Egg Shell As A Fine Aggregate In Concrete For Sustainable Construction

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ABSTRACT: This work has investigated the potential use of usedegg shell as a concrete material. The usedegg shells were used as fine concrete aggregate. In the laboratory test, conventional fine aggregate was replaced at 100% replacement level. A total of 18 cubes were cast, cured and tested. The strength development of the concrete mixes containing egg shell aggregates was compared to that of conventional concrete with sand as fine aggregate. The result showed a reduction in compressive strength of the concrete but still falls within limits of lightweight concrete. This paper recommends that egg shell can be used for producing concrete where a lighter weight concrete is required and a reduction of dead load of structure is desired.

Keywords: Concrete, egg shell, coarse aggregate, light weight concrete.

INTRODUCTION

Through out the world, concrete is being widely used for the construction of most of the buildings, bridges etc. Hence, it has been properly labeled as the backbone to the infrastructure development of a nation. Sustainable construction has become an interest in the engineering community and several standards have been developed to assess the environmental impact of new construction projects. (Isler, 2012). Researches have shown that it is possible to use recycled materials to replace some of the traditional mixture components in concrete products and produce a more sustainable building material. One common material that can be recycled and have the possibility of use in concrete applications is used egg shell. Eggshell waste falls within the category of food waste, which is materials from the preparation of foods and drinks, if subjected to adequate scrutiny, and they could can be suitable alternative material for construction (DohS.I. 2014). Concrete is a manmade building material that looks like stone. The word "concrete" is derived from the Latin concretus, meaning "to grow together." Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. Alternatively, we can say that concrete is a composite material that consists essentially of a binding medium in which are embedded particles or fragments of aggregates. The simplest definition of concrete can be written as; concrete = filler + binder. Concrete can be used for all standard buildings both single storey and multistory and for containment and retaining structures and bridges. In the usage of concrete, the designer should be knowledgeable of the strength and weaknesses of concrete. In the production of "good" concrete, fine and coarse aggregates combined in a correct ratio or proportion are bonded together by a cementitious material (usually Portland cement) to form a harden matrix concrete (Zongjin Li, 2011).

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TYPES OF CONCRETE

According to the unit weight of concretes, they can be classified into four categories, as shown in Table 1. Ultra-lightweight concrete can only be used to build up nonstructural members. Lightweight concrete can be used to build both nonstructural and structural members, depending on its specified composition. Normal-weight concretes are commonly used concretes in the construction of infrastructures and buildings. Heavyweight concrete is used to build some special structures, such as laboratories, hospital examination rooms, and nuclear plant, where radioactive protection is needed to minimize its influence on people's health (Zongjin Li, 2011).

Classification	Unit Weight (Kg/m^3)
Ultra-lightweight concrete	<1200
Lightweight concrete	1200 < UW < 1800
Normal-weight concrete	~2400
Heavyweight concrete	>3200

Table 1: *Classification of concrete in accordance with unit weight*
Source: *Zongjin Li (2011)*

This research paper discusses the use of egg shell as an alternative fine aggregate to the more conventional granite/gravel. Eggshells are agricultural throw away objects produced from chick hatcheries, bakeries, fast food restaurants among others which can damage the surroundings and as a result comprising ecological issues/contamination which would need appropriate treatment. In the ever soaring tasks to change waste to wealth, the efficiency of adapting eggshells to advantageous application constitutes a concept worth-accepting. It is systematically acknowledged that the eggshell chiefly consists of compounds of calcium (Sivakumar .M, and Mahendran .N, 2014)

MATERIALS

Cement: In the most general sense of the word, cement is a binder, a substance that sets and hardens independently, and can bind other materials together. It is the basic binding material in concrete.

Properties	Values
Initial Setting time	30 minutes
Final Setting time	600 minutes
Specific gravity	3.15

Table 2: *Properties of Ordinary Portland cement*

The cement used for the various experiments and test is ordinary Portland cement of grade 43. Grade of cement indicates minimum strength of cement in N/mm^2 tested as per standard conditions. A 43grade cement should give minimum strength of 43 N/mm^2 at 28 days.

Water: Water is a key ingredient in concrete production. It helps in binding the mixture of cement and aggregate together to form a cementitious paste. It hydrates cement and also makes concrete workable. Water used in concrete needs to be pure and free from chemical impurities in order to prevent adverse reactions from occurring which may weaken the concrete, the role of water is important because the water to cement ratio is the most critical factor in the production of concrete. During the test period, potable water gotten from the taps in the civil engineering department labs were used.

