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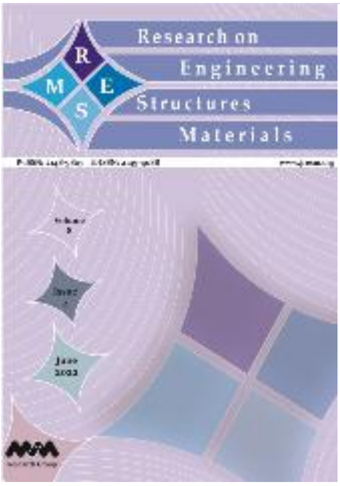

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Online Publication Date: 10 March 2023

URL: http://www.jresm.org/archive/resm2022.483st0723.html

DOI: http://dx.doi.org/10.17515/resm2022.483st0723

Journal Abbreviation: *Res. Eng. Struct. Mater.*

To cite this article

Pawar L, Sangle KK, Bhirud YL. Experimental investigation along with 3-D Finite Element Analysis to determine the stress bearing ability of concrete containing waste plastic aggregates. *Res. Eng. Struct. Mater*., 2023; 9(3): 1081-1099.

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Research Article

Experimental investigation along with 3-D Finite Element Analysis to determine the stress bearing ability of concrete containing waste plastic aggregates

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Article Info

Article history:

Received 23 Jul 2022
Accepted 06 Mar 2023

Keywords:

Design management; Geometric modeling; Engineering analysis; Finite Element Method

Abstract

Earth is becoming more and more polluted as a result of the unrelenting growth of plastic garbage in land surface. Also, plastic wastes are regarded as the most hazardous of the wastes produced in today's society because they take a long time to biodegrade and account for 85% of all garbage produced globally. However, the use of these plastic waste products in the building sector can help to alleviate the strength of the concrete structures while lowering the current environmental issues. Hence, in this research aggregate waste plastics were added to the concrete mixture to increase the strength of the concrete. In which aggregate waste plastics are added to the concrete mix in three different types of structures like cube, cylinder and beam which are then checked for its mechanical properties using compressive test, split tensile test, and flexural test respectively. Finally, the strength of concrete at various plastic proportions with three different structures under varying loading conditions is investigated using Finite Element Method (FEM) in Abaqus software and the results are discussed and the optimal specimen of the concrete mixture are determined. The result obtained showed high compressive, splitting tensile, and flexural strength values of concrete since coarse particles are replaced with plastic in amounts of 10%, 20%, 30 % and 40% which outperforms traditional mix that have higher percentages of more than 40% plastic waste, indicating the worst-case scenario in mechanical properties.

1. Introduction

The ever-increasing volume of solid waste items all across the world has provided a new waste management dilemma. Waste management that is insufficient and inefficient, pollutes the environment and harms water and land. Plastic-based solid waste products account for a significant portion of all waste materials created across the world [1]. Polyethylene is the most common type of plastic waste, followed by polypropylene, polyethylene Terephthalate, and polystyrene [2]. Fortunately, waste plastics may be reused or turned into other goods in a variety of ways by recycling. Recycling is the act of converting waste materials into new goods in order to avoid wasting potentially useful materials [3]. The economy and the environment would benefit by replacing plastic resources with recycled or discarded products. Different sorts of waste plastic, for example, are produced on a daily basis, with the bulk of it ending up in open areas and landfills which can be incorporated into concrete [4]. The use of waste metalized plastic fibers in the manufacturing of concrete has shown a path toward sustainable and green building, with the added benefit of a safe waste plastics disposal option [5]. Consequently, waste plastic has demonstrated that the features of plastics are suitable for the production of new concrete, subject to certain constraints. With the growing need for concrete in

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DOI: http://dx.doi.org/10.17515/resm2022.483st0723

building sites, these resources are also becoming increasingly scarce, necessitating the search for alternatives [6].

Concrete cracks are regarded as a leading sign of structural degradation and long-term durability. In most developed nations, crack examination is a standard part of routine maintenance [7]. The cracking behavior of concrete has an impact on the load capacity of concrete structures [8]. The cracking pattern is linked to failure modes ranging from flexural to flexural-shear failure, affecting in load failure. Even if concrete offers various advantages, including high compressive strength, toughness, and other long-term durability chacterstics. Concrete, on the other hand, is a brittle substance with low tensile strength [9]. However, adding fibers to concrete can help overcome these flaws, resulting in more ductile concrete with narrower fissures. Reduced fracture width reduces the entry of hostile species into concrete, improving its durability. Asbestos, rubber, glass, plastic, and bamboo fibers are some of the fibers that can be added to the concrete mix. Recently, there is being much research going on the use of recycled garbage and virgin plastic components in traditional concrete. Plastic fibers may be made from both new and recycled materials [10-14]. Especially, waste plastics can be used with concrete in two ways: as plastic fibers in fiber-reinforced concrete and as plastic aggregate in place of natural aggregates (coarse or fine) [15].

Jainet et al [16] investigated the workability, density, compressive and flexural strength, water permeability, static and dynamic modulus of elasticity, and abrasion resistance properties of concrete by adding different percentages (0,0.1,1,2,3, and 5%) of waste plastic bags by weight of concrete is a non-structural concrete additive that used in non-structural projects. Such modified concrete appears to be a particularly environmentally beneficial form of WPB disposal that minimizes natural resource loss. Building park benches, stone curbs, temporary buildings, roads, pathways, and concrete barriers are all examples of scenarios where their modified concrete is used. This enhanced concrete can also withstand freeze-thaw cycles. However, their work further needs to include a durability test. Samuel et al [17] experimentally tested the PET pulverized mix with the concrete. In concrete, crushed PET was used in percentages of 5%, 10%, and 15% by weight of conventional fine aggregate. There were four distinct types of concrete specimens made, as well as a control. After 3 days, 7 days, 14 days, and 28 days of curing, the flexural and compressive strengths of the concrete specimens were measured. The concrete specimen with 5% PET by weight exhibited higher compressive strength than the other specimens, according to the findings. However, the experiment did not look into the mechanical impact of the specimens due to higher load gradients.

