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Studies on compressive strength of Geopolymer Concrete Partially Substituted with Recycled Coarse Aggregate and Quarry Stone Dust under natural and acidic environments

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Abstract

Finding an alternative for the huge environmental pollution emanating from cement manufacturing industry and utilization of solid wastes are the two major challenges faced by the construction industry. Geopolymer concrete offers an attractive solution for abating these issues as cement can be offset with silicate salts in an alkaline environment in the presence of aggregates. To curtail pollution and also to effectively utilize solid wastes, an attempt has been made in this study to prepare Geopolymer concrete using locally available alternatives. Recycled Coarse aggregate (RCA) was used as a partial substitute for conventional coarse aggregate and locally available Quarry Stone Dust (QD) was used as a partial substitute for fine aggregate in varying proportions. Also tests were performed on durability of the prepared concrete in an acidic environment. It was observed that at 40% of Quarry Stone Dust, the compressive strength of concrete attained optimum of 76N/mm2 at 90 days of ambient curing. Similarly, replacement with Recycled Coarse Aggregate reduced the compressive strength, to a minimum of 46 N/mm2. Acidic environment affected the durability of the prepared geopolymer concrete which was observed with a decrease in compressive strength value to 41N/mm2. Thus Geo-polymer concrete with RCA can be utilized effectively as a substitute for conventional concrete for pollution control as well as for utilization of solid wastes.

Keywords: Geopolymer concrete, sodium hydroxide, sodiumsilicate, Recycled Coarse Aggregate, QD

Introduction

With the explosion in population there is a synonymous increase in infrastructure requirements of the world. Ordinary Portland cement is the widely used cementing material in the construction industry. The manufacture of cement involves consumption of large quantities of valuable natural resources which cause harm to the environment. Also, during the stage of manufacturing of cement large quantities of greenhouse gases are evolved which cause global warming. Added to this the byproducts produced from cement manufacturing industries are a cause for concern, as they are capable of degrading our environment. Geopolymer concrete offers an attractive alternative for pollution abatement wherein the usage of cement can be offset using salts of silica under an alkaline environment in the presence of aggregates. Also with increase in technological innovations and improvement in lifestyle of people, the generation of solid wastes, especially from demolition of structures has tremendously increased. Therefore there is a twofold challenge to curtail usage of cement and also to effectively utilize solid wastes generated from demolition of structures.

Several studies have been made for utilization of locally available solid waste as aggregates for geopolymer concrete with varying degrees of success. Dolomite based Quarry stone dust was used as a substitute for fine aggregates in geopolymer concrete and it was observed that a 40% substitution is optimum[1]. Jayarajan and Arivagalan have successfully demonstrated the application of flyash as fine aggregate substitute in geopolymer concrete[2]. Sundis et.al., have observed that aggregate substitution with glass aggregates has resulted in less than 15% of loss of strength compared with conventional aggregates[3]. VenuMadhavet.al.,have found that Quarry Rock Dust of particle size less than 4.75 mm is an effective substitute for conventional aggregates in case of geopolymer concrete[4]. Palmshell was used as a coarse aggregate substitute by Azizul Islam and it was found that the compressive strength of geopolymer concrete obtained was 33 MPa[5]. According to N Vishnu et.al., use of wollastonite and graphene oxide as 10% substitution with conventional materials has resulted in the compressive strength increase from 1.6% to 8.3% [6]. Biomass aggregate produced by burning palm oil aggregates and fly ash at 80 degrees was capable of producing a geopolymer concrete with a compressive strength greater than the conventional concrete by about 51%[7]. Substitution by Basalt fibre in the range of 4.8 % to 1.2 % resulted in an overall increase of compressive strength of geopolymer concrete by about 25% compared to conventional geopolymer concrete[8].A 0.6% addition of polypropylene fibre resulted in a very good improvement in the compressive strength of geopolymer concrete as well as an increase in its longevity was observed[9]. Rice husk Ash substitution exhibited a 28 day compressive strength improvement from 36 MPa to 36.1 MPa according to PeemNuaklong[10]. Incorporation of 2.5% hybrid Nanomaterials resulted in a superior increase in compressive strength as per Menatalah et.al.[11]. A 5% addition of Millet Husk Ash resulted in an increase in compressive strength value of Geopolymer concrete to about 53.8 MPa[12]. Sisal fibres were also found to be effective in increasing the strength parameters of Geopolymer concrete[13]. Replacement with Ferrochrome slag for coarse aggregate resulted in a 30% increase in compressive strength[14]. Usage of Pumice as aggregate in Geopolymer concrete resulted in twin benefits of increase