Progress in Engineering Application and Technology Vol. 2 No. 2 (2021) 127–141
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PEAT

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Finite Element Analysis on Cube and Prism Beam of Ceramic Waste Concrete

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DOI: https://doi.org/10.30880/peat.2021.02.02.014
Received 13 January 2021; Accepted 01 March 2021; Available online 02 December 2021

Abstract: Ceramic and sanitary waste is typically produced from industries in which it occurred before and during the phase of manufacturing due to flaws in design, human negligence, or even insufficient raw supplies. Enormous quantity of ceramic waste leads to damage of environment. This study was aimed to develop model for series of cube and prism beam of ceramic waste using Abaqus 6.14 software. Another objective was to analyse flexural behaviour of ceramic waste concrete under load. This paper was conducted by collecting data of ceramic concrete density, modulus elasticity, compressive strength, and flexural strength from previous study. Concrete grade 30 N/mm^2 has been used for concrete control (CC) and other ceramic waste coarse aggregate concrete with partial replacement of coarse aggregate 25.00 %, 50.00 % and 75.00 % (CCA25, CCA50 & CCA75). Data of ceramic concrete density and modulus elasticity were essential elements to be put in the Abaqus simulation in order to design both models of cube with size of 150 x150 x150 mm and prism beam with dimension of L=700 mm, W=150mm, D=150 mm. From both two model's simulation in this paper, cube and prism beam, prism beam produced the same stress value to the concrete control, however recorded highest strain value at 75.00 % partial replacement. While for cube model, resulted in the opposite way where 75.00 % partial replacement produced the lowest stress value compared to the concrete control.

Keywords: Ceramic Wastes, Finite Element, Flexural Behaviour

1. Introduction

Concrete is ordinarily a composition of coarse aggregates, fine aggregates and cement binders. In concrete mixture, aggregates are the most important thing to use. This is because, aggregates produce some special connection between paste, in which it produces a very high quality of concrete strength. There are abundant issues regarding manufacturing of concrete, in which it gives negative effect to environment such as ecosystems damage due to products mining, mega extraction for resources, transporting and processing of cement. Nowadays, the advancement of construction industry area is

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growing rapidly in whole worldwide that makes increase demand for building materials. The dominant material that needs to have in concrete mixture is aggregate. However, to maintain the availability of aggregate in construction industry, it needs to undergo continuous mining that is bad for environment. In order to control this critical issue, green concrete has been adapted. This because it is low in cost as its only use waste products in its production. Moreover, green concrete can be classified as an environmental ethics in which it gives attention to all properties, starting from the process of raw supplies to mix design, infrastructure design and the buildings and service lives. There are few examples of waste that can be used to replace natural stone aggregates, which are, construction waste, agricultural waste, and ceramic waste [1].

Ceramic waste has been selected in this study; it is to modify mixture of concrete by replacing natural stone aggregates with ceramic waste coarse aggregates. In Malaysia, ceramic and sanitary waste is typically produced from industries in which it occurred before and during the phase of manufacturing due to flaws in design, human negligence or even insufficient raw supplies. Due to fast population size and speedy advancement of technology and people' attitudes, making it more difficult for community to practice waste disposal cycle as the waste is crucial to health and also it gives economic pressures because disposal cost is increasing [2]. Altogether, ceramic waste has strong physical composition and also its chemical properties became a successful and safe alternative to be adapted in concrete mixture. Concrete is the primary component element of several structures. Conduct of the concrete is non-linear and full in complexity. Increased use of computer-based design and simulation methods have also boosted the need for an accurate solution to the problems. This leads to problems in simulating and modelling concrete structures. A successful solution has been choosing for this project is to use the general intent of the Abaqus finite element program. The objectives of this study are to develop model for series of cube and prism beam of ceramic waste using Abaqus 6.14 software and also to analyse flexural behaviour of ceramic waste concrete under load.

2. Concrete

Concrete is ordinarily a composition of coarse aggregates, fine aggregates and cement binders. In concrete mixture, aggregates are the most important thing to use. This is because, aggregates produce some special connection between paste, in which it produces a very high quality of concrete strength. There are abundant issues regarding manufacturing of concrete, in which it gives negative effect to environment such as ecosystems damage due to products mining, mega extraction for resources, transporting and processing of cement. These lead to all scholars and decision makers put their heads together in investigating and fixing the massive deformations in climate that has already become a worldwide issue [3,4].

Concrete is a mixture that contains high volume of water that induces the alkaline wastewater, in which it contaminates the vegetation and waterways via infiltration. Depletion and disputable extraction are the main causes of the uncontrollable usage of natural aggregates and will increase the environmental problems such as landscape damage and ecosystem disturbance, air, water, and soil pollution. Hence, it is a crucial need to produce more economic sustainability of concrete elements. The manufacturing and application process of OPC that produces CO^2 is shown in Figure 1. The figure states limestone quarries during cement processing are one of the sources of CO^2 [4,5].

Figure 1: Shows main output and processes for OPC [5]

2.1 Green Concrete

Green concrete is a fundamental that used environmentally friendly concrete materials to magnify the system quality. Green concrete is low in cost to produce as waste material being used. Problems occur in many times due to continuous mining for the availability of course or fine aggregates. There is a solution to overcome the trouble, which is by practicing green concrete. It is an environment-thinking technique that take part in every element starting from raw supplies processing to design mix, the design of infrastructure, buildings and service lives. Green concrete is made from eco-friendly concrete. There a few advantages of green concrete, which are shown below [6,7], Figure 2.