Wu et al [18] presented a new test method for measuring the complete load-displacement curve of concrete under mixed mode I-II fracture. For their project, three-point bending beams with a multi-segment notch in the midspan were used. The notch depth ratio of the first segment and the inclination angle of the last segment affected the ratio of stress intensity factors. Following the recommended strategy to get the whole load vs. displacement curves for the KII/KI ratio up to 1.23 was less difficult than using the current testing methods. The complete crack propagation process was replicated using the finite element approach and their result are found. However, the stress and strain did not take their work. Rohden et al [19] their research looked at the possibility of using hard-to-recycle plastic waste as a polymeric component in high-strength concrete, with a focus on the capacity to reduce heat-induced spalling and its impact on mechanical properties. The garbage correlates to soft and hard plastic, particularly domestic polymers, which are typically disposed of in landfills while being theoretically recyclable. Mechanical and physical properties, cracking, mass loss, and the incidence of spalling in high strength concrete samples constructed with either plastic waste or polypropylene fibers were tested after a 2-hour exposure to 600 C. In addition, the effect of plastic aggregate-produced concrete on beam structures and other structural parts must be investigated. However, for [16] durability test is needed, for [17] experiment did not look into the mechanical impact of the specimens due to higher load gradients, for [18] stress and strain did not take their work, and for [19] the effect of plastic aggregate produced concrete on beam structures and other structural parts must be investigated. The main contributions of this paper are as follows: Improve the strength of concrete under a heavy load by adding plastic wastes with polycarboxylic-based super plasticizers as aggregate. Investigating the mechanical behavior of concrete with various proportions of waste plastic aggregate using various strength tests using three different shaped structures. Thus determining the optimal addition of plastic reinforcement to improve the strength of concrete structures.

2. Experimental Program

2.1. Materials and Methods

This research investigated the binder made out of Portland cement (CEM II 52.5 R) and plastic waste. The sand-to-binder ratio was set at 0.4. Silica sand with a mesh size of 106 to 120 lm (120 to 150 mesh) was included in the mix. A polycarboxylic-based superplasticizer was present in all of the combinations (30 percent solid content). To explore the influence of plastics on the load resistance of concrete with appropriate workability of the new mixture and aggregate plastic dispersion, the concrete was prepared with 0 to 40% plastic wastes to get adequate ductility. After being ground and melted, the post-consumption waste plastic is collected and chopped into little pieces. After cooling, the same particles are utilized as coarse aggregate in concrete. The diagram of plastic wastes aggregate is depicted in Figure 1.

Fig. 1. Plastic wastes aggregate

2.2. Materials and Methods

To produce the specimens, five different proportions of plastic waste were mixed into the concrete: 0%, 10%, 20%, 30%, and 40%, respectively. The 0% represents pure concrete specimens that have not been contaminated with plastic waste. The specimens were created and tested in order to evaluate the effects of incorporating plastic trash into traditional concrete. The above-mentioned proportions are used to make three sorts of specimens: a cube, a cylinder, and a beam specimen. The cube is prepared with dimensions 150x150x150 mm^3 so that the surface area of the cube is 135000 mm^2. The cylindrical specimen is made with dimensions having a diameter of 150 mm and height of 300 mm with a surface area of 176625 mm^2 and the beam is made with dimensions 150x150x700 mm3. The diagram of fabricated specimens is a) Cube b) Cylindrical specimen and c)

Rectangular beam are depicted in Figure 2. The chemical and physical properties of the Portland cement and silica sand are tabulated in Tables 1 and 2.

Fig. 2. Fabricated specimens (a) cube (b) cylindrical specimen and (c) rectangular beam

Table 1. Chemical properties of portland cement and silica sand

Chemical Composition	Portland Cement	Silica Sand
Calcium Oxide (CaO)	63.40	0.02
Silicon Dioxide (S_iO_2)	21.60	99.79
Aluminum Oxide (Al_2O_3)	4.45	0.06
Sulphur Trioxide (SO_3)	1.92	-
Ferric Oxide (Fe_2O_3)	5.35	0.02
Magnesium Oxide (MgO)	1.65	0.01
Sodium Oxide (Na_2O)	0.11	0.02
Potassium Oxide (K_2O)	0.22	0.01
Loss of Ignition (LOI)	0.78	0.07

Table 2. Physical properties of portland cement and silica sand

Physical Properties	Portland Cement	Silica Sand
Initial setting time (minutes)	170	5.75 min for 20% SF
Final setting time (minutes)	225	16.50 min for 20% SF
Specific gravity	3.10	2.60
Blaine specific surface area(m^2/kg)	340	—
28-day compressive strength(MPa)	42.5	20.70

2.3 Testing Methods

The cube concrete samples were made according to BS EN 12390-2, 3:2009. After 24 hours, the concrete cubes were removed and submerged in water for 90 days. The cubes were then removed from the water tank and dried at room temperature, with the mass of the specimens being monitored until they achieved a stable weight. The initial mass of all concrete specimens was measured before the thermal exposure test, and the specimens were subsequently evaluated for a non-destructive UPV test using ASTM C597-0 criteria. Morever , the proposed cube specimens, cylindrical specimens, and rectangular specimens are checked the compressive strength, flexible strength, and split tensile strength by using a compressive testing machine and a universal testing machine. The compressive strength test was performed on the compressive testing machine. The compressive strength of all samples increased with the increase of curing age. The mechanical characteristics of the newly tested concrete were determined using three types of specimens, as shown in Table 3.

Table 3. Three types of specimens.

Specimen Shape	Dimensions	Type of Test
Cubes	150x150x150 mm^3	Compressive strength test
Cylinders	150 x300 mm	Split tensile strength test
Rectangular Beams	150x150x700 mm^3	Flexural strength test

2.3.1 Compressive Strength Test

The primary mechanical characteristic required in the construction of concrete buildings is compressive strength, which is one of the most essential qualities of concrete. Concrete compressive strength is determined by adding aggregate plastic dispersion with 0% to 40 %. Each strength test was performed on five cube specimens, with the average taken. The compressive strength was measured at different temperatures such as 35°C, 600°C, and 800°C. The compression test setup of the cube specimen is depicted in Figure 3. The compressive strength of the specimen is calculated using the formula

$$CT = p/A \quad (1)$$

Where

p – Maximum load

A – Cross-sectional area of the material resisting the load

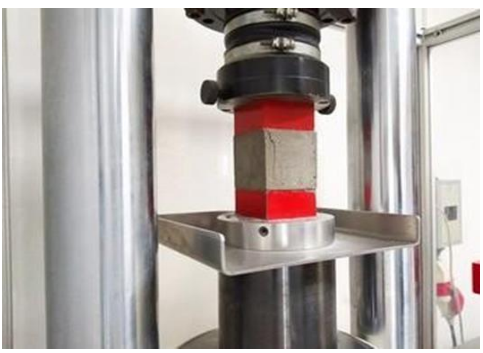


Fig. 3. Compression test setup of cube specimen

2.3.2 Flexural Strength Test

Flexural testing is performed to assess a material's flex or bending qualities. It entails inserting a sample between two points or supports and beginning a load with a third point. The proposed beam has 3 points and the dimensions are 150 × 150 × 150 with load at the center. Each strength test was performed on four cube specimens, with the average taken. Flexural strength was tested using flexural strength testing equipment, and it was found that flexural strength had been reduced by adding the waste plastic aggregates. The Flexural strength test setup of the beam specimen is depicted in Figure 4. The flexural strength of the beam is calculated using the formula

$$FS = pL/wf^2 \quad (2)$$

Where

p – Maximum load

L – supported length (cm)

w – Width of the specimen (cm)

f – failure point depth (cm)

