The Use of Recycled Aggregates and Used Tyres As Replacement of Natural Aggregates for Flood Wall

Ng Yao Xin Saeralyn[1], Ng Kim-Soon[1], Nur Fatihin Najila[1], Suwarna Subramaniam[1], Ismail Yusof[1]

[1]Universiti Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

saeralynng.uthm@gmail.com

Abstract

Waste materials that are not biodegradable often cause disposal problem and environmental pollution. The use of recycled aggregates (RA) as replacement natural aggregates (NA) in concrete is a sustainable industry alternative. However, there is lack of use of RA as a substitute to NA as a structural material in the construction industry, and this is more so in its application as a construction material to build flood wall to retain water. Thus, this project has been carried out in the laboratory to test the compressive strength, workability and permeability strength of the formulated RA and design a flood wall model using RA to demonstrate its uses in retaining water. The aggregates used in the investigation comprises of 80% used aggregates and 20% recycled tyres as replacement of the coarse and fine aggregates for structure material for flood wall. Suitability of concrete using the used aggregates and vehicle tyres to cast concrete in the flood wall model has shown positive results. It is suggested that other than its application in flood wall, the concrete using used aggregates and used vehicle tyres to replace natural aggregate can also be used in lightweight structures and in construction where lower strength of concrete can be applied.

Keywords: Recycled Aggregates, Used Tyres, Flood Wall

Introduction

Waste materials that are not biodegradable often cause disposal problem and environmental pollution [1]. The use of construction materials has been affecting human health and contributing negative impacts on environment such as soil erosion, flooding, and depletion of natural resources [2]. The main construction material in the construction industry is concrete. Globally, a huge quantity of concrete, with an estimated at 25 billion tons is generated each year [3]. In relation to this and to reduce the negative effects on environment and pollutions caused by human activities, the applications of industrial wastes and recycled materials should be stimulated in the construction industry [2]. In Malaysia, the quantity of waste tyre generated annually was estimated to be approximately 57,391 tonnes, and nearly 60% of them are disposed to landfills [4]. Researches have shown that the use of RA as replacement NA in concrete is a sustainable industry alternative, however, there is still lack of use of RA as a substitute to NA as a structural material in the construction industry[5], and this is more so in its application to build flood wall to retain water.

Objectives of the study

The objectives of this study are stated below:

1. To formulate recycle aggregate (RA) using used aggregates (80%) and recycled tyres (20%) as replacement of coarse and fine aggregate for structure material.
2. To test the compressive strength, workability, and permeability strength of the formulated RA.
3. To design a flood wall model using RA and demonstrate its uses in retaining water.

Literature Review

This section is on the literature and articles that are related to this study.

Alexander and Mindess [6] reported that NA can be in crushed or remain in uncrushed condition with a passing of 4.75 mm sieve. Recycled aggregate in comparison to the aggregate obtained from natural resources is characterized by higher water absorption, lower density, higher content of organic and possibly harmful substances with a higher level of crushability, reduced abrasion resistance and reduced resistance to frost. In addition, in cases when the recycled aggregate originates from many different sources, that is, if produced from a number of different waste concretes, quality unevenness in the sense of variations in properties will be much obvious than in the case of natural aggregates. Therefore, it is a common practice of concrete manufacturers to check the properties of recycled aggregates is being used [7].

Recycled aggregate using used aggregate concrete can be considered lightweight concrete as its density is lower when compared to natural aggregate concrete [8]. [5] found that although strength is inversely proportional to RA content, RA should be widely introduce and replace NA in structural applications as it is sustainable in the construction industry. The use of RA in concrete has shown to be a sustainable and economical alternative to NA, and also it is effective as non-structural components where strength is not critical [5]. It has been suggested that RA should be sourced from recycled low strength concrete as it provides cleaner aggregate [5]. The percentages of recycled concrete aggregates were varied, and it was observed that properties such as compressive strength showed a decrease of up to 10% as the percentage of recycled concrete aggregates increased. Water absorption of recycled aggregates was found to be greater than natural aggregates, and this needs to be compensated during mix design [9].

