

**ARTICLE**

**Evaluation the Effects of Coarse Aggregates Size on Concrete Properties**

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**ABSTRACT**

Concrete is the most generally used construction material in buildings, pavements, and infrastructures. Concrete is a construction material composed of cement as binder, fine aggregates and coarse aggregates mixed with water which hardens with time. Concrete is a versatile construction material within the housing industry of the planet. The standard of the concrete is tormented by various factors and from those various factors which may have an effect on the concrete quality are, the coarse combination size has its own nice role on the standard of concrete production. A laboratorial experiment was conducted to work out the results coarse aggregates size on recent and hardened concrete properties. For this study totally different crushed volcanic rock aggregates sizes were collected from almost Jimma city for determination of the results of coarse aggregate sizes in concrete production. Three coarse aggregate nominal sizes of 10 mm, 14 mm and 20 mm were used for samples production to envision the scale effects on concrete properties. For this study the procedures that was followed, the types and quantity of materials for concrete creating were similar whereas sizes of nominal basaltic coarse aggregate were different. The fresh concrete has a slump value of 67 mm, 72 mm and 83 mm for 10mm, 14 mm and 20 mm aggregate sizes respectively. A total of thirty six concrete cube samples were ready and tested using compressive strength testing machine at totally different ages of the cube 7 days, 14 days, and 28 days, to know their strengths. The compressive strength was 23.524 Mpa, 22.643 Mpa and 22.41 MPa for aggregate sizes of 10 mm, 14 mm and 20 mm respectively. The laboratory results show that 10mm coarse aggregate size gave the most effective compressive strength and comparatively lowest slump at similar water/cement ratio of 0.6. At 28<sup>th</sup> day 10mm coarse aggregate size gave 23.524 Mpa compressive strength which is the maximum compressive strength from the remainder coarse aggregates so, the optimum maximum size of coarse aggregate for this study was 10mm.

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## 1. Introduction

### 1.1 Concrete

Concrete is the most generally used construction material in buildings, pavements, and infrastructures. Normal Concrete (NC) typically contains Ordinary Portland Cement (OPC), Coarse Aggregate (CA), Sand (S), and water. Recently, heaps of attentions are given to the utilization of different materials within the concrete mixtures to supply a lot of property concretes<sup>[12]</sup>. Concrete is the most generally used manmade construction materials within the world and it's the extremely demanded material next to water on the earth. It is obtained by totally admixture of binding materials, water, fine and coarse aggregates and generally admixtures in needed proportions<sup>[8]</sup>. Since concrete is a reasonable and reliable material, that is extensively used throughout within the infrastructure of a nation's construction, industrial, transportation, defense, utility and residential sectors. It becomes an enormous trade in the construction industry. Over a metric ton of concrete is created annually for each individual on earth<sup>[1]</sup>. Over forty million jobs are created to humans by concrete trade<sup>[13]</sup>. Whereas there is a big service inside concrete {construction trade or housing industry or industry} all sides of the concrete industry share a standard objective a sincere need to deliver a prime quality, long lasting, competitive, eco-friendly and property product<sup>[15]</sup>. Concrete is a composite material produced by the homogenous mixing of selected proportions of water, cement, fine and coarse<sup>[9]</sup>. Strength is that the most desired quality of an honest concrete. It ought to be sturdy enough, at hardened state, to resist the various stresses to which it would be subjected<sup>[3]</sup>.

### 1.2 Aggregates

Construction coarse aggregate is a vital stuff for concrete production within the housing industry. However, conducting a check on the standard of aggregate is usually not performed within the right manner. This has a great effect on the life and maintenance of construction which may increase the value of repair or replace and even it should cause structural failure and risk to human lives<sup>[7]</sup>. Coarse aggregate consists of over one-third of the volume of concrete, and research analysis indicates that changes in coarse aggregate will change the strength concrete. To predict the behavior of fresh and hardened concrete it needs an understanding of the results of coarse aggregate sizes. This understanding is often obtained by conducting intensive testing and observation on the aggregates<sup>[1]</sup>. The concrete creating materials are cement, water, aggregates