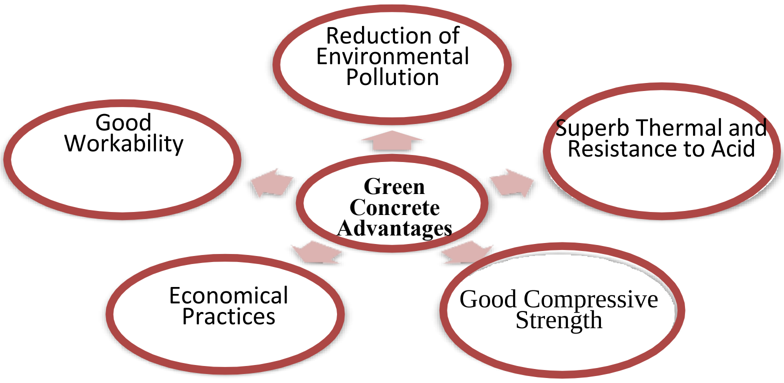


Figure 2: Advantages of green concrete, the new generation of concrete [6]

Waste from construction industry has been widely used as aggregates in the new generation of concrete. Moreover, agricultural waste also wants to be applied in manufacturing of concrete, such as palm oil industry waste along with the ash from palm oil fuel, waste from coconut industry and coir, also rice husks. Besides that, other than those two sources of waste, agricultural waste and construction waste, ceramic waste also a good quality product in which it offers the best values to use as the replacement either for fine aggregates or coarse aggregates [7].

2.2 Ceramic Wastes

Ceramic waste is typically produced from industries in which it occurred before and during the phase of manufacturing due to flaws in design, human negligence or even insufficient raw supplies. Huge amount of this is produced from transport and storage process. Ultimately, all of them are produced from houses demolition. The features of the products are different as they are going through in different processes of manufacturing. They are consequently incompetent for operation and give bad effect to ecosystem. Ceramic waste is a successful and safe alternative to be adapted in mixture of concrete because the materials itself have strong physical composition and chemical properties [8]. Partial aggregate replacement in concrete is an excellent potential use for recycled ceramic material on a large scale, hence, it can be used as the steps to minimise the massive amount of ceramic wastes. Moreover, this action will also reduce the usage of natural stone aggregate like river stone or crushed rock that collected from the earth and then transported to the construction site to be used as an important component in the mixture of concrete [9].

Figure 3: Example of ceramic wastes [8]

A series of past studies has conducted laboratory experiments to identify the suitability of ceramic waste to be applied as partial replacement to natural stone coarse aggregate in concrete mixture, Table 1. For first laboratory experiments, research paper done on ceramic waste aggregate with partial replacement of natural coarse and fine aggregates are 25.00 %, 50.00 % and 75.00 %. Fifty-four (54) cubes and twenty-one (21) cylinders were casted and tested to for physical and mechanical properties of concrete. Compressive strength test and modulus of elasticity were the test conducted. According to the experiments, it was recorded that 50.00 % recycled ceramic fine aggregates (CFA) and 75.00 % of ceramic coarse aggregate (CCA) produced higher compressive strength of concrete when compared to conventional concrete that used natural stone coarse and fine aggregate. So, making it applicable to be applied in concrete as the partial replacement of ceramic waste concrete. Unfortunately, the elastic modulus of concrete decreasing due to the higher value of ceramic waste used [8]. Moreover, a laboratory experiments was applied in four (4) concrete mixtures were prepared. Three (3) types of concrete mixtures with partial replacement of 0.00 %, 50.00 % and 75.00 % of conventional aggregate by the ceramic waste aggregate. No additive, admixture or plasticizer is used in this work. Moreover, the workability of ceramic concrete also reduced along with the increasing amount of ceramic waste aggregates in concrete mixture while for compressive strength recorded increased in value as the increase in ceramic waste content, which is on 75.00 % [9].

Next, laboratory experiment conducted by [10] where the replacement of coarse aggregate in concrete was investigated with three (3) different waste ceramic tile materials in the partial replacement of 20.00 %, 25.00 %, 35.00 %, 50.00 %, 65.00 %, 75.00 %, 80.00 % and 100.00 %. Four (4) cubes of size 150 x150 x150 mm to conduct compression behaviour of cube, while four (4) cylinders of diameter 150 x300 mm to test modulus elasticity, and lastly four (4) prism beams of size 500 x100 x100 mm to test flexural behaviour. The findings from this study states that it is successful research to use ceramic waste aggregate as 25.00 % coarse aggregate partial replacement in concrete, recorded higher strength compared to concrete control if the brittleness of concrete increased is not an important factor. Furthermore, another research was conducted by using 25.00, 50.00, 75.00, and 100.00 % of natural coarse aggregate. Concrete cubes with dimensions of 150 mm and cylinders of 100 mm x 200 mm were casted in the laboratory. According to [11], testing was conducted to measure compressive and split-tensile strength. Based on the result, it can be concluded that by replacing 100% natural coarse aggregate with ceramic waste coarse aggregate, the compressive and split-tensile strength of concrete would be increased. Fortunately, this eco-friendly initiative by using ceramic waste was highly recommended to be used as the replacement to natural coarse aggregate.