Shredded vehicle tyre is used to replace gravel or aggregate (NA) with sizes about 13 to 76mm, crumb vehicle tyre of range 0.425 to 4.75 mm sizes is suitable for replacement of sand, and ground rubber is often used as filler to cement substitution as they are range in sizes of 0.075 to 0.475 mm [10]. Although the density decreases with increment of used vehicle rubber tyre, the concrete with replacement of aggregate with the used vehicle rubber tyre lost 80% of its compressive strength as compared to the control concrete using the BS method as rubber particles is also considered to be light weight [11]. Tyre concrete lacks of internal bonding between cement and tyre compared to aggregate concrete, and this can cause cracking when non-uniform distribution stresses are applied which decreases the compressive strength as physical and mechanical properties of constituent materials influence the compressive strength [12].

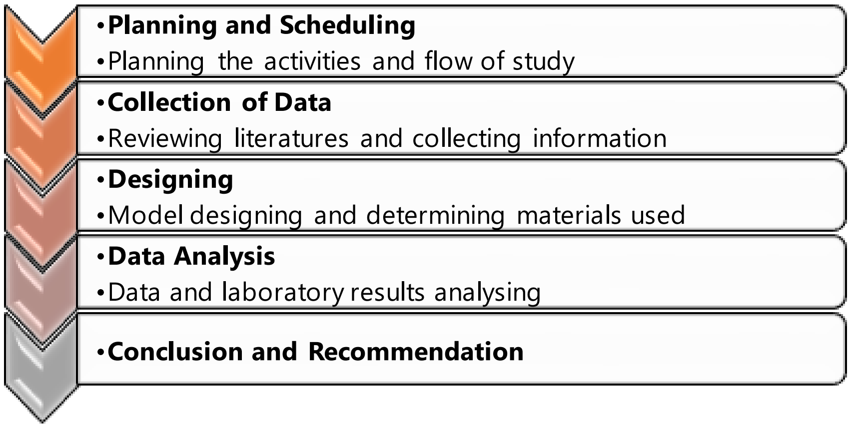
When flood water rises, it causes problem and misery to homes and authorities. Flooding can cause environment and health issues to the public as it also effects sewerage plants [13]. The flood wall is constructed along the banks of a stream, river, lake, or other body of water for the purpose of protecting the landside from overflowing runoff by confining the stream flow in the regular channel.

Methodology

This section describes the experiment methodology tests and the design of flood wall of this research work.

The methodology flow of this research is shown in Figure 1. The experimental method is adapted from [14]. The British Standard mix design procedure is adopted (i.e., BS 5328-2:1997) to arrive the mix proportions for M 25 grade of concrete. The concrete specimens were prepared by substituting the coarse aggregate with shredded vehicle tyres at 20% and fine aggregate with recycled aggregate at 80% as composition in the concrete with the water cement ratio of 0.45 to 0.50. This prepared concrete mixture was casted in cubes by using hand compaction. A standard concrete was also casted as a control to indicate the differences between the tested samples and the control. After the completion of 24 hours casting of the concrete, the mould was removed, and the casts were cured by using portable water at a temperature of 25±5˚C (BS EN 12390-2:2000). The specimen was fully immersed in portable water for specific age of 7 and 14 days. These cured casted concrete were then tested [14].

Figure 1: Methodology flow chart of the study



The main objective of workability test is to determine the correct water-cement ratio of the concrete. Slump test was done before the concrete mixes were poured into the cube moulds. For the water-cement ratio, the standard ratio has been used, which is 0.40 to 0.50. Table 1 tabulated the number of samples to be taken against the quantity of concrete. Based on the table Number of Samples to be taken depends on Quantity of Concrete by [15], the sample size taken for each of the tests for quantity of concrete in the work of 1 m^3 and 5 m^3.

For the slump test, there are a few measurements that should be taken and noted along the test. Basing on 'Fresh Concrete' classification and slump values and workability of concrete by [18], the slump value (mm) need to be within 1/3 of the slump cone for good workability. [18] reported that the lower the slump value, it indicates the lower workability of concrete and vice versa.

Aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete in order to produce a good concrete mix. Aggregates account for 60 to 75 percent of the total volume of concrete, and are divided into two distinct categories which respectively are fine and coarse aggregate. Gradation and size test is used to determine aggregate particle size distribution. In this study, used recycled aggregates and vehicle tyres were used to replace the natural aggregates. The range of size of the particles was fixed according to the optimum sizes between large, medium and small sizes (5%, 10% and 15% retained percentage) from the standard concrete work specifications distribution curve with reference to the previous research works [19].