(fine and coarse aggregates), aggregates take about three-quarter of the volume of concrete with the coarse aggregates taking between 50 and 60% of the concrete mix depending on the mix proportion used<sup>[9]</sup>. The larger share of coarse aggregate in concrete combine makes it to contribute heaps to the strength of concrete. Its properties like toughness, hardness, shape, size, soundness, density, and relative density conjointly have an effect on the strength of concrete as cited on<sup>[10]</sup>. From concrete making materials, fine and coarse aggregates build regarding seventieth by volume. It implies that the standard of concrete is powerfully influenced by aggregates physical and mechanical properties additionally as chemical composition of the parent aggregates creating material. This calls for a critical identification and classification of aggregates so that they are used to meet the intended purpose<sup>[6]</sup>. The aggregates can be classified as; coarse aggregate which is usually greater than 4.75 mm, while fine aggregate is less than 4.75 mm. The compressive strength of aggregate is an important factor in the selection of aggregate<sup>[14]</sup>. When determining the strength of normal concrete, most concrete aggregates are several times stronger than the other components in concrete and therefore not a factor in the strength of normal strength concrete<sup>[3]</sup>. According to<sup>[6]</sup>, more than 60% of concrete is a coarse aggregate by volume, which plays a main role in concretes' fresh as well as hardened properties in the concrete production. The objective of this study was to judge through an experiment the results of coarse aggregate sizes on fresh and hardened properties concrete. During this analysis, the physical properties of coarse aggregates and the mechanical properties of concrete were examined within the laboratory. The sources of coarse aggregate samples were primarily quarried from around Jimma town, where the major share of construction works were taken place. The test results were compared with the standard. Based on the findings, conclusions and recommendation were drawn and also recommendations forward.

### 1.3 Statement of the Problem

The concrete structure quality is certainly depends on the standard of concrete creating materials. Among these concrete creating materials coarse aggregates takes the immense portion of the concrete and therefore the aggregates have an excellent influence on the properties recent and hardened concrete<sup>[11]</sup>. When the constructors are using poorly graded coarse aggregate in concrete matrix, concrete holes will be developed and it has its contribution in the causes of structural failure. This also leads to an existence of cohesionless composite of

aggregate and cement paste bond. In such case concrete will not be able to effectively transmit the incoming external load to the reinforcement, thus resulting in structural failure as the concrete will be subjected to compressive stresses than it can resist. Therefore it is imperative to determine the effect of coarse aggregate size on the strength of concrete<sup>[10]</sup>. There are several arguments on the effects of coarse aggregate size on concrete properties, principally about the effects on fracture energy. Some research has shown that there is a rise in fracture toughness with an increase in aggregate size<sup>[3]</sup>. However,<sup>[10]</sup> have stated that, in some high-strength concretes where the coarse aggregates rupture during fracture, size is not expected to influence the fracture parameters. Therefore the aim of this study was to determine effects of maximum coarse aggregate sizes on concrete properties.

## **2. Research Methodology**

### **2.1 Equipment**

In order to conduct the laboratory tests the following equipment and tools were used; series of sieves, balance, slump cone, ruler, mixers, vibrators, curing tank, oven dry, soaker, enamel tree, compressive testing machine and others were used.

### **2.2 Materials Required**

#### **2.2.1 Cement**

Cement is a cementations material which can create a cement paste when it is mixed with water. In order to find a qualified concrete, the properties of cement should be in the right quality. For this study the researcher used commercially available ordinary port land cement (Dangote cement) with the specific gravity of 3.15.

#### **2.2.2 Coarse Aggregate**

Coarse aggregate is one of the main constituting concrete making materials. It has great role in concrete fresh and hardened properties. The researcher collected the coarse aggregates from aggregates crushing plants which are found near to the study area. For this study the researcher has collected three different sizes of coarse aggregates to check their effects on concrete fresh and hardened properties. These are 10 mm, 14 mm & 20 mm.

#### **2.2.3 Sand**

The sand which was used for concrete productions is

natural fine aggregate which was available nearby to the study area. In order to investigate its properties for the required application different tests were carried out which include: grading of fine aggregate, fineness modulus, specific gravity, absorption capacity, moisture content, silt content and unit weight.

### **2.2.4 Water**

The main quality requirement of water that should be checked before using it in concrete production is its impurity. The concrete sample was prepared by the potable water. This potable water was available from Jimma University students' laboratory water supply distribution. Potable water is free from any visible waste was used for this experiment.