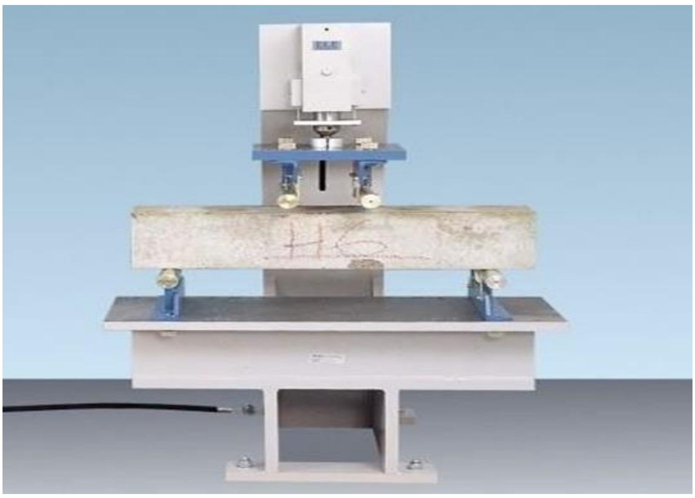


Fig. 4. Flexural strength test setup of beam specimen

2.3.3 Split Tensile Strength

A cylindrical specimen with a diameter of 150 mm and a length of 300 mm was used to test split tensile strength. The split tensile strength test setup of the cylindrical specimen is depicted in Figure 5. The specimen's split tensile strength is computed using the equation

$$T = 2\,p\,/\pi ld \quad (3)$$

Where

p – max applied load indicated by the testing machine

l – length of the specimen in mm

d – diameter of the specimen in mm

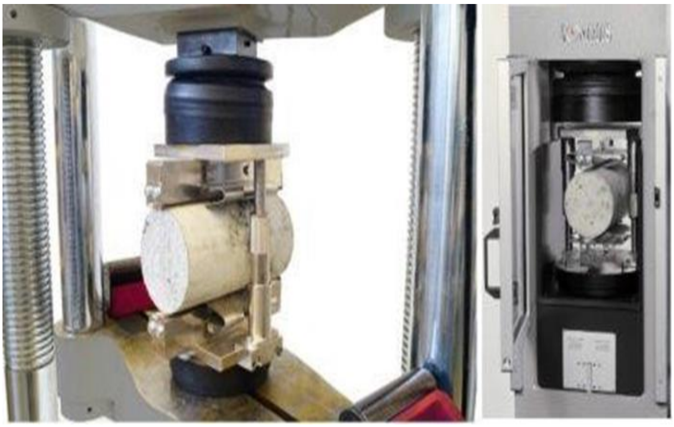


Fig. 5. Split tensile strength test setup of a cylindrical specimen

The 3D finite element analysis has been carried out for the proposed plastic waste aggregation mixture. The model is simulated on Abacus 6.14-5 with Windows 10 and a 64-bit processor considering 8 GB of RAM.

3. Results and Discussion

The compressive strength, flexural strength, and split tensile strength of the proposed plastic waste aggregation mixture have been evaluated. In addition to the experimental work in the laboratory, the 3D finite element analysis has been carried out through Abaqus software, which is presented in this section to describe model parameter of three types of specimens such as cube, cylinder, and Beam are depicted in Table 4.

Table 4. Model parameter of three types of specimen

Model parameter	Cube	Cylinder	Beam
Length (mm)	1	200	700
Width (mm)	1	-	150
Height (mm)	1	-	150
Radius (mm)	-	50	-

The mesh size depends on total number of nodes and total number of elements which are 313120 and 28320, respectively and General 3D solid, C3D4 is the element type. In order to add plastic aggregate to concrete, 0.3% of steel fibre by weight of cement is added to provide bonding between the concrete and plastic aggregate.

3.1 Experimental Test Results

The results of compressive strength, flexural strength, and split tensile strength for all types of concrete members experimentally were summarized in Tables 5, 6, and 7, the first group of specimens was tested with 0% waste plastic aggregate in order to be reference values for comparing other results. The waste plastic aggregate was mixed with proportions gradually starting from 10,20,30 reaching up to 40% then these samples were tested to find the effect of adding the waste plastic aggregates. Overall compressive strength of concrete is improved by adding 30% of plastic in mixture which reach maximum range of 36.59% compared to 0%. The compressive, tensile, and flexural strength s increased when comparing the results without adding waste plastic aggregates.

The increasing strength of a) cube, b) cylinder, and c) beam specimens are depicted in Figure 6.