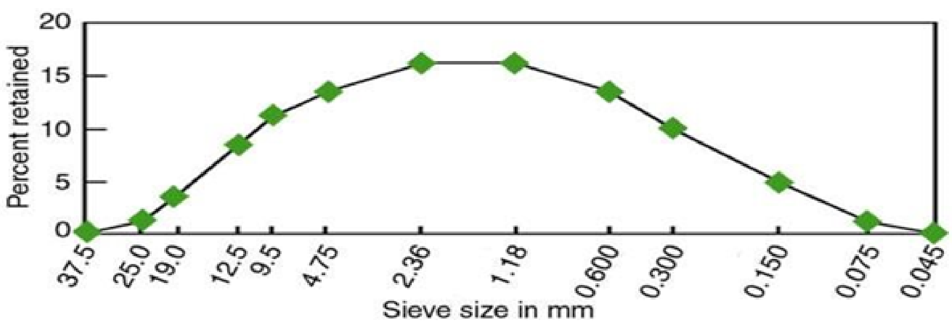


Figure 2: Optimum Combined Aggregate Grading for Concrete
Source: (Seegebrecht, 2017)

Substitution of natural aggregate by 20% was recommended for all structural applications as it shows better results in water absorption, abrasion, and water permeability [1]. Combinations of coarse rubber and fine aggregates obtained the highest compressive strength compared to crumb rubber and aggregates. [17]. For the ratio of recycled aggregates and vehicle tyres, recycled vehicle tyres occupied a percentage of 20 percent with most of is being the finer size of particles between 1.18 to 12.5mm as compared to aggregates of size of 12.5 to 19 mm. The vehicle tyre particles shredded and sieved used aggregate were graded into standard sizes of not more than 20 mm to substitute the NA for this research.

Permeability Test or penetration test is a rather critical aspect to cover in the research study as it is important for water retaining structures such as flood wall.

Figure 3: Concrete Permeability Test Machine

The compressive strength test for the concrete cubes casted were tested on the 7 and the 14th day.

After the data was obtained and being analysed for the purpose of the study to ensure the compatibility with the research objectives, the data for the compressive strength, workability and permeability strength of the formulated RA was analysed to determine the suitability of the concrete as a structure material. These data obtained has been used to determine the applicability of the flood wall model.

Based on the results i.e. the compressive strength, workability and permeability strength obtained from testing the casted concrete cube, the applicability for the flood wall was determined and the flood wall model was built as the data indicated its suitability for use in flood wall. The designs, including dimensions (mm) of the flood wall model, and they were expanded in detailed in Figure 4 to Figure 6.

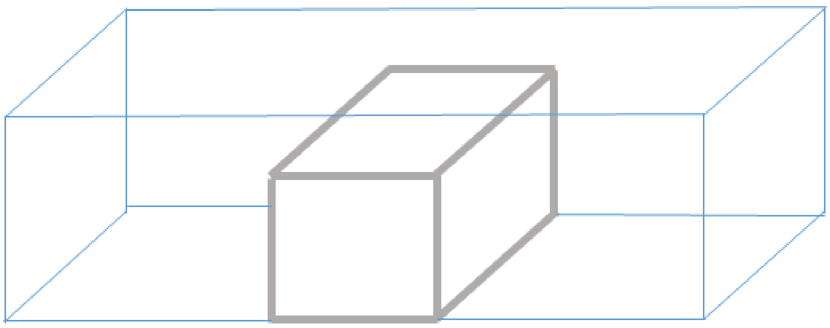


Figure 4: Model of Flood Wall

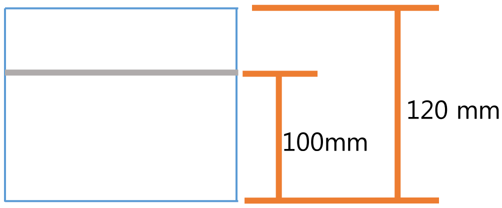


Figure 5: Side Elevation of Flood Wall Model

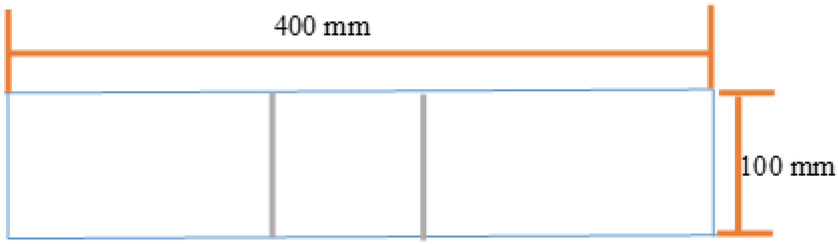


Figure 6: Top View of Flood Wall Model

Results and Discussion

Each experiment was conducted according to the standard procedure, and precaution steps were taken to prevent any occurring errors throughout the process in order to ensure the preciseness and accuracy of the data and findings.