Fine Aggregates: Aggregates passing through a No. 4 (4.75 mm) sieve and predominately retained on a No. 200 (75 µm) sieve are classified as fine aggregate. No. 200 (75 µm) sieve are classified as fine aggregate.Finely grinded eggshell is used as fine aggregate in this research at 100% replacement for fine sand.The main ingredient in eggshells is calcium carbonate (the same brittle white stuff that chalk, limestone, cave stalactites, sea shells, coral, and pearls are made of). The shell itself is about 95% CaCO3 (which is also the main ingredient in sea shells). The remaining 5% includes Magnesium, Aluminum, Phosphorous, Sodium, Potassium, Zinc, Iron, Copper, Ironic acid and Silica acid. Eggshell has a cellulosic structure and contains amino acids;
thus, it is expected to be a good bio-sorbent and it was reported that large amounts of eggshells are produced in some countries, as waste products and disposed in landfills annually (Karthick J. et al. 2014).

Advantages of egg shell

1. Considerable reduction in alkali-silica and sulfate expansions.
2. Meets the most stringent environmental regulations nationwide.
3. Ideal for painting in occupied spaces.
4. Excellent durability and washable finish.
5. Resist mold and mildew on the paint film.
6. Saves money; less material required.
7. Meets strict performance and aesthetic requirements.

Name	Physical Properties
Specific Gravity	0.85
Moisture content	1.18
Bulk Density (g/m^3)	0.8
Particle Density (g/m^3)	1.012
Porosity (%)	22.4 BET
Surface area m^2/g	21.2

Table 3: *Physical Properties of Egg Shell*
Source: *(Karthick J. et al. 2014).*

Coarse Aggregate: Coarse aggregate: Aggregates predominately retained on a No. 4 (4.75-mm) sieve are classified as coarse aggregate. Generally, the size of coarse aggregate ranges from 5 to 150 mm. For normal concrete used for structural members such as beams and columns, the maximum size of coarse aggregate is about 25 mm. For mass concrete used for dams or deep foundations, the maximum size can be as large as 150 mm. Figure 1 shows some examples of coarse aggregates (Zongjin Li, 2011).

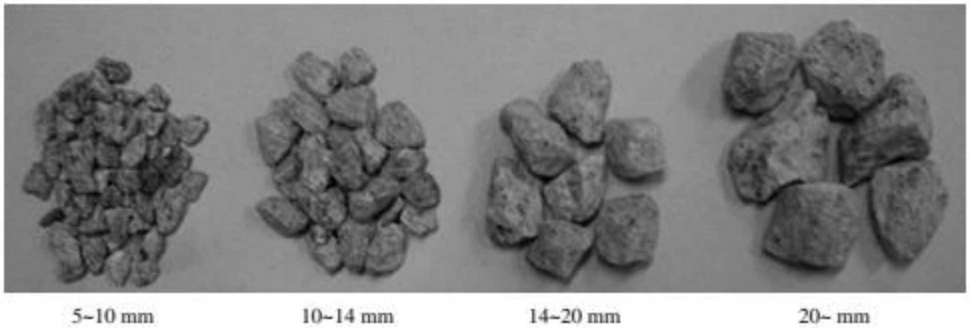

Figure 1: *Different sizes of coarse aggregates*
Source*: Zongjin Li (2011).*

EXPERIMENTAL PROCEDURES & MIX DESIGN

Test Procedure
The experimental process followed the flow diagram shown below.