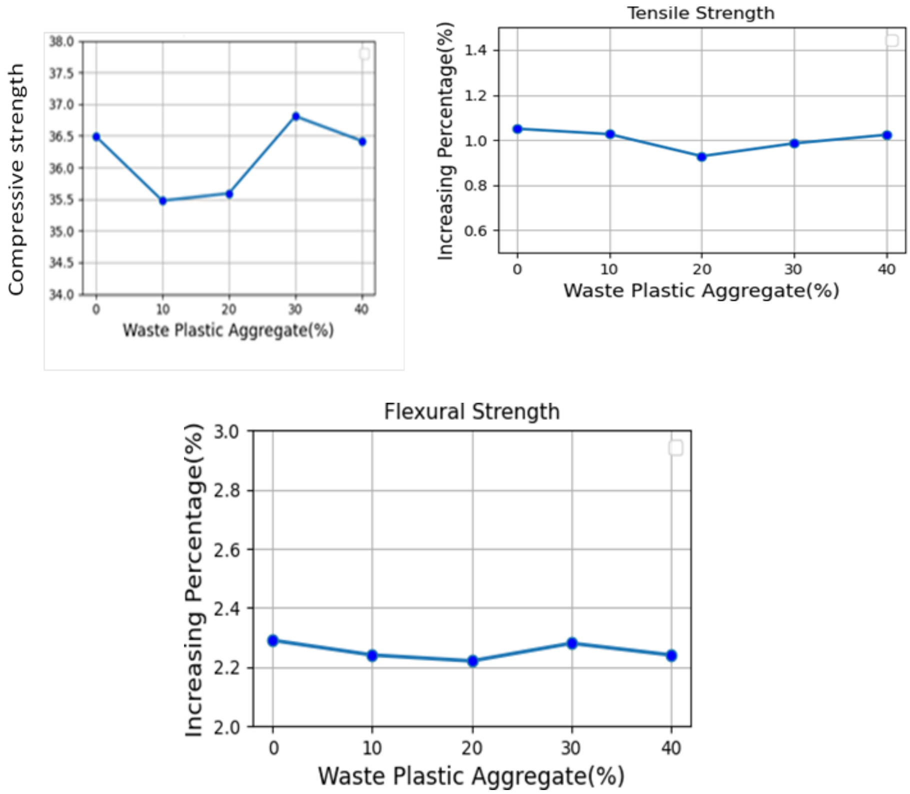


Fig. 6. Strength of cube, cylinder, and beam specimens

The graphs plotted in Figure 6 represent the strength of the cube, cylinder, and beam specimens at 35 degrees Celsius for 0%, 10%, 20%, 30%, and 40 % plastic addition. The specimens were kept at 35 degrees Celsius and weighed a maximum of 9.44 kg with no plastic added therefore the increasing strength of cube, cylinder, and beam in 0% waste plastic aggregate was 36.49%, 1.06%, and 2.29% respectively. Similarly, for 10 % addition, the maximum weight is 9.32 kg for 35°C the strength of the cube, cylinder, and beam are 35.47%, 1.02%, and 2.43% respectively. The strength of percentage for the 20% addition of waste plastic aggregate and the maximum weight is 9.20 kg in cube, cylinder, and beam specimens are 36.81%, 0.985%, and 2.289% respectively. The strength percentage for the 30% addition of waste plastic aggregate and the maximum weight is 9.08 kg in cube, cylinder, and beam specimens are 36.81%, 0.985%, and 2.289% respectively. Moreover, 4 0 % of additional plastic waste aggregate the maximum weight is 9.43% in cube, cylinder, and beam specimens 36.42%, 1.02%, and 2.24% respectively. The physical characteristics of the parameters are quantified in the cube material model are density, young's modulus, and Poisson ratio have values of 7.8E-008, 210000, and 0.33, respectively. Graphical representation and table of compressive strength test on the cube are shown in Figure 7 and Table 5.

Figure 7 shows the compressive strength test graph for the cube concrete with added waste plastic aggregates (10%, 20%, 30%, and 40%) specimen for 35°C, 600°C, and 800°C respectively. The compressive strength values of the proposed cube concrete values are tabulated in Table 5. As a result, comprehensive strength is increased due to a stronger link between the plastic and the concrete matrix, which improved the stress transfer between the plastic waste aggregates and unlocked their full capacity to withstand stress and strain.

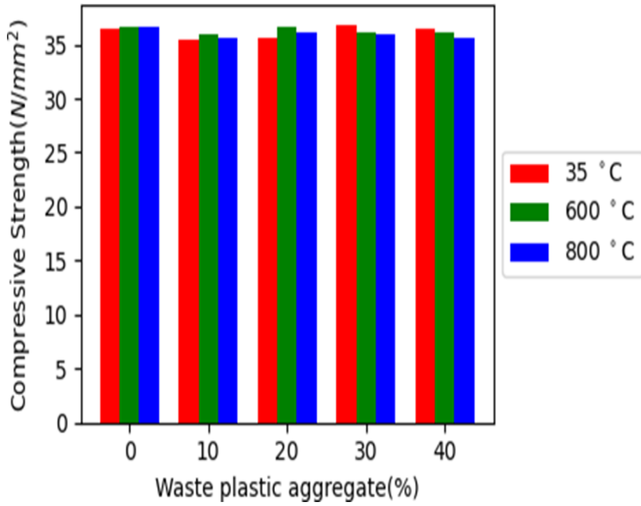


Fig. 7. Compressive strength test graph on the cube

Table 5. Compressive strength test values on the cube

Mix Specification	Value (N/mm²)	Value (N/mm²)	Value (N/mm²)	Value (N/mm²)	Value (N/mm²)
Proportion of waste plastic	0%	10%	20%	30%	40%
35°C	36.49	35.47	35.59	36.81	36.81
600°C	36.65	36.04	36.64	36.11	36.11
800°C	36.63	35.69	36.06	35.87	35.63

Waste plastic aggregates of 36.49, 36.65, and 36.63 were used to raise the strength of a cube by 0% for varied proportions of 35°C, 600°C, and 800°C. Similar to this, adding 10% more plastic waste aggregates increases strength by 35.47%, 36.04%, and 35.69%; adding 20% more, 35.59, 36.64, 36.06; adding 30% more, 36.81%, 36.11, and 35.87%; and adding 40% more, 36.81%, 36.11%, and 35.63%.

Graphical representation and table of split tensile strength on the cylinder are shown in Figure 8 and Table 6.

The split tensile strength test on the cylinder graph is shown in Figure 11. The cylinder concrete with plastic waste aggregates specimen was tested at 35°C, 600°C, and 800°C temperatures respectively. The split tensile strength test values on the cylinder is tabulated in Table 6. The physical characteristics of the parameters are quantified in the cylinder material model are density, young's modulus, and Poisson ratio have values of 7.8E-008, 210000, and 0.33, respectively. These parameters result in stress values of 450, 700 and plastic strain values of 0, 0.02. As a result, split tensile strength increased due to the use of plastic aggregate.

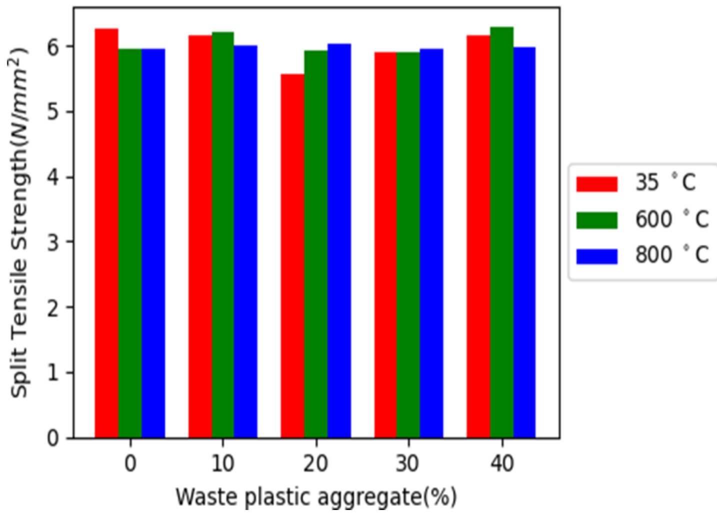


Fig. 8. Split tensile strength test graph on the cylinder

Table 6. Split tensile strength test values on the cylinder

Mix Specification	Value (N/mm^2)	Value (N/mm^2)	Value (N/mm^2)	Value (N/mm^2)	Value (N/mm^2)
Proportion of waste plastic	0%	10%	20%	30%	40%
35°C	6.35	6.16	5.57	5.91	6.17
600°C	5.96	6.2	5.98	5.89	6.29
800°C	5.96	6.01	6.03	5.94	5.98

To enhance the split tensile strength of cylinders under different proportions, such as 35°C, 600°C, and 800°C of plastic waste with 0%, 10%, 20%, 30%, and 40%. Aggregates of waste plastic in 0% are 6.35% at 35°C, 5.96% at 600°C, and 5.96% at 800°C. Comparable to 10% the strength is improved by 6.16%, 6.2%, and 6.01%, and 20% to increase strength by 5.57%, 5.98%, 6.03%, and in 30% to increase strength by 5.91%, 5.89%, and 5.94% finally in 40% to increase strength by 6.17%, 6.29%, 5.98%. Graphical representation and table of Flexural strength test on beam are shown in Figure 9 and Table 7.