## **3. Methods**

### **3.1 Materials**

To check the effects of coarse aggregates on properties of concrete, first the concrete making materials such as coarse aggregates, fine aggregates and cement were purchased from the suppliers which are available near to the study area. Then these both coarse and fine aggregates were tested for their physical properties to check the suitability of aggregates for concrete making.

### **3.2 Physical Properties of Both Fine and Coarse Aggregates**

#### **3.2.1 Physical Properties of Fine Aggregates**

The fine aggregate shall have not more than 45 % passing any sieve and retained on the next consecutive sieve and its fineness modulus should not be less than 2.2 or more than 3.2 (Neville A.M 1987). Grain size distribution, density, specific gravity, unit weight, moisture content and water absorption of fine aggregate were checked.

To determine the particle fineness modulus for fine aggregate, the following apparatus were used. Balance, set of standard sieves in following sizes 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm and pan. The other physical properties were determined by using soaker, oven dry, pycnometer, enamel tree and measuring jar.

#### **3.2.2 Physical Properties of Coarse Aggregates**

The coarse aggregates should have the required physical properties in order to use it as concrete making materials. Therefore to check such properties the following

experiments were performed in the laboratory by using the appropriate apparatuses. Grain size distribution, density, specific gravity, unit weight of coarse aggregates, moisture content and water absorption of aggregates were tested.

### 3.3 Preparing Mix Design

Concrete mix design is a way in which the concrete making materials are proportioned in the concrete production. The weighting balance method of concrete mix design was used with mix proportion of 1:2:4 and the water /cement ratio of the experiment was 0.6. The researcher has prepared 36 concrete cubes (150 mm x150 mm x 150mm) for hardened properties test of concrete. Except the coarse aggregate sizes the other all things were not vary to all the cube samples. The slump test method was used for workability checking in line with ASTM C 143 of slump testing.

### Preparing the Samples

According to different concrete testing standards like European standard and American standard to conduct any concrete properties a minimum of three samples should be prepared. Therefore based on these limitations three cube samples were prepared for each maximum aggregate size of 10 mm, 14 mm, and 20 mm coarse aggregates to test properties of concrete.

### Testing the Slump Value and Compressive Strength Of The Fresh Concrete

After the suitability of each concrete making material was tested and the mix design was prepared the next step is testing the slump value for fresh concrete and compressive strength tests to hardened concrete. The slump value was tested by using slump cone. The compressive strength was carried out with 2000 KN capacity universal compressive strength machine on the 150 mm x150 mm x 150 mm cubes after curing for 7,14 and 28 days. The peak load was the load which causes crushing of sample cubes. The compressive strength of each sample was determined at 7<sup>th</sup> days, 14<sup>th</sup> days and 28<sup>th</sup> days and the results of all experimental outputs were presented under result and discussion.

## 4. Experimental Results and Discussion

### 4.1 Some Physical Properties of Fine Aggregates

#### 4.1.1 Grading of Fine Aggregates

The fine aggregates gradation is a means of determining

the grain size distribution in a given sample. It is performed by sieve analysis by using a series of sieves. The sieve analysis result of fine aggregate is as shown below in Table 1 and Figure 1 and the percentage pass is within the standard limit.

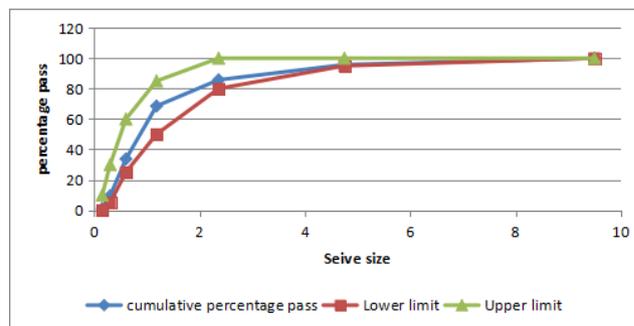
**Table 1.** Gradation for fine aggregates

Sieve Size in mm	Weight retained	Percentage of weight retained	Cumulative of percentage retained	Percentage of passing	Percentage of passing standard
9.5	0	0	0	100	100
4.75	85	4.25	4.25	95.75	95 to 100
2.36	200	10	14.25	85.75	80 to 100
1.18	345	17.25	31.5	68.5	50 to 85
0.6	695	34.75	66.25	33.75	25 to 60
0.3	485	24.25	90.5	9.5	5 to 30
0.15	169	8.45	98.95	1.05	0 to 10
pan	21	1.05	100		
total	2000	100			

The fineness modulus of fine aggregate =

$$\frac{\sum \text{cumulative percentage retained}}{100} = \frac{298.3}{100} = 2.983$$

The standard value of fineness modulus of fine aggregate is from 2.2-3.2. Since the fineness modulus value of the sample is 2.983 which are within the standard limit. Therefore the sample fine aggregate achieve gradation physical properties to use in concrete production.