Fifteen (15) cubes where three (3) cubes specimen for each of 0.00 %, 25.00 %, 50.00 %, 75.00 % and 100.00 % were casted and tested for compressive strength and analysed to achieve the optimum percentage of partial replacement limit of ceramic waste coarse aggregate. The test result showed that the ultimate load carrying capacity was found maximum for 25.00 % replacement of ceramic waste aggregate at 28 days. Various other properties of ceramic waste aggregates made it suitable to be used as supplementary material coarse aggregate in concrete. According to the test executed by [12] it is observed that there is no significant difference in strength of concrete on 25.00 % partial replacement of ceramic waste aggregate with coarse aggregate, hence, it is quite clear that ceramic waste aggregate can be used to make concrete, and the environment will be saved to be greener.

Based on all the previous studies on ceramic waste concrete, two (2) studies recorded the same highest compressive strength, on 75.00 % replacement of ceramic waste aggregate. Modulus elasticity decreases for replacement of 25.00 %, 50.00 % and 75.00 % [8,9]. Next, the results of the third study show that it is sufficient to apply recycled ceramic coarse aggregate as 25.00 % replacement recorded higher strength compared to concrete control if the brittleness of concrete increased is not an important factor [10]. While for the fourth and fifth study recorded increased in compressive and split-tensile strength when applied 100.00 % replacement of ceramic waste aggregate, while the last study indicates the ultimate load carrying capacity was found maximum for 25.0 % replacement of ceramic waste aggregate [11,12].

Table 1: Previous studies on ceramic wastes concrete [8, 9, 10, 11, 12]

No.	Percentage Aggregate Replacement (%) / Journals	C	25	50	75	100	Testing Applied	Improvement done by ceramic waste concrete
1	Influence of industrial ceramic waste aggregates on elastic properties of concrete [8]	√	√	√	√		Elastic Modulus Strength	Strength increases as the highest at CCA75.
2	Experimental and analytical selection of sustainable recycled concrete with ceramic waste aggregate [9]	√		√	√		Density Flexural Test	Flexural strength increases from 3.4 MPa to 5.6 MPa in CCA75.
3	Mechanical properties of concrete utilising waste ceramic as coarse aggregate [10]	√	√	√	√	√	Flexural Test Elastic Modulus	Flexural strength recorded highest at CCA25.
4	Characterization of ceramic waste aggregate concrete [11]	√	√	√	√	√	Density Flexural Test	Flexural strength recorded highest value in CCA100.
5	Effective utilization of ceramic waste as a raw material in concrete [12]	√	√	√	√	√	Density Compression Test	Recorded maximum strength at CCA25.

2.3 Finite Element Method

Concrete is a three-phase composite at mesoscopic scale, in which it contains coarse aggregate, mortar matrix and interfacial zones. By using finite element method, concrete composite behaviour can be identified when generating random structure of aggregate which defines structure of mesoscopic of concrete. Besides that, by analysing the interaction between the three phases also can be used to study the concrete composite behaviour. A nonlinear finite element method suitable for mesoscopic study of concrete. First, it is needed to use a very fine mesh to properly demonstrate mesoscopic structure geometry, stress concentrations near crack tips are more closely reflected in the finite element results than in lower-level analysis. Furthermore, the finer the mesh is, the higher the stresses will be developed near to the tips of crack. Once the mesh used is very fine, stresses that is higher than tensile strength might be obtained, and the cracks formed could be unstable in the numerical analysis [15].

To sum up of all things showed in literature review, it can be concluded that it is definitely a must to practice green concrete as the concrete manufacturing effects to environment, in which it gives negative effect to environment such as ecosystems damage due to products mining, mega extraction for resources, transporting and processing of cement. These lead to all scholars and decision makers put their heads together in investigating and fixing the massive deformations in climate that has already become a worldwide issue. Moreover, the application of ceramic waste as coarse aggregate in concrete produce a lot of benefits and improvements to the compression and flexural behaviour of concrete itself, and this also can be proven by a lot of findings from previous studies. This study also develops cube and prism beam models in Abaqus software version 6.14.

3. Methodology

Mechanical properties that would be analysed in this study were, compressive strength and flexural strength in finite element method by using Abaqus software version 6.14. Cube modelling would be designed in Abaqus software for compressive strength while prism beam modelling for flexural strength. Three essential elements need to be inserted first, before start to modelling, which are Poisson's ratio, density and modulus elasticity of ceramic waste concrete. All these data in 0.00 %, 25.00 %, 50.00 % and 75.00 % of coarse aggregate partial replacement, are collected from a research study, conducted by [16]. For this study, the size of cube model used is 150 x150 x150 mm while prism beam model with dimensions of L=500 mm, W=150 mm, D=150 mm. Flowchart of methodology shown in, Figure 4.

