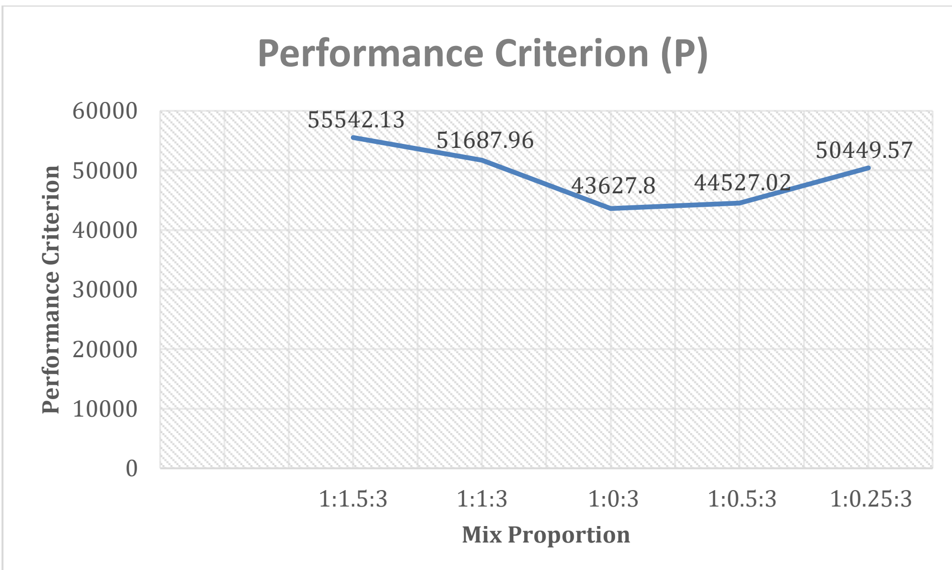


Figure 3; Graphical representation of p

Analysis

Performance criterion 'p' depends upon ratio of compressive strength and density. According to test result, max 'p' value is obtained in Trial 1(C1), which had the maximum sand ratio, with maximum compressive strength and maximum density. When we observed other trials, the quantity of sand is reduced and omitted in 3rd trial, in that scenario, the strength and the density are reduced compared to the first one. But we want maximum strength and low density, here without having any base point, we tried to figure out the relationship between sand and cement to make it more optimal. However, according to our project, best result is obtained for trial 1 and observed that the compressive strength of normal M20 concrete and lightweight concrete are almost the

*- Refer discussion
[1], [2], [3] – Refer references

same. We noticed that substituting perlite aggregate with normal coarse aggregate does not make much difference in compressive strength.

DISCUSSION

1. * **Water cement ratio and Bleeding**: Perlite has an unpredictable behavior. During the design of first trial, we anticipated that the perlite water absorption would be more and selected w/c ratio as 0.69, but, during casting we observed bleeding, and which made us to reduce the water cement ratio to 0.56.
2. **Strength to density ratio**: As strength and density are inversely related for p value calculation, attaining higher strength with lower density was very difficult and challenging.
3. **Design procedure**: Mix design without proper guide or manual was very tough to decide whether we are in correct track or not.

CONCLUSION

1. The compressive strength of perlite concrete will decrease with increase of perlite content.
2. The compressive strength of perlite concrete will increase with increase of fine aggregate.
3. The maximum 'p' value is achieved for the ratio 1:1.5:3 i.e. C1 trial mix.

MIX DESIGN CALCULATIONS

Trial 1

	density(pcf)	mix ratio	Volume (ft^3)	Weight per ft^3 (lb)	Weight per in^3 (lb)	Weight for 3 cubes (lb)
cement	195	1	**0.27**	**53.18**	0.03	0.74
sand	100	1.5	0.41	40.91	0.02	0.57
aggregate	8.11563	3	0.82	6.64	0.00	0.09
	total =	5.5				

size of one cube = 2 in x 2 in x 2in
Assuming 1 unit of dry volume equals 1.5 unit of wet volume
Volume = (mix ratio/5.5)*1.5
Volume of cement = (1/5.5)*1.5 =**0.27 ft^3**
Weight of cement per ft^3 = volume * density = **53.18 lb**

*- Refer discussion
[1], [2], [3] – Refer references

Trial 2

	density(pcf)	mix ratio	Volume (ft^3)	Weight per ft^3 (lb)	Weight per in^3 (lb)	Weight for 3 cubes (lb)
cement	100	1	**0.25**	**48.75**	0.03	0.68
sand	8.11563	1	0.25	25.00	0.01	0.35
aggregate	0	4	1	8.12	0.00	0.11
	total =	5.5				

size of one cube = 2 in x 2 in x 2in
Assuming 1 unit of dry volume equals 1.5 unit of wet volume
Volume= (mix ratio/5.5)*1.5
Volume of cement = (1/5.5)*1.5 =**0.25 ft^3**
Weight of cement per ft^3 = volume * density = **48.75 lb**

Trial 3

	density(pcf)	mix ratio	Volume (ft^3)	Weight per ft^3 (lb)	Weight per in^3 (lb)	Weight for 3 cubes (lb)
cement	195	1	**0.3**	**58.50**	0.03	0.81
sand	100	0	0	0.00	0.00	0.00
aggregate	8.11563	4	1.2	9.74	0.01	0.14
	total =	5.5				

size of one cube = 2 in x 2 in x 2in
Assuming 1 unit of dry volume equals 1.5 unit of wet volume
Volume= (mix ratio/5.5)*1.5
Volume of cement = (1/5.5)*1.5 =**0.3 ft^3**
Weight of cement per ft^3 = volume * density = **58.5 lb**

Trial 4

	density(pcf)	mix ratio	Volume (ft^3)	Weight per ft^3 (lb)	Weight per in^3 (lb)	Weight for 3 cubes (lb)
cement	195	1	**0.27**	**53.18**	0.03	0.74
sand	100	0.5	0.14	13.64	0.01	0.19
aggregate	8.11563	4	1.09	8.85	0.01	0.12
	total =	5.5				

*- Refer discussion
[1], [2], [3] – Refer references

size of one cube = 2 in x 2 in x 2in
Assuming 1 unit of dry volume equals 1.5 unit of wet volume
Volume = (mix ratio/5.5)*1.5
Volume of cement = (1/5.5)*1.5 =**0.27 ft^3**
Weight of cement per ft^3 = volume * density = **58.18 lb**

Trial 5

	density(pcf)	mix ratio	Volume (ft^3)	Weight per ft^3 (lb)	Weight per in^3 (lb)	Weight for 3 cubes (lb)
cement	195	1	**0.29**	**55.71**	0.03	0.77
sand	100	0.25	0.07	7.14	0.00	0.10
aggregate	8.11563	4	1.14	9.28	0.01	0.13
	total =	5.5				

size of one cube = 2 in x 2 in x 2in
Assuming 1 unit of dry volume equals 1.5 unit of wet volume
Volume= (mix ratio/5.5)*1.5
Volume of cement = (1/5.5)*1.5 =**0.29 ft^3**
Weight of cement per ft^3 = volume * density = **55.71 lb**

REFERENCES

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[2] http://www.perlite.info/hbk/0031401.htm
[3] https://www.simetric.co.uk/si_materials.htm
[4] Concrete M.Y.D Textbook

*- Refer discussion
[1], [2], [3] – Refer references

TEAM MEMBERS

*- Refer discussion
[1], [2], [3] – Refer references