**Figure 1.** Gradation curve of fine aggregates by cumulative percentage pass

### 4.1.2 Unit Weight, Moisture Content and Absorption of Fine Aggregate

As we have seen from Table 2 below the unit weight of fine aggregate is 1565kg/m<sup>3</sup> and moisture content is

greater than the absorption capacity of the aggregate. This high water or moisture content fine aggregate has great effects on concrete mix design. Therefore the researcher performs a moisture adjustment in concrete mix design in order to minimize the effect of excess amount of water on concrete properties.

**Table 2.** unit weight, moisture content, water absorption and specific gravity of fine aggregate

S.No	Type of aggregates	Unit weight kg/m <sup>3</sup>	Moisture content	Absorption (%)	Specific gravity
1	Fine	1,565.00	2.10	1.52	2.35

**4.2 Some Physical Properties of Coarse Aggregates**

In this experimental study the main aim was to evaluate the effects of coarse aggregates size on fresh and hardened concrete properties. Therefore the researcher has taken three different coarse aggregate sizes which are 20 mm, 14 mm and 10 mm. some of the physical properties of coarse aggregates were as tabulated below tables.

**4.2.1 Grading of Coarse Aggregate with 20 mm, 14 mm and 10 mm Maximum Size**

As we have seen from Tables 3, 4, 5 and Figure 2 below the gradation analysis of coarse aggregates were done. The percentage pass of coarse aggregates satisfied ASTM C33 standard of percentage of passing on each sieve opening sizes. All the three samples were within ASTM 33 standard in their grain distribution. As it is seen from Figure 2 aggregate size of 14mm and 20 mm were near to the upper limit for larger opening size of the sieve.

**Table 3.** Gradation analysis for 20mm coarse aggregate

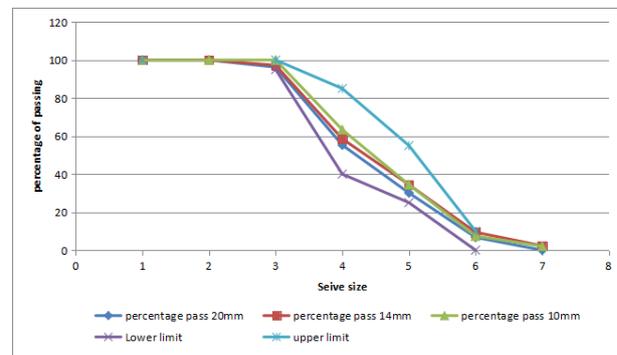
Sieves size in mm	Weight retained	Percentage of weight retained	Cumulative percentage retained	Percentage of passing	ASTM C33 Percentage of passing Specification
37.5	0	0	0	100	100
*28	0	0	0	100	
20	188.2	3.764	3.764	96.236	95-100
*12.5	2048.6	40.972	44.736	55.264	40-85
9.5	1257.7	25.154	69.89	30.11	25-55
4.75	1169	23.38	93.27	6.73	0-10
2.36	336.5	6.73	100	0	
pan	0	0	100	0	0-5
total	5000				

**Table 4.** Gradation analysis for 14mm

sieves size in mm	weight retained	Percentage of weight retained	Cumulative percentage retained	Percentage of passing	ASTM C33 Percentage of passing Specification
28	0	0	0	100	100
20	0	0	0	100	
14	138.3	2.766	2.766	97.234	95-100
*12.5	1933.2	38.664	41.43	58.57	40-85
9.5	1207	24.14	65.57	34.43	25-55
4.75	1250	25	90.57	9.43	0-10
2.36	356.5	7.13	97.7	2.3	
pan	115	2.3	100	0	0-5
total	5000				