Slump test is used to determine the consistency as well as workability of fresh concrete. The RA that were casted concrete possesses a medium workability with a drop of 50 mm, which shows medium workability.

Concrete gains its strength rapidly till 7th and 14th days, then, from there, it only increases gradually. Once it attains certain strength at 14 day as shown by [20], only 9% of strength is going to increase.

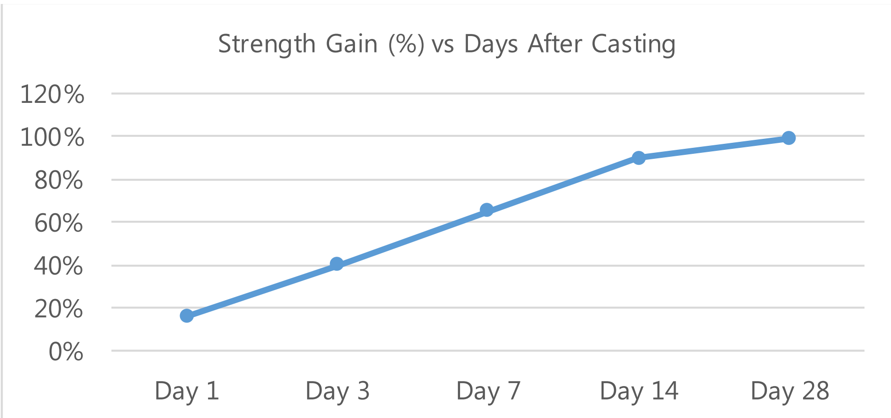


Figure 7:Percentage of strength gain vs days after casting
Source: (Compressive Strength of Concrete Cubes - Lab Test and Procedure, 2017)

The results for day 7 and 14 were used to project the value for day 28th using the extrapolation method. The calculations are as follow:

Control concrete: $\frac{X-34.8}{34.8-34.0} = \frac{99-90}{90-65} = 35.09$

Concrete using RA and vehicle tyre: $\frac{X-13.6}{13.6-7.8} = \frac{99-90}{90-65} = 15.69$