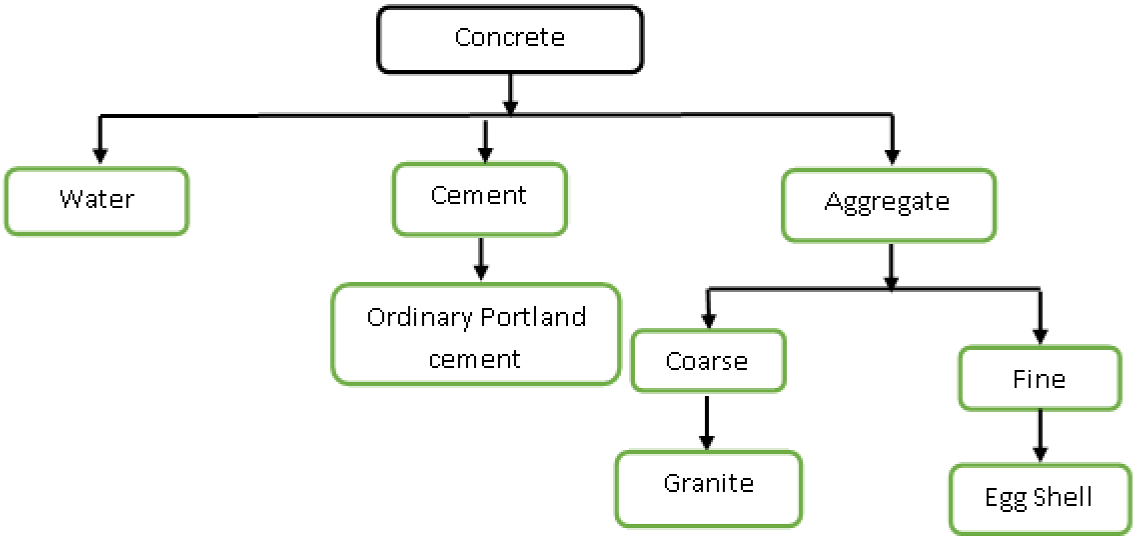

Figure 2: *Flow chart of the laboratory test*

The conventional concrete was produced using aggregate (granite &egg shell), OPC and water. The concrete sample were formed into three shapes; cube, prism and cylindrical.

Mix Design
The basic objective of concrete mix design is to find the most economical proportions (Optimization) to achieve the desired end results (strength, cohesion, workability, durability. As mentioned earlier the proportioning of concrete is based on certain material properties of cement, and aggregates. Concrete mix design is basically a process of taking trials with certain proportions. Concrete mix design is the method of correct proportioning of ingredients of concrete, in order to optimize the above properties of concrete as per site requirements. In other words, we determine the relative proportions of ingredients of concrete to achieve desired strength & workability in a most economical way.The test samples were cured and subsequently tested at 7days and 28days.

Concrete Shapes	number	Dimensions (mm)	Area (mm^2)	days	Shape cor. factor
Cube	3	22 x 22 x 22	484	7	5
Cylinder	3	20 x 25	1570	14	5
Prism	3	50 x 30 x 30	1500	21	5
total	9 @ 4 days (36)			28	

Table 4: *Sample Characteristic Shapes*

Figure 3: *Samples*

Compressive strength test
Compressive strength of concrete is the value of uniaxial compressive stresses reached when concrete fails completely. The compressive strength of concrete is given in terms of the characteristic compressive strength of 150mm (or 100mm) sizes cubes tested at 28days. The characteristic strength is defined as the strength of concrete below which not more than 5% of the test results are expected to fail.

Size of cube =100mm×100mm×100mm
Area of specimen = 10,000mm^2
Expected maximum load = fck × area × f.s
Where fck = characteristic strength at 28 days
f.s = factor of safety
Maximum applied load = P (N)
Compressive strength = $\frac{\text{Load (N)}}{\text{Area (mm}^2\text{)}}$
The samples were fed into the Universal Testing machine simultaneously in which the plunger was allowed to have contact with the surface of the specimen before the load was applied for the specimen to be crushed. Results were collected.

Figure 4: *Crushing in Progress*

Results and discussion

Test No.	Force @ Peak (N)	Force @ Upper Yield (N)	Force @ Yield (N)	Stress @ Peak (N/mm2)	Stress @ Yield (N/mm)	Youngs Modulus (N/mm2)	Time to Failure (secs)	Area (mm2)
1	37.300	24.500	24.500	0.077	0.051	7.266	25.226	484.00
2	43.900	33.100	40.100	0.091	0.068	8.270	15.347	484.00
3	17.700	11.900	11.900	0.037	0.025	9.140	29.678	484.00
mean	32.967	23.167	25.500	0.068	0.048	8.225	23.417	484.00
Compressive strength = (32.967/484.00) = 0.068N/mm^2				Percentage difference to control = 97.617				
Compressive strength control = 2.854 N/mm^2								

Table 5: *compressive strength results from Universal Testing Machine (cube 7 days)*

Test No.	Force @ Peak (N)	Force @ Upper Yield (N)	Force @ Yield (N)	Stress @ Peak (N/mm2)	Stress @ Yield (N/mm)	Youngs Modulus (N/mm2)	Time to Failure (secs)	Area (mm2)
1	57.800	15.700	15.700	0.037	0.010	0.373	19.566	785.000
2	31.200	11.100	11.100	0.020	0.007	1.213	27.692	785.000
3	59.600	38.900	38.900	0.038	0.025	0.941	20.257	785.000
mean	49.533	21.900	21.900	0.032	0.014	0.842	22.505	785.000
Compressive strength = (49.533/785.000) = 0.063N/mm^2				Percentage difference to control = 96.532				