Figure 12 shows the flexural strength test graph for the beam concrete with added waste plastic aggregates (10%, 20%, 30%, and 40%) specimen for 35°C, 600°C, and 800°C temperatures respectively. The flexural strength values of the proposed beam concrete values are tabulated in table 7. The physical characteristics of the parameters are quantified in the beam material model are density, young's modulus, and Poisson ratio that have values of 7.8E-008, 210000, and 0.33, respectively. These parameters result in stress values of 690, 700, 750, 850,900, and 950,990 and plastic strain values of 0, 0.007, 0.039, 0.05, 0.065, 0.1, and 0.13. As a result, increased flexural strength due to increased load absorption by the plastics found in the concrete matrix.

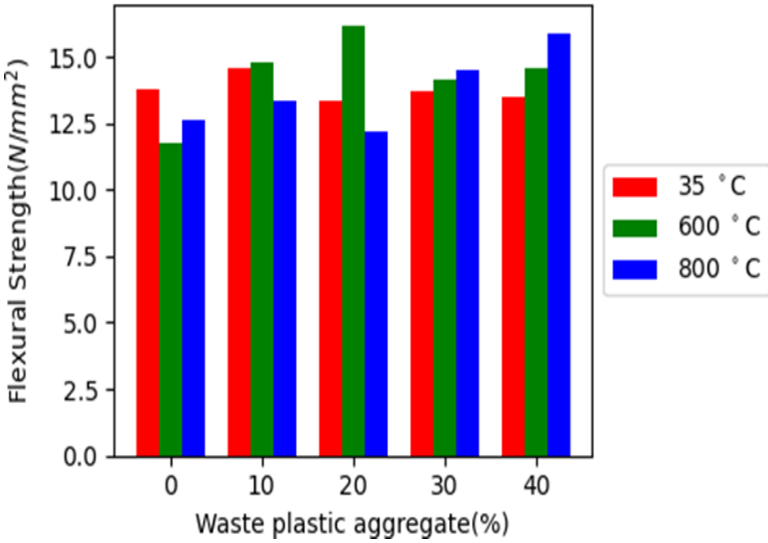


Fig. 9. Flexural strength test graph on beam

Table 7. Flexural strength test values on beam

Mix Specification	Value (N/mm^2)	Value (N/mm^2)	Value (N/mm^2)	Value (N/mm^2)	Value (N/mm^2)
Proportion of waste plastic	0%	10%	20%	30%	40%
35°C	13.79	14.59	13.32	13.73	13.49
600°C	11.77	14.81	16.17	14.11	14.57
800°C	12.59	13.36	12.17	14.5	15.9

To enhance the flexural strength based on beam for under different proportions, such as 35°C, 600°C, and 800°C of plastic waste with 0%, 10%, 20%, 30%, and 40%. Aggregates of waste plastic in 0% are 13.79% at 35°C, 11.77% at 600°C, and 12.59% at 800°C. Comparable to 10% to improve strength by 14.59%, 14.81%, and 13.36%, and 20% to increase strength by 13.32%, 16.17%, 12.17%, and in 30% to increase strength by 13.73%, 14.11%, and 14.5% finally in 40% to increase strength by 13.49%, 14.57%, 15.9%

3.2 3-D Finite Element Analysis

The proposed system results and findings obtained from the data of Finite Element Method (FEM) Abaqus software are discussed in this section. The 3-model specimen taken cube concrete, cylinder concrete, and beam concrete were created and meshed in Abaqus with waste plastic aggregates of 0%, 10%, 20%, 30%, and 40%. The analysis result of concrete cube, concrete cylinder, and concrete beam containing each percentage of waste plastic aggregates was discussed.

3.3 Cube Specimen

The proposed cube model under the compressive strength test is depicted in Figure 10 (a & b).

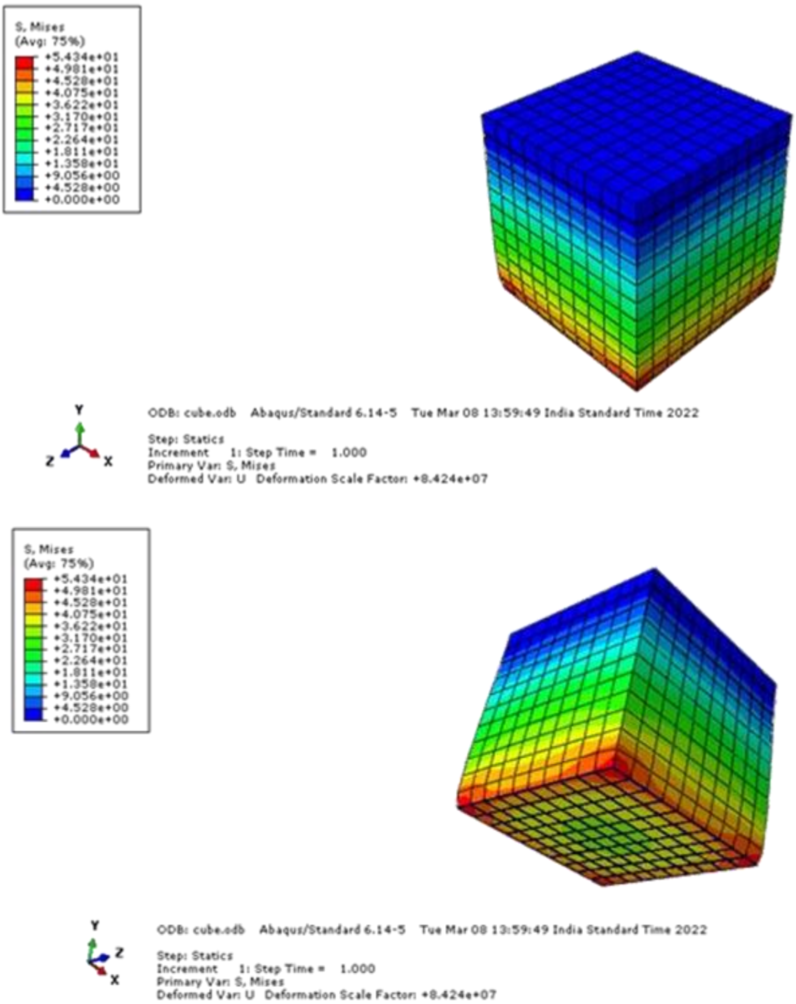
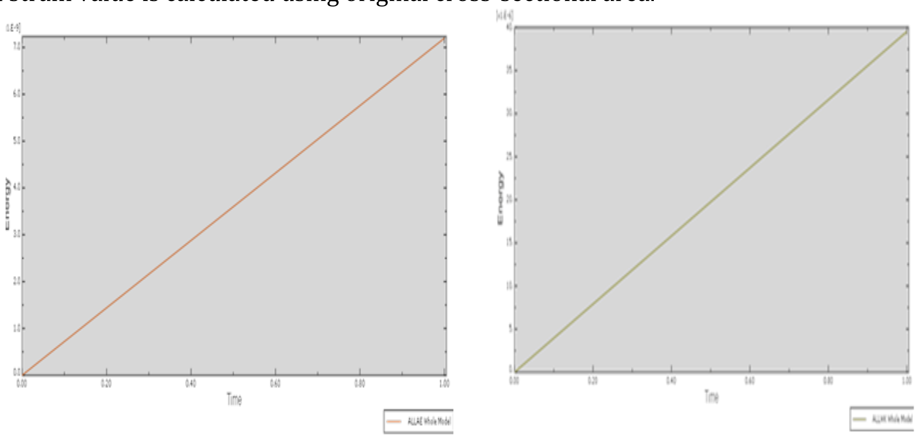