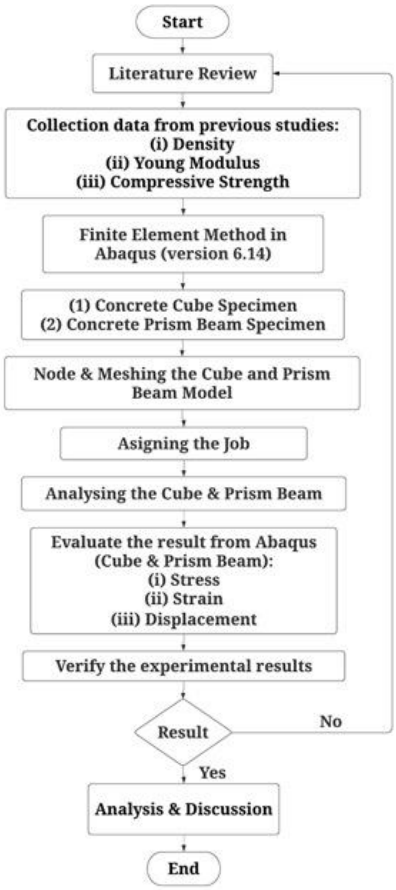


Figure 4: Flowchart of Methodology

3.1 Parameter of Experimental Study Assigning to Abaqus Model

All the data information below has been collected from two journals, the flexural strength of CCA75, Table 3, the highest percentage of partial replacement specimens recorded higher in value (5.6 MPa) when compared to the control concrete (3.40 MPa). This is possibly because of the properties of ceramic waste aggregate surface that the generation of the strong bonds on the rough and porous surfaces enabled the hydrated cement products to penetrate inside the voids, thereby contributing to increase bond strength.

Table 3: Concrete mixture proportions [8,16]

Mix Code	Grade Concrete	No. of days	Density of concrete (Kg/m^3)	Modulus elasticity (MPa)	Compressive strength (MPa)	Flexural strength (MPa)
CC	30	28	2307	27	37.39	3.4
CCA25	30	28	2268	18	34.18	3.8
CCA50	30	28	2238	17	35.17	5.2
CCA75	30	28	2223	15	40.70	5.6

Note: CC=Control Sample, CCA25=Ceramic Coarse Aggregate-25%, CCA50= Ceramic Coarse Aggregate-50%, CCA75=Ceramic Coarse Aggregate-75%

4. Results and Discussions

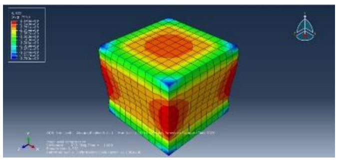
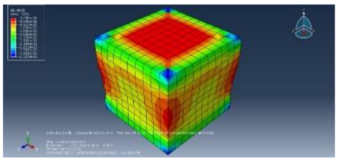
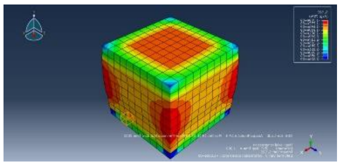
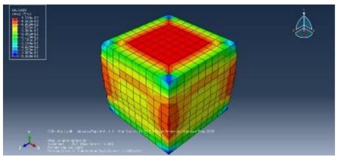
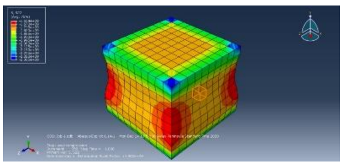
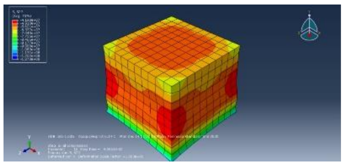
The finite element method data output on concrete cube and concrete prism beam in which was integrated by using parameter of a composite replacement in concrete using ceramic waste was collected and simulated in Abaqus/CAE as a medium. The result of the study is essentially focus on the simulation of cube deformation and the relationship of stress strain for the model of concrete cube and concrete prism beam specimen.

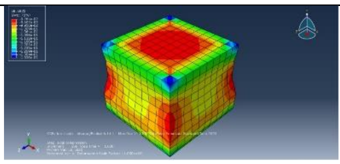
4.1 Stress-strain Deformation of Concrete Cube

Cube deformation for stress can be defined as stresses either compressive or tensile. The variable parameter for chosen materials is according to their ability in resisting compressive forces, based on the application. For detail, concrete has strong endurance to compression but relatively weak in enduring tension. Stress deformation for concrete cube model of 0.00 %, 25.00 %, 50.00 % and 75.00 % will be demonstrated below in Table 4. Strain is a transition in the length of its original shape when compared with after any fusion of different variation in the materials. Strains deformation in concrete cube are the volume reduction of cube concrete model after the application of loading which change the volume with respect to volume of concrete before applied loading.

From cube models in Figure 5, 6, 7, and 8 below, showed four (4) types of colour indicator, which are blue, green, yellow and red. Blue colour indicated for low stress or strain level area imposed on the concrete cubes, while both of green and yellow colours indicated for medium stress or strain level area imposed on the concrete cubes. Lastly, red colour indicated for high stress or strain level area due to the dispersion of stress or strain in concrete cubes due to the imposed load from above. However, all the colour indicators only used to show the intensity of stress or strain in each area of concrete cubes due to the high load imposed from above.

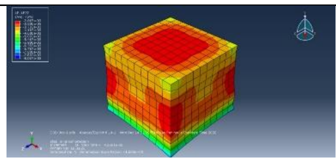
Table 4: Stress-strain Deformation of Concrete Cube Models

Stress-strain Deformation of Concrete Cube Models.	
(1) Stress-strain Deformation of CC  (a)  (b) **Figure 5: (a) Stress Deformation of CC, (b): Strain Deformation of CC**	(2) Stress-strain Deformation of CCA25  (a)  (b) **Figure 6: (a) Stress Deformation of CCA25, (b): Strain Deformation of CCA25**
(3) Stress-strain Deformation of CCA50  (a)	(4) Stress-strain Deformation of CCA75  (a)



(b)

Figure 7: (a)Stress Deformation of CCA50, (b): Strain Deformation of CCA50



(b)

Figure 8: (a)Stress Deformation of CCA75, (b): Strain Deformation of CCA75

4.2 Stress-strain Deformation Graph of Concrete Cube Model

From previous study, CCA75 produced higher flexural strength compared to the concrete control and the highest among the other partial percentage. These were possibly because of the surface properties of the ceramic waste aggregate where one side was very rough and highly porous, due to the presence of the clay, while the other side was glassy and less porous. Due to its rough and porous surfaces, stronger bonds produced in which enabled the hydrated cement products to penetrate inside the voids, hence, increase the bond strength. The chemical bonds resulted to a higher strength and possible pozzolanic effect to the ceramic waste aggregate compared to the natural aggregate and improving the flexural strength of the ceramic waste concretes [8,16].