Compressive strength control = 1.817 N/mm^2

Table 6: *compressive strength results from Universal Testing Machine (cylinder 7 days)*

Test No.	Force @ Peak (N)	Force @ Upper Yield (N)	Force @ Yield (N)	Stress @ Peak (N/mm2)	Stress @ Yield (N/mm)	Youngs Modulus (N/mm2)	Time to Failure (secs)	Area (mm2)
1	**45.100**	**37.400**	**37.400**	**0.030**	**0.025**	**0.996**	**15.270**	**1500.000**
2	**284.300**	58.900	58.900	0.190	0.039	1.694	41.425	**1500.000**
3	**19.600**	13.500	13.500	0.013	0.009	1.053	20.428	**1500.000**
mean	116.333	36.600	36.600	0.078	0.024	1.248	25.708	1500.000
Compressive strength = (116.333/1500) = 0.078/mm^2				Percentage difference to control = 94.495				
Compressive strength control = 1.417 N/mm^2								

Table 7: *compressive strength results from Universal Testing Machine (prism 7 days)*

Test No.	Force @ Peak (N)	Force @ Upper Yield (N)	Force @ Yield (N)	Stress @ Peak (N/mm2)	Stress @ Yield (N/mm)	Youngs Modulus (N/mm2)	Time to Failure (secs)	Area (mm2)
1	28.200	6.100	6.100	0.058	0.013	4.379	19.333	484.000
2	15.800	15.800	15.800	0.033	0.033	2.142	6.818	484.000
3	30.400	19.900	19.900	0.063	0.041	3.786	12.208	484.000
mean	24.800	13.933	13.933	0.051	0.029	3.436	12.786	484.000
Mean control								
Compressive strength = (24.800/484.000) = 0.051N/mm^2				Percentage difference to control = 90.438%				
Compressive strength control = 5.334N/mm^2								

Table 8: *compressive strength results from Universal Testing Machine (cube 28 days)*

Test No.	Force @ Peak (N)	Force @ Upper Yield (N)	Force @ Yield (N)	Stress @ Peak (N/mm2)	Stress @ Yield (N/mm)	Youngs Modulus (N/mm2)	Time to Failure (secs)	Area (mm2)
1	24.300	18.000	18.000	0.031	0.023	1.991	4.691	785.000
2	30.400	20.700	20.700	0.039	0.026	4.858	4.473	785.000
3	35.600	23.800	23.800	0.045	0.030	1.986	16.549	785.000
mean	30.100	20.833	20.833	0.038	0.026	2.945	8.571	785.000
Compressive strength = (30.100/785.000) = 0.040/mm^2				Percentage difference to control = 90.00%				
Compressive strength control = 4.00N/mm^2								

Table 9: *compressive strength results from Universal Testing Machine (cylinder 28 days)*

Test No.	Force @ Peak (N)	Force @ Upper Yield (N)	Force @ Yield (N)	Stress @ Peak (N/mm2)	Stress @ Yield (N/mm)	Youngs Modulus (N/mm2)	Time to Failure (secs)	Area (mm2)
1	20.000	5.000	5.000	0.013	0.003	0.878	6.786	1500.000
2	24.401	17.901	17.901	0.018	0.008	0.553	13.191	1500.000
3	25.400	20.200	20.200	0.017	0.013	0.792	15.912	1500.000
mean	**23.267**	**14.367**	**14.367**	**0.016**	**0.008**	**0.741**	**11.963**	**1500.000**
Compressive strength = (23.267/1500) = 0.016 N/mm^2				Percentage difference to control = 99.70%				
Compressive strength of control 5.334 N/mm^2								

Table 10: *compressive strength results from Universal Testing Machine (Prism 28 days)*

Shape	**Average Percentage difference to control**

Cube	94.028
Prism	97.098
cylinder	93.266

Table 12: *Summary*

CONCLUSION

The following conclusions are made based on compressive strength test on the samples

- There is a high difference between the control and result obtained from the tested samples
- Egg shell cannot be used as fine aggregate in the production of concrete at 100% level of replacement.

RECOMMENDATION

- It is recommended that the egg shell should not be used as fine aggregate in the production of concrete at 100% replacement level.
- Furtherresearch should be carried out at different level of replacement
- Further research should also be carried out to ascertain the prospect of using egg shell to replace cement in concrete at different level of replacement

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