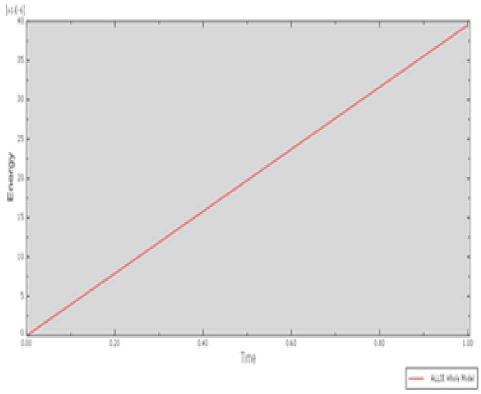
Fig. 10. (a-b) Proposed cube model under compressive strength test

The 3-D finite element cube concrete model was employed to simulate the compressive strength test which are illustrated in Figure 10. Figure 10 showed 4-types of color which are blue, green, yellow, and red. Two different views of cube model are depicted in Figures 10 (a) and (b). The load has been applied on two ends of the cube. The maximum stress value of the cube is +5.434e+01 and the minimum stress value of the cube is +4.528e+00. Artificial energy (ALLAE) of whole model of cube are depicted in Figure 11 (a), External work (ALLWK) of whole model of cube are depicted in Figure 11(b). Total strain energy (ALLTE) of whole model of cube are depicted in Figure 11 (c). Recoverable strain energy (ALLSE) whole model of cube are depicted in Figure 11 (d). The proposed cube model of stress and strain are depicted in Figure 11(e &f).

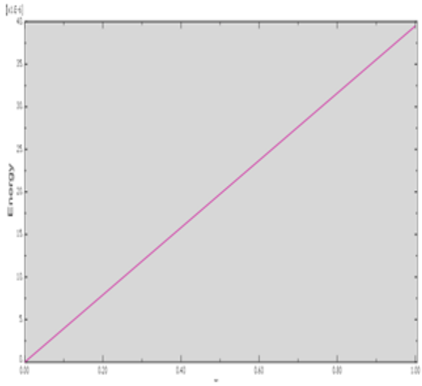
Figure 11(a) illustrates the artificial energy (ALLAE) of the proposed plastic waste aggregate cube model. The variable ALLAE of the presented model represents the total energy expended as artificial strain energy, whereas ALLSE represents the elastic, or recoverable, strain energy. ALLAE comprises both viscous and elastic components; however, because the viscous word is generally dominating, the majority of the energy that goes into artificial strain energy is lost. The artificial energy of the proposed cube concrete model has been increased linearly as 0.01 J in 0.01 seconds and 7.2 J in 1.00 seconds due to strength of confinement effect on concrete as well as a greater connection between the plastic and the concrete matrix. Figure 11(b) illustrates the external work applied on the whole cube concrete model for testing, which can be evaluated only for the whole model. The model can sustain while applying 5J energy in 0.10 seconds then the sustainability increases linearly to withstand for 40 J energy in 1.00 seconds. Figure 11(c) depicts the total strain energy of the proposed cube concrete model, which has been evaluated by the addition of recoverable strain energy (ALLSE), energy dissipated by rate-independent and rate-dependent plastic deformation (ALLPD), energy dissipated by viscoelasticity (ALLCD), artificial strain energy (ALLAE), energy dissipated through quiet boundaries (ALLQB), electrostatic energy (ALLEE), and energy dissipated by damage (ALLDMD). ALLTE is obtained as sustaining 7.5 J in 0.20 seconds then increases to sustain 40 J in 1.00 seconds. Figure 11(d) illustrates the recoverable strain energy of the proposed waste plastic mixture cube model. In steady-state dynamic analysis, ALLSE is the cyclic mean value. When applying 5.0 J energy in 0.10 seconds, the model can be recovered to the same after deformation. The waste plastic admixtures cube model strain and stress is depicted in figure 11 (e) and (f). From the figure (e), when time increased from 0.01 seconds to 1.00 seconds as well as the proposed cube model strain decreased. At same as the figure (f) shows, the stress of the whole model is decreased when the time is increased due to stress and strain value is calculated using original cross-sectional area.