However, for this study, Figure 9 below, the stress and strain result achieved for concrete cube modelling from the simulation in Abaqus is different from the previous study result. The stress for CC of cube model remains the highest stress, where the peak stress is. The lowest stress from the figure below is CCA75. This happened because, stress will be reduced by increasing the amount of ceramic waste. The main reason for strength reduction of ceramic waste concrete when the amount of ceramic waste coarse aggregates increase, can be the fact that the ceramic waste aggregates have inadequate strength and stiffness compared to natural stone aggregates. The existence of ceramic waste in the concrete lead to the enlargement of the area and creation of a weak transition zone between the aggregates and cement paste.

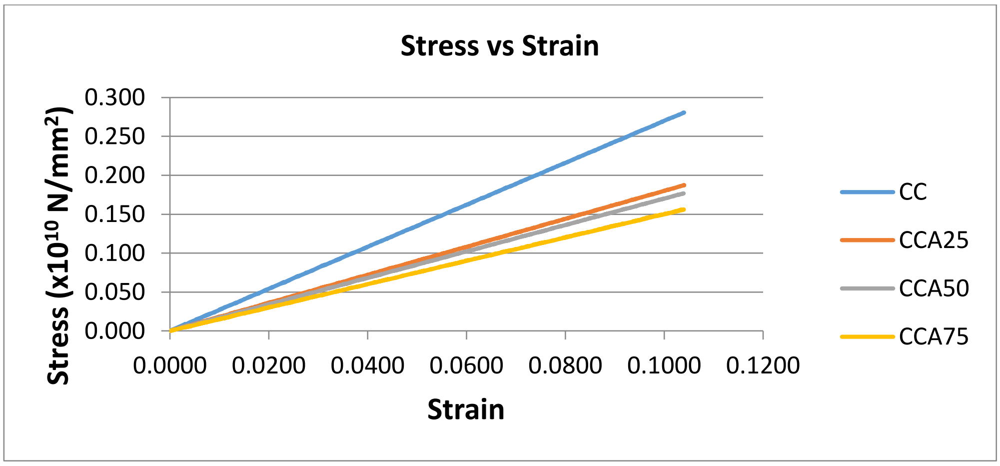


Figure 9: Graph of stress against strain for concrete cube model

From Table 5, CC recorded stress in 0.281 $\times 10^{10}$ N/mm^2 and 0.1040 strain, which was the highest among the other percentage as CC was not containing ceramic waste aggregate and the normal concrete texture did not get damaged by other substitution. CCA25 recorded stress in 0.187 $\times 10^{10}$ N/mm^2 and 0.1040 strain. CCA50 recorded stress 0.176 $\times 10^{10}$ N/mm^2 while CCA75 recorded stress 0.156 $\times 10^{10}$ N/mm^2 with 0.1040 strain. CCA75 recorded the lowest value of stress due to increasing amount of ceramic waste coarse aggregate where the ceramic waste aggregates had inadequate strength and stiffness compared to natural stone aggregates, hence increased the area of concrete that would create a weak transition zone between the aggregates and cement paste.

Table 5: Result data of stress and strain from Abaqus simulation for all concrete cube models

Percentage Replacement (%)	Strain	Stress (x10^{10} N/mm^2)
0	0.1040	0.281
25	0.1040	0.187
50	0.1038	0.176
75	0.1040	0.156

4.3 Displacement-time Deformation Graph of Concrete Cube Model

Displacement-time graph shows on how the changes of displacement for a moving object against the time. The object is stationary (not moving due to the displacement does not change) when a horizontal line appears on the displacement-time graph. While the object is moving if a sloping line appears on the displacement-time graph. Moreover, the slope or gradient of the line on a displacement-time graph, is equal to the object velocity. The steeper the line, the faster the object is moving.

From Figure 10, the value of R2 for the CC graph below was 0.9997, which was close to 1 or the value is 1. This showed that the line corresponding with the data recorded an almost a linear line. The linear equation of CC graph was y = 5.0055x - 0.0032.

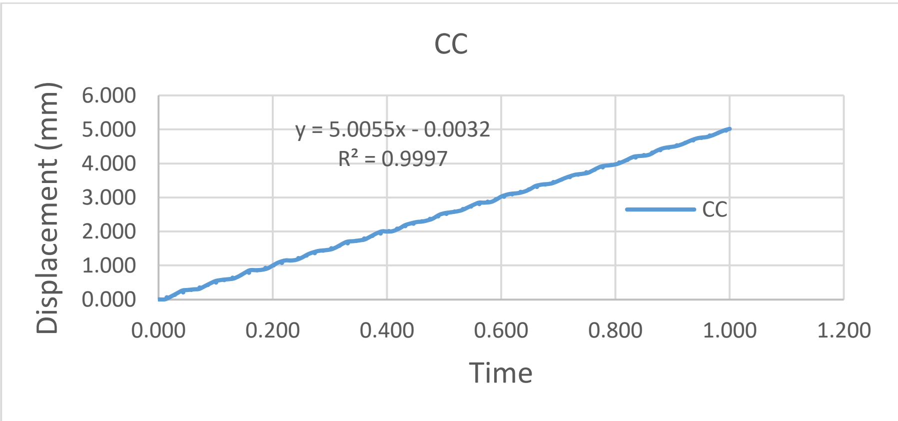


Figure 10: Graph of displacement against time for CC cube model

Figure 11 showed the value of R2 for the CCA25 graph below was 0.9995, which was close to 1 or the value is 1. This showed that the line corresponding with the data recorded an almost a linear line. The linear equation of CCA25 graph was y = 5.0034x - 0.0021.