**Table 5.** Gradation analysis for 10mm

Sieves size in mm	Weight retained	Percentage of weight retained	Cumulative percentage retained	Percentage of passing	ASTM C33 Percentage of passing Specification
20	0	0	0	100	100
14	0	0	0	100	
12.5	0	0	0	100	95-100
10	1833.210	36.664	36.664	63.336	40-85
9.5	1445.290	28.906	65.57	34.43	25-55
4.75	1350.810	27.016	92.586	7.414	0-10
2.36	265.790	5.316	97.902	2.098	
pan	105.000	2.1	100	0	0-5
total	5000	100			



**Figure 2.** Gradation curves of coarse aggregate for 20mm, 14mm and 10mm by their percentage of passing

### 4.2.2 The Coarse Aggregates' Unit Weight, Absorption and Specific Gravity

**Table 6.** Unit weight, water absorption and specific gravity of coarse aggregates

S.No	Type of aggregate	Unit weight kg/m <sup>3</sup>	Specific gravity	Absorption (%)
1	Coarse aggregate with 20mm (Basalt)	1623	2.48	1.32
2	Coarse aggregate with 14mm (Basalt)	1618	2.37	1.35
3	Coarse aggregate with 10mm (Basalt)	1597	2.25	1.62

The coarse aggregate that are used in Jimma town is not definitely known by the construction parties but the actual maximum size is vary from site to site since the source of the coarse aggregates are different for different constructing parties in the town.

### 4.3 Concrete Properties with Different Aggregates Sizes

As we have seen from Tables 7, 8 and 9 the slump value of the concrete is increased when the coarse aggregates size increased. The is due to the physical properties of the coarse aggregates in which the aggregates size increase the surface area of the aggregate decrease and this leads to the decrease the water absorption. This in turn increases the flow ability of the fresh concrete and that is why the slump value is increasing as the size of coarse aggregate increased. From experimental result the compressive strength of the concrete increased as the coarse aggregate sizes decreased as shown from the tables and figures below.

**Table 7.** Results of slump value and compressive strength for aggregate size of 10 mm

Maximum coarse aggregate size	Slump (mm)	Age (Days)	Average Weight (Kg)	Average failure load (KN)	Average compressive strength (Mpa)
10mm (Basalt)	67	7	8.08	487.13	21.65
	67	14	8.12	513.27	22.812
	67	28	8.23	529.29	23.524

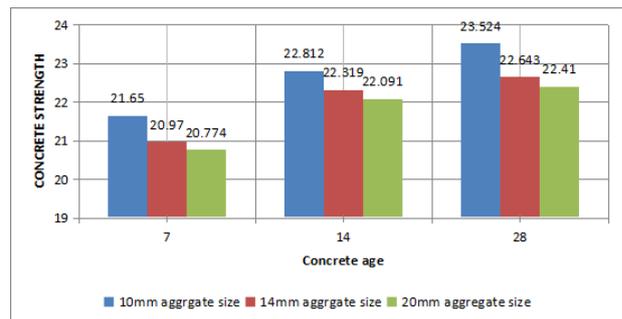
**Table 8.** Results of slump value and compressive strength of aggregate size 14mm

Maximum size of coarse aggregate	Slump value (mm)	Curing Age (Days)	Weight (Kg)	Peak load (KN)	Compressive strength(Mpa)
14mm (Basalt)	72	7	8.010	471.83	20.97
	72	14	8.033	502.18	22.319
	72	28	8.116	509.47	22.643

**Table 9.** Results of slump value and compressive strength of aggregate size 20mm

Maximum size and type of coarse aggregate	Slump (mm)	Age (Days)	Average Weight (Kg)	Average failure load (KN)	Average compressive strength(Mpa)
20mm (Basalt)	83	7	7.99	467.42	20.774
	83	14	8.12	497.05	22.091
	83	28	8.26	504.23	22.41

As we have seen from the bar graph of Figure 3 below the compressive strength of the concrete is increased as the aggregate size is decreased at different curing age of the concrete. This is due to an existence of high bondage of paste to aggregate when the size of the coarse aggregate decreased.