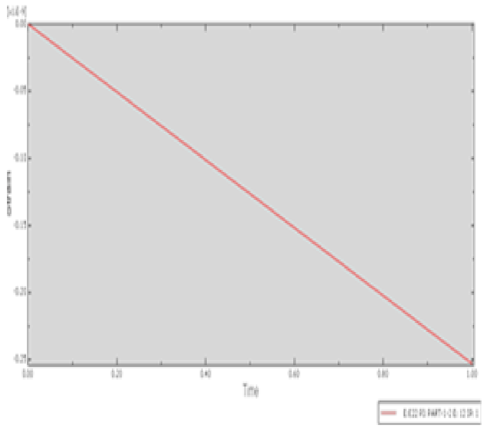
(a) (b)



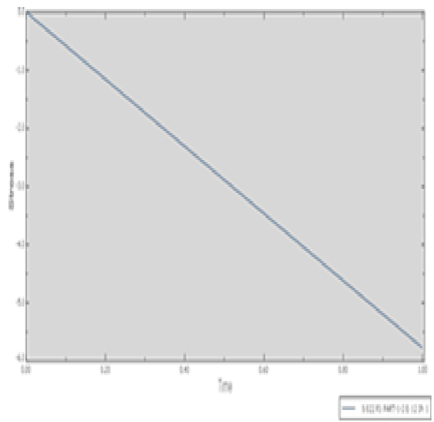
(c)



(d)



(e)



(f)

Fig. 11. (a) Artificial energy (ALLAE) of whole model of cube (b) External work (ALLWK) of whole model of cube (c) Total strain energy (ALLTE) of whole (d) Recoverable strain energy (ALLSE) of whole model of cube (e) stress and strain of proposed cube model

3.3.1 Cylinder Specimen

The proposed cylinder model under split tensile strength test are depicted in Figure 12 (a& b).

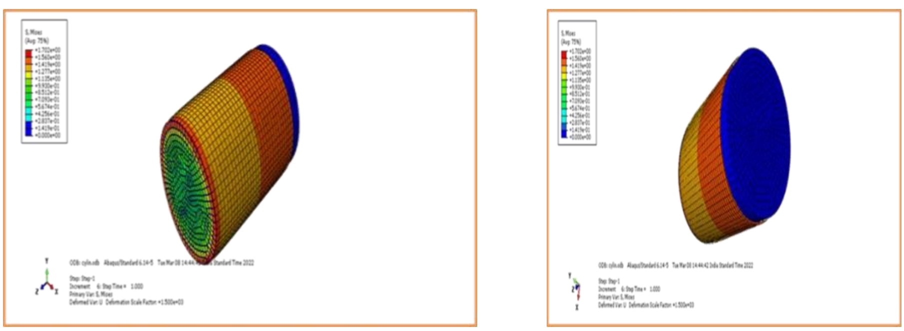


Fig. 12. (a-b) Proposed cylinder model under split tensile strength test

The 3-D finite element cylinder concrete model was employed to simulate the split tensile strength test which are illustrated in Figure 12. In Figure 12 showed 4-types of color which are blue, green, yellow, and red. The maximum stress value of the cylinder is ++10702e+00 and the minimum stress value of the cylinder is +1.419e-01. Two different views of cylinder model are depicted in figure 12 (a) and (b). The load has been applied on two ends of the cylinder. The recoverable strain energy (ALLSE) of whole model of cylinder are depicted in Figure 13 (a). Artificial energy (ALLAE) of whole model of cylinder are depicted in Figure 13 (b). The stress and strain of proposed cylinder model are depicted in Figure 13 (c) & (d).

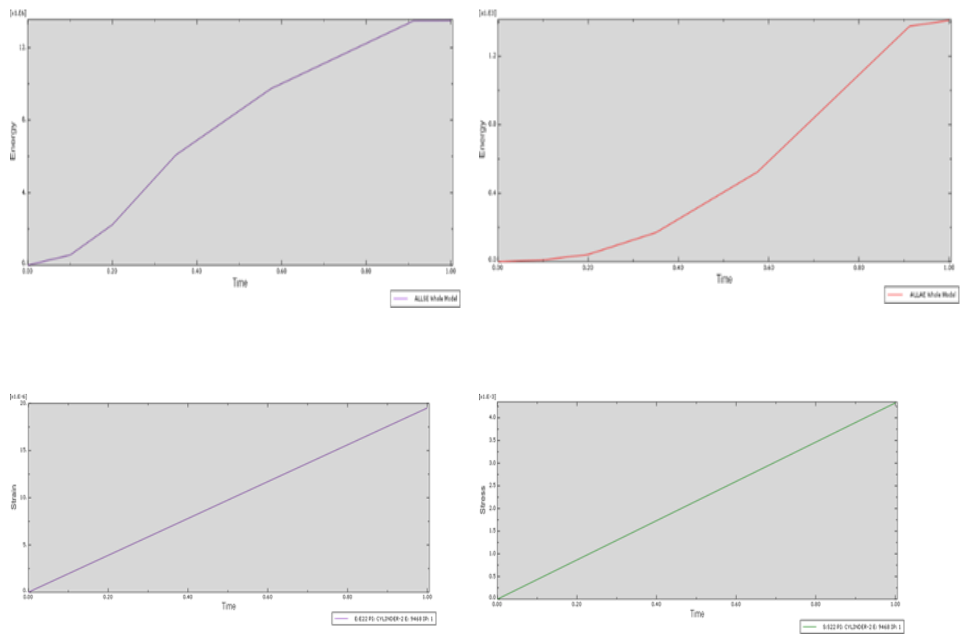
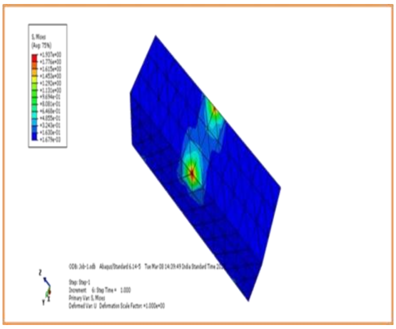


Fig. 13. (a) Recoverable strain energy (ALLSE) of whole model of cylinder (b) Artificial energy (ALLAE) of whole model of cylinder (c&d) stress and strain of proposed cylinder model

The recoverable strain energy of the suggested waste plastic mixed cylinder type is shown in Figure 13(a). ALLSE is the cyclic mean value in steady-state dynamic analysis. The model can be restored to its original shape after deformation with 3.5 J energy applied in 0.20 seconds. The proposed plastic waste aggregate cylinder model's artificial energy (ALLAE) is shows in Figure 13 (b). The artificial energy of the proposed cylinder concrete model has been increased linearly as 0.01 J in 0.20 seconds and 1.3 J in 1.00 seconds. The substitution of polycarboxylic-based superplasticizer for the fine aggregate led to an increase in split tensile strength which improve the mechanical qualities of this concrete. Figure 13 (c) and (d) exhibit the waste plastic admixtures cube model strain and stress. From the figure (c), when time increased from 0.01 seconds to 1.00 seconds as well as the proposed cube model strain decreased. At same as the figure (d) shows, the stress of the whole model is decreased when the time is increased.

3.3.2 Beam Specimen

The proposed model under flexural strength test in beam specimen are depicted in Figure 14 (a&b) .