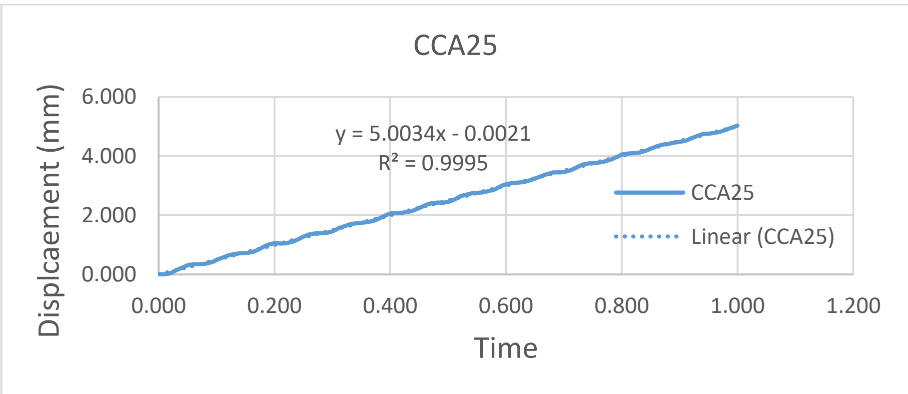


Figure 11: Graph of displacement against time for CCA25 cube model

Figure 12 showed the value of R2 for the CCA50 graph below was 0.9994, which was close to 1 or the value is 1. This showed that the line corresponding with the data recorded an almost a linear line. The linear equation of CCA50 graph was y = 5.0026x - 0.0025.

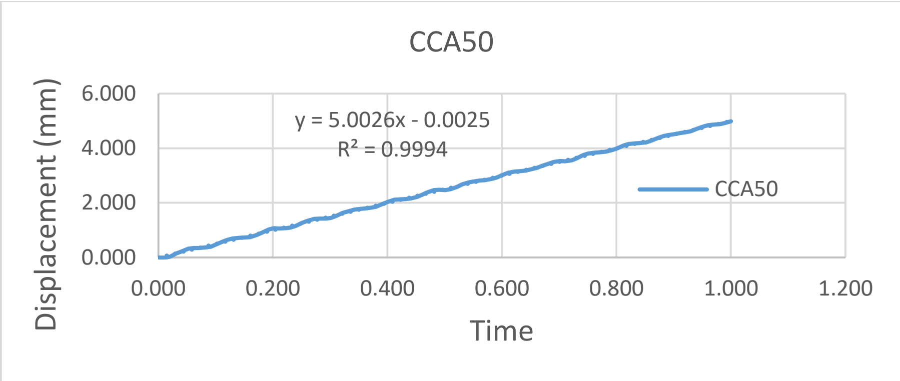


Figure 12: Graph of displacement against time for CCA50 cube model

Figure 13 showed the value of R^2 for the CCA75 graph below was 0.9994, which was close to 1 or the value is 1. This showed that the line corresponding with the data recorded an almost a linear line. The linear equation of CCA75 graph was y = 5.0018x - 0.0016. All the linear equations of graph recorded difference in its value as the percentage of ceramic waste aggregate replacement was different to each other. Meaning that, there was still a slightly difference between those ceramic waste aggregate partial replacement.

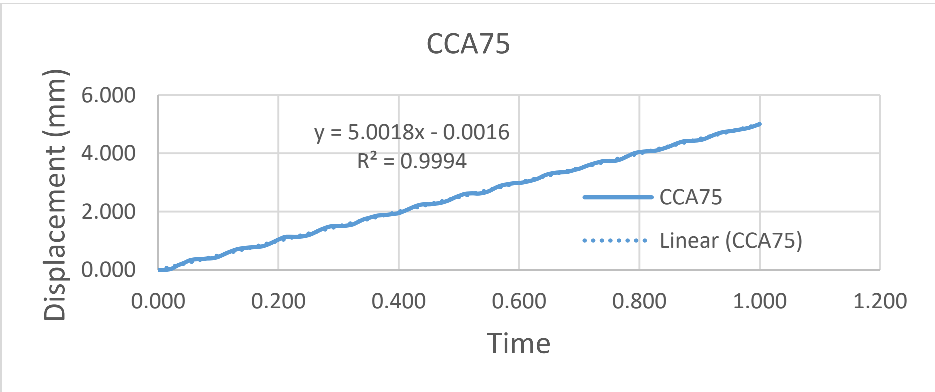


Figure 13: Graph of displacement against time for CCA75 cube model

Based on Figure 14 below, it showed there was only a small difference between all the ceramic waste concrete due to lack of parameter obtained in developing concrete cube models. The parameter that could not be obtained were concrete damage plasticity which it covers concrete plasticity, compressive and tensile behaviour such as yield stress, viscosity parameter, inelastic and also the cracking strain of concrete cubes. All those reasons lead to the incomplete output of concrete cube models as it was hard for Abaqus to run analysis with only few parameters, hence producing minimum differences of displacement between concrete cube models. However, for displacement result achieved in this study, for concrete cube modelling from the simulation in Abaqus is different and also not followed the pattern from the previous study result. As for previous study, CCA75 produced higher flexural strength, lower strain value compared to the concrete control and the highest among the other partial percentage.