**Figure 3.** Compressive strength of concrete at different ages with different aggregate sizes

## 5. Conclusions and Recommendation

### 5.1 Conclusions

The source of coarse aggregate for Jimma town construction activity is from surrounding quarry sites. The constructing parties did not know the exact coarse aggregate sizes that are used in their construction. As the size of coarse aggregate size increases, the slump height of fresh concrete increase, this due to the reason that when the aggregate size increases the surface area of the aggregates decreases and in turn the mixing water absorption capacity of the aggregates decreases at constant water/cement ratio. Therefore when the water/cement ratio is the same for all types of aggregate sizes, there is more amount of water requirement in order to increase the slump height for concrete with smaller aggregate size. But the larger size aggregates consume less amount of water relative to the smaller size aggregates. The concrete compressive strength of 10 mm aggregate was greater than that of 14 mm and 20 mm nominal sizes due to the above reason. However, regarding to the slump height, concrete with 20mm coarse aggregate size is higher

than that of 10mm and 14mm sizes at the same water/cement ratio. For this study, 10mm coarse aggregate size is an optimum maximum size for production of high compressive strength concrete at 28 days.

## 5.2 Recommendation

It is recommended that the all constructing parties in Jimma town should be known what is the maximum size of their coarse aggregate that should be used for concreting. Because it has its own effect on concrete quality and when the researcher conducting pilot surveying they did not know the exact size of the coarse aggregate what they are using. It is strongly recommended to all stakeholders who are participating in the construction activities to use the coarse aggregate which has the maximum aggregate size of 10mm aggregates if they want to have the maximum compressive strength of concrete for their construction.

For further researcher it is recommended that to do their research on other sizes of coarse aggregates which are not considered in this study because the maximum compressive strength of the concrete may be achieved with other size of coarse aggregates which was not checked here in this research.

## References

- [1] Neville, A.M., Brooks, J.J., 2010. Concrete technology (second Edition). London: second Edition.
- [2] Abayneh, Mikyas, June 1987. Construction Materials, A Teaching Material. Addis Ababa: Addis Ababa University Press.
- [3] Aginam, Chidolue, Nwakire, 2013. Investigating the Effects of Coarse Aggregate Types on The Compressive Strength Of Concrete. International Journal of Engineering Research and Applications (IJERA). 1140-1144.
- [4] Ajamu, S.O., 2015. Effect of Coarse Aggregate Size on the Compressive Strength and. Journal of Engineering Research and Applications. 67-75.
- [5] American Concrete Institute Supersedes, E1-99. E1-07, ACI Education Bulletin. 2007.
- [6] Dinku, Abebe, 2005. The Need for Standardization of Aggregates for Concrete Production in Ethiopian Construction Industry. International Conference on African Development. Michigan: Western Michigan University. 1-16.
- [7] Ethiopian Standard, ES.C.D.201.1990. Specific Gravity for fine Aggregate.
- [8] Gambhir, M L., 2013. Concrete Industry. In Concrete technology, by MGHILL, 763. New Delhi: McGRAW HILL EDUCATION.
- [9] Ganesh Kumar S., Zeryhun Mulu Dinesh S., 2018. Comparitive Study On Engineering Propoerties Of The Aggregates And Compressive Strength Of Conventional Concrete Using Crushed And River Gravel, Coarse Aggregates Around Jimma Zone. International Research Journal of Engineering and Technology (IRJET): 496-506.
- [10] Ige, Ajamu, 2015. Effect of Coarse Aggregate Size on the Compressive Strength and the Flexural Strength of Concrete Beam. S.O. Ajamu Int. Journal of Engineering Research and Applications: 67-75.
- [11] Mitchell, Clive, 2015. Construction aggregates: evaluation and specification. Nottingham, UK. 1-7.
- [12] Mohammadi, Emadaldin, Behnood, Ali, Arashpour, Mehrdad, 2019. Predicting the compressive strength of normal and High-Performance Concretes using ANN and ANFIS hybridized with Grey Wolf Optimizer. Elsevier: 1-14.
- [13] Neville, A.M., 1987. Concrete Technology. New York: Longman Scientific & Technical Series.
- [14] Neville, A.M., 2011. Properties of concrete, 5th edition. p. Cm.
- [15] Wickpidia, Jan 12, 2014. The Effect of Aggregate Properties on Concrete. <https://www.engr.psu.edu/ce/courses/ce584/concrete/library/materials/aggregate/aggregatesmain.htm> (Accessed 10 26, 2019).