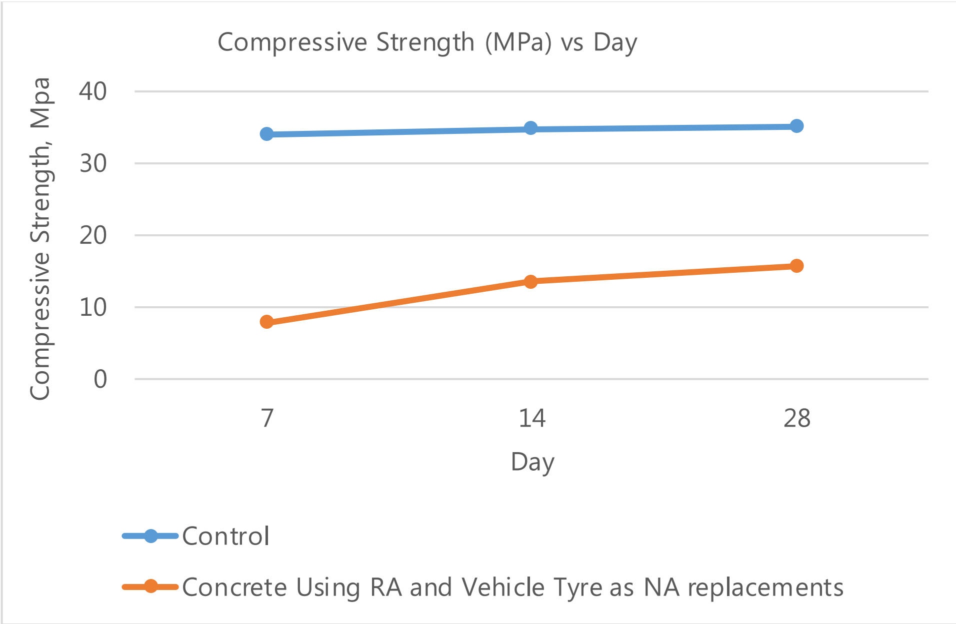


Figure 8: Compressive Strength (MPa) vs Day

The nominal strength of the concrete is 25 N/mm^2 (table 1 BS 5328-2: 1997). From here, it is known that the strength of concrete drops 50 % in concrete with RA and vehicle tyre replacements. It is noticed that the shape of the concrete with RA and shredded vehicle tyre remains cohesive compared to control concrete. This may be due to the ductile nature of rubber, which is resistance to cracking. It can withstand deformation but can resist less strength.

Permeability is the most effective internal factor in concrete durability. The concretes were weighted and their mass were recorded. From their mass, the density was calculated.

Table 1: Mass and density of concrete

Specimen	Control	Using RA and Vehicle Tyre as NA replacements
Mass (kg)	2.34	2.04
Density (kg/mm^3)	2340	2040

The mass of the concrete for control and with NA replacements increases by 20 % and 25 % respectively, which are 2.81 and 2.55 kg.

Water was poured on one of the columns to test the water penetration of the flood wall model to observe its permeability from one end of the cement concrete to the other end of the concrete column. The method was a success. Observations made show that no water penetrates through the cement wall of the model after the 3rd, 7th, and the 14th days.

Figure 9: Test on the flood wall model

Conclusions

Based on the laboratory experimental research, it is concluded that compressive strength of concrete decreases when tested with formulated RA, while there is also 15 % reduction in density in concrete compared to control concrete due to lightweight nature of vehicle tyres.

Suitability of concrete with used aggregates and vehicle tyres in flood wall model has shown positive results. Flood wall does not need high value in strength. Hence, used aggregate and used vehicle tyres can be used to substitute natural aggregates in the construction of flood wall.

It shows that not only in the application of flood wall, the concrete using used aggregates and used vehicle tyres to replace natural aggregate can also be used in lightweight structures and in construction where lower strength of concrete is used. These concrete can also use for aesthetic wall where the loads are low. The use of used vehicle tyre and used aggregate is a sustainable practices for the construction industry, and thus, it should be promoted of its uses to lessen issues of disposal problem and environmental pollution and should be encouraged of its suitability in the construction industry.

Recommendation

RA can be formulated using used aggregates (80%) and recycled tyres (20%) as replacement of coarse and fine aggregate for structure material. The formulated RA which were tested of its compressive strength, workability and permeability strength shows that it is suitable to design a flood wall and it has been demonstrated its uses in a laboratory model to retain water.

For further enhancement of water proving, it is suggested that to paint a layer of cementitious water proving coating example using construction chemical polymer Patents-305 on the cement slap surface. It is suggested that other than the application of flood wall, the concrete using used aggregates and used vehicle tyres to substitute natural aggregate can also be used in lightweight structures and in construction where lower strength of concrete is used. These concrete can also be used for aesthetic wall as by nature, the loads are lower.

Conflicts of Interest

Authors hereby declared there is no conflict of interest whatsoever exist in the writing of this articles.

Acknowledgments

The authors wish to thank the technicians of the Universiti Tun Hussein Onn Malaysia (UTHM). This work was supported by the Department of Civil Engineering Department, UTHM.