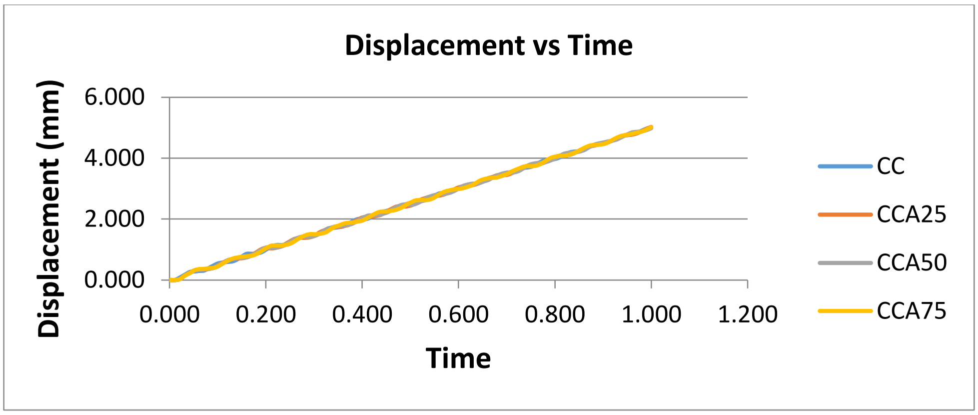


Figure 14: Graph of displacement against time for cube model

Table 6 showed displacement value recorded on 50.00 % partial replacement of ceramic waste coarse aggregate with 4.980 m, the lowest displacement among the others. While displacement recorded the highest for 25.00 % ceramic coarse aggregate, 5.028 m. CC recorded as 5.017 m and 75.00 % partial replacement of ceramic waste concrete recorded displacement as 5.011 m. By decreasing value of displacement, then the value of strain would also decrease that would be resulting concrete in a good condition for application.

Table 6: Result data of displacement and time from Abaqus simulation for all concrete cube models

Percentage Replacement (%)	Time	Displacement (m)
0	1.000	5.017
25	1.000	5.028
50	1.000	4.980
75	1.000	5.011

4.4 Stress-strain Deformation Graph of Concrete Prism Beam Model

From previous study, CCA75 produced higher flexural strength compared to the control concrete and the highest among the other partial percentage. These were possibly because of the surface properties of the ceramic waste aggregate where one side was very rough and highly porous, due to the presence of the clay, while the other side was glassy and less porous. Due to its rough and porous surfaces, stronger bonds produced in which enabled the hydrated cement products to penetrate inside the voids, hence, increase the bond strength. The chemical bonds resulted to a higher strength and possible pozzolanic effect to the ceramic waste aggregate compared to the natural aggregate and improving the flexural strength of the ceramic waste concretes [8,16].

Next, for the second model of this study, which was prism beam modelling, Figure 15 below, showed the stress and strain result achieved for concrete beam modelling from the simulation in Abaqus is different from the previous study result. The stress for CC, CCA25, CCA50 and CCA75 of prism beam model recorded the same value, which was 2560 N/mm^2, meaning that there would be no peak stress as all the stress value recorded the same. However, there would be few differences on strain value for each partial replacement.

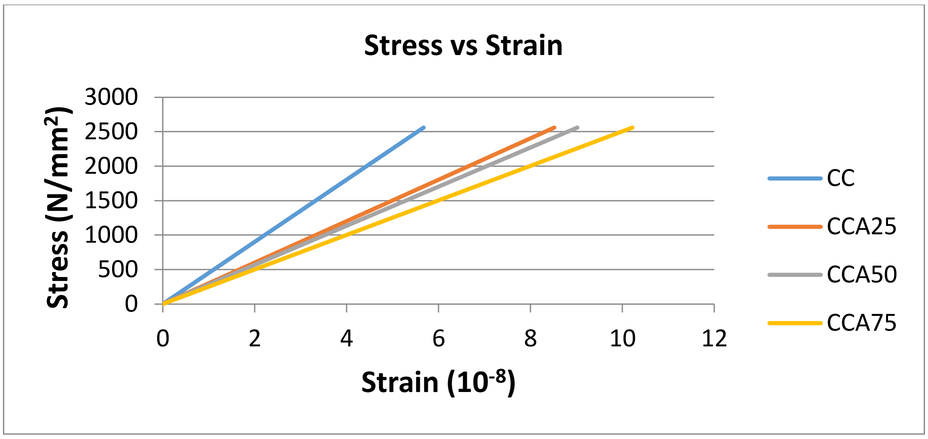


Figure 15: Graph of stress against strain for concrete prism beam model

From Table 7 below, the stress for CC, CCA25, CCA50 and CCA75 of prism beam model recorded the same value, which was 2560 N/mm^2. However, the strain value for CCA75 of prism beam model recorded the highest, with 10.219 x 10^{-8}. Meaning that the highest strain recorded, the lowest practicable of prism beam concrete model. This is because, if the concrete model recorded high strain value, then the model itself would be easily elongated and not able to restrain high load imposed on it.