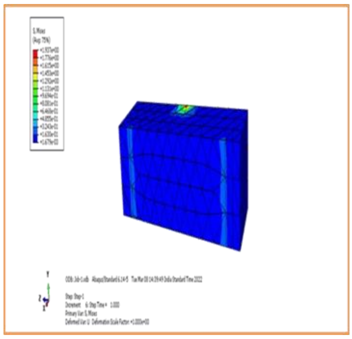
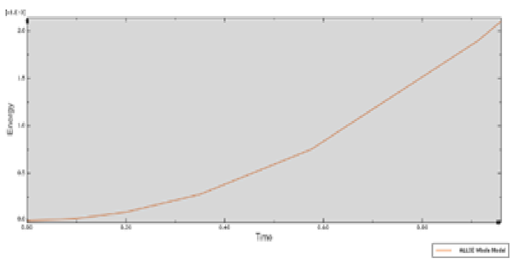


Fig. 14. (a-b) Proposed beam model under flexural strength test

The 3-D finite element beam concrete model was employed to simulate the flexural strength test which are illustrated in figure 14. To reduce mesh size, triangular meshing is utilized instead of rectangular mesh by cutting the diagonals of the quadrilateral structured mesh but the mesh values are coarse hence mesh optimization has been done to get optimum mesh values by lowering the energy function. Two different views of beam model are depicted in figure 14(a) and (b). The load has been applied on two ends of the beam. The maximum stress value of the beam is +1.937e+00 and the minimum stress value of the beam is +1. 679e+03.The total strain energy (ALLTE) of whole model of beam are depicted in Figure 15 (a). The recoverable strain energy (ALLSE) whole model of beam are depicted in Figure 15 (b).

Figure 15 (a) shows the total strain energy of the proposed beam concrete model, which was calculated by adding recoverable strain energy (ALLSE), energy dissipated by rate-independent and rate-dependent plastic deformation (ALLPD), energy dissipated by viscoelasticity (ALLCD), artificial strain energy (ALLAE), energy dissipated through quiet boundaries (ALLQB), electrostatic energy (ALLEE), and energy dissipated by damage (ALLEE) (ALLDMD). ALLTE achieved by maintaining 0.02 J for 0.20 seconds, then increasing to 2.5 J for 1.00 seconds due to limited addition of aggregate plastic waste in concrete. The recoverable strain energy of the suggested waste plastic mixed beam model is shows in Figure 15 (b). The model restored to its original shape after deformation with 0.02 J energy applied in 0.20 seconds. The comparison graph of force and displacement curve are depicted in Figure 16.



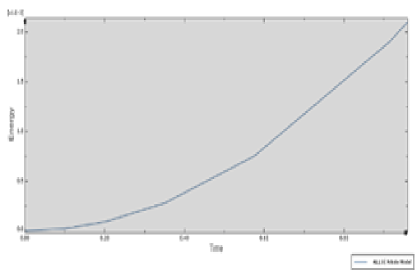


Fig. 15. (a) Total strain energy (ALLTE) of whole model of beam (b) Recoverable strain energy (ALLSE) of whole model of beam

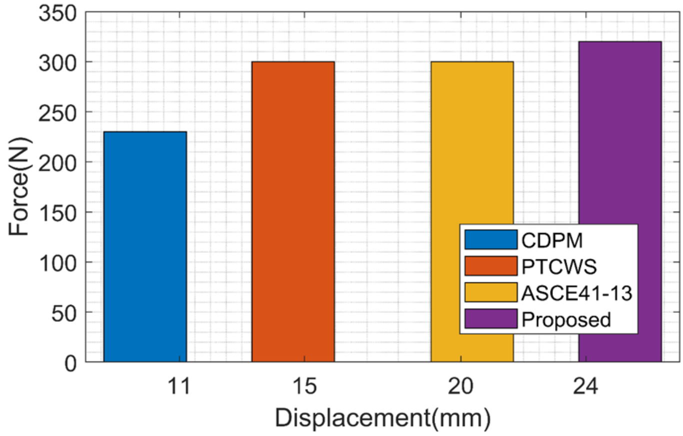


Fig. 16. Comparison graph of force and displacement

Figure 16 shows proposed model achieved high performance compared to other models in terms of force and displacement which increased the strength and workability of nonstructural concrete while using less plastic, and that can be used to improve the mechanical properties of concrete. When the concrete has hardened and the tension on the reinforcing steel has been relieved, the concrete is compressed by an internal force. Loads cause the concrete's compressive force to decrease and the reinforcing steel to experience increased stress. The relationship between force and displacement is inverse. Although the greatest range of displacement is only 24, the maximum range of force is over 300.

Overall when compared to compressive strength, the reduction in split tensile strength and flexural strength caused by the presence of plastic aggregate was considerably less due to inadequate bonding between the concrete and plastic aggregate. By volumes of 10%, 20%, 30%, and 40%, coarse particles in concrete can be also substituted with plastic. However, the use of plastic in non-structural concrete is encouraged because it exhibits higher workability and reduces environmental waste due to plastic's durability, waterproofing, and insulating properties. It is advised that up to 30% of the volume be replaced; up to this point, the M25 concrete's typical strength was attained. Another discovery is that non-structural lightweight elements can be used with 40 and 50% substitution by volume. As a result, the utilization of waste plastic aggregate can efficiently be employed from the perspectives of conservation, cost-effectiveness, and energy conservation.

4. Conclusion

Plastics waste aggregates are added to mixtures of concrete to maximize the strength in order to increase the load of the structure. Three different specimens, including cubes, cylinders, and beams, are used to assess the durability of the concrete. The cube concrete model's artificial energy has been increased linearly from 0.01 J in 0.01 seconds to 7.2 J in 1.00 seconds in order to test the compressive strength of the model. As time goes on, stress and strain will decrease. When the artificial energy of the concrete cylinder has been increased linearly as 0.01 J in 0.20 seconds and 1.3 J in 1.00 seconds in order to test the strength for split tensile strength, time-increasing stress and strain would eventually diminish. The artificial concrete beam's strength was evaluated for flexural tensile strength with an increment of 2.5 J for 1.00 seconds and these models are under various temperatures such as $35°C$, $600°C$, and $800°C$ temperatures. The strength of the concretes is identified from the results and concluded from the results 40% addition of the plastic waste in cube increased the strength by 36%, in cylinder the strength is increased by 6%, and in beam the strength is increased by 14.65%. As a result, the strength of the proposed cube, cylinder, and beam model is maximized using waste plastic aggregate, which lowers the cost of using non-structural concrete. However, one of the biggest problems of using plastic as concrete reinforcement is that it is prone to corrosion, especially on the surface of the concrete when exposed to saltwater without the proper safeguards. Hence, it is advised to continue researching how plastic trash performs over the long term in concrete as well as its long-term effects on the ecosystem.

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