References

1. N. K. Sharma, P. Kumar, S. Kumara, B. S. Thomas, and R.C. Guptaa. (2017). Properties of Concrete Containing Polished Granite Waste as Partial Substitution of Coarse Aggregate, *Construction and Building Materials*, Vol. 151(1), pp. 158-163, 2010. DOI: https://doi.org/10.1016/j.conbuildmat.2017.06.081
2. L. J. Chai, P. Shafigh, H. Mahmud, and M. Aslam. (2017). Effect of Substitution of Normal Weight Coarse Aggregate with Oil-Palm-Boiler Clinker on Properties of Concrete, *Sains Malaysiana*, Vol. 46(4), pp. 645-653, 2017. DOI: http://dx.doi.org/10.17576/jsm-2017-4604-18
3. K. K. Wong. (2012). Concrete Waste: Discard or Recycle?" Borneo Post, 2012. http://www.theborneopost.com/2012/10/31/concretewaste-discard-or-recycle/.
4. K. H. Boon, D. Yeoh, and N. Jamaluddin. (2017). Properties of Pervious Concrete Containing Scrap Tyre Tubes, *MATEC Web of Conferences 103*, 01015, Universiti Tun Hussein Onn Malaysia.
5. S. Senaratne, G. Lambrousis, O. Mirza, V.W.Y. Tam and W. Kang. (2017). Recycled concrete in structural applications for sustainable construction practices in Australia, *Procedia Engineering* 180, 751 – 758. DOI: 10.1016/j.proeng.2017.04.235
6. M. Alexander, and S. Mindess. (2010). Aggregates in Concrete: Modern Concrete Technology. Retrieved from: https://books.google.com.my/books?id=FtNApxs2sx4C&dq=aggregates+in+concrete&lr=&source=gbs_navlinks_s
7. M. Malešev, V. Radonjanin, and G. Broćeta. (2014). Properties of recycled aggregate concrete, *Contemporary Materials*, Vol. 2, 239-249. DOI: 10.7251/COMEN1402239M
8. M. C. Rao, S. K. Bhattacharyya, and S.V. Barai. (2011). Influence of field recycled coarse aggregate on properties of concrete, *Materials, and Structures*, Vol. 44, 205 – 20, 2011.
9. M. Rakshvir, and S. V. Barai. (2006). Studies on recycled aggregates-based concrete, *Waste Management & Research*, Vol. 24(3), 225 – 233. DOI: https://doi.org/10.1177/0734242X06064820
10. V. Choudhary and A. Choudhary. (2017). Use of tyre waste in concrete: A review, *International Research Journal of Engineering and Technology (IRJET)*, Vol. 4(10), pp. 1924-1936, 2017. e-ISSN: 2395-0056, p-ISSN: 2395-0072.
11. A. M. Almaleeh, S. M. Shitote, and T. Nyomboi. (2016). Use of Waste Rubber Tyres as Aggregate in Concrete, *Journal of Civil Engineering and Construction Technology*, Vol. 8(2), 11-19. DOI: 10.5897/JCECT2016.0421
12. A. Sofi. (2017). Effect of waste tyre rubber on mechanical and durability properties of concrete – A review, *Ain Shams Engineering Journal* (2017). DOI: doi.org/10.1016/j.asej.2017.08.007
13. B. Evans, Flood wall design. (2016). Retrieved from: http://blockwalls.co.uk/flood-wall-design.
14. G. Venkatesh, K. Gopal, M. Nandhini, V. Pavithra, and M. Vignesh. (2017). Experimental Investigation on Replacement of Magnetic Water and Partial Replacement of Steel Slag by Coarse Aggregate in Concrete, *International Research Journal of Engineering and Technology (IRJET)*, Vol. 4(3), 2456-2460, 2017. DOI: https://www.irjet.net/archives/V4/i3/IRJET-V4I3641.pdf
15. Suryakanta. (2016). How to make test cubes from fresh concrete, civilblog.org. Retrieved from: http://civilblog.org/2016/09/23/how-to-make-test-cubes-fresh-concrete/ (25 Oct, 2017)
16. X. (2012). Traditional Materials: Uses of Cement, *Civil Engineering*, Retrieved from: http://www.civilengineeringx.com/traditional-materials/uses-of-cement/ (11 Nov 2017).
17. A. A. Yasin (2012). Using Shredded Tires as an Aggregate in Concrete, *Contemporary Engineering Sciences*, Vol. 5(10), 473 – 480, 2012.

18. P. J. M. Bartos. (2014). *Fresh Concrete: Properties and Tests*, Amsterdam: Elsevier Science Publishers, 1992.
19. G. Seegebrecht. (2014). The Role of Aggregate in Concrete, concretenetwork.com. Retrieved from: https://www.concretenetwork.com/aggregate/ (25 Oct 2017).
20. X. (2017). Compressive Strength of Concrete -Cube Test, Procedure, Results, The constructor civil engineering home. Retrieved from: https://theconstructor.org/concrete/compressive-strength-concrete-cube-test/1561/ (4 Dec, 2017).