Table 7: Result data of stress and strain from Abaqus simulation for all concrete prism beam models

Percentage Replacement (%)	Strain (10^{-8})	Stress (N/mm^2)
0	5.677	2560
25	8.516	2560
50	9.016	2560
75	10.219	2560

4.5 Displacement Deformation Graph of Concrete Prism Beam Model

Displacement-time graph shows on how the changes of displacement for a moving object against the time. The object is stationary (not moving due to the displacement does not change) when a horizontal line appears on the displacement-time graph. While the object is moving if a sloping line appears on the displacement-time graph. Moreover, the slope or gradient of the line on a displacement-time graph, is equal to the object velocity. The steeper the line, the faster the object is moving.

Based on Figure 16 below, it showed there was also a slightly difference between all the ceramic waste concrete. However, for displacement result achieved in this study, for concrete cube modelling from the simulation in Abaqus is different and also not followed the pattern from the previous study result. From previous study, CCA75 produced higher flexural strength, lower strain value, compared to the control concrete and the highest among the other partial percentage.

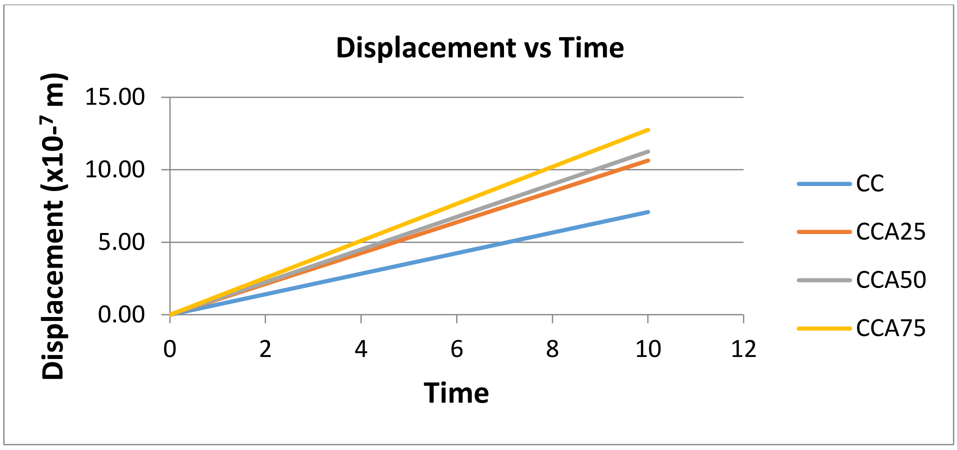


Figure 16: Graph of displacement against time for prism beam model

Table 8 showed displacement value recorded on 0.00 % partial replacement of ceramic waste coarse aggregate with 7.09 x 10^{-7} m, the lowest displacement among the others. While displacement recorded the highest for 75.00 % ceramic coarse aggregate, 12.76 x $^{10-7}$ m. CC recorded as 7.09 x 10^{-7} m and 75.00 % partial replacement of ceramic waste concrete recorded displacement as 12.76 x $^{10-7}$ m. By decreasing value of displacement, then the value of strain would also decrease that would be resulting concrete in a good condition for application. For this graph of displacement against time showed that CC for prism beam model was still produced better result when compared to the other ceramic aggregate partial replacement in prism beam model.

Table 8: Result data of displacement and time from Abaqus simulation for all concrete prism beam models

Percentage Replacement (%)	Time	Displacement (x10^{-7}m)
0	10	7.09
25	10	10.63
50	10	11.25
75	10	12.76

5. Conclusion

Two types of models had been successfully being developed in this study, which were cube model and prism beam model of ceramic waste concrete by using Abaqus software version 6.14. However, the models that were being conducted in the Abaqus software, produced different pattern results for ceramic waste concrete cube and ceramic waste concrete prism beam, by referring to previous data study. The stress value of concrete cube CCA75 recorded the lowest compared to normal concrete and others partial percentage replacement, while recorded the same value in strain. This is due to increasing amount of ceramic waste coarse aggregate where the ceramic waste aggregates had inadequate strength and stiffness compared to natural stone aggregates, hence increased the area of concrete that would create a weak transition zone between the aggregates and cement paste. Next, concrete cube displacement of CCA50 recorded the lowest value among the others and this would-be resulting concrete in a good condition for application. While for all prism beam models, recorded the same values in stress, only showed differences in strain value, where CCA75 recorded the highest strain value. Same goes to prism beam concrete displacement, CCA75 also recorded the highest displacement among others. Meaning that the highest strain recorded, the lowest practicable of prism beam concrete model. This is because, if the concrete model recorded high strain value, then the model itself would be easily elongated and not able to restrain high load imposed on it.

There are still needed to have a lot of improvement to be taken in order to make more reliable and acceptable results and outcomes. Recommendations for optimising the outcomes are as follows:

- In order to execute and export various graphs and shapes of the model from Abaqus simulation, it is needed to find and collect more or use different data information (input data) from previous study or even a laboratory experiment.
- Use the latest version of Abaqus software in order to get the latest features and make the data analysis progress running smoothly.
- It is recommended to have a lot of training and practice to use Abaqus simulation so that we can understand the usage, technique and flow of Abaqus software. Hence, make it easier to stimulate various kind of models other than cube and prism beam models.

Acknowledgement

This author would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, for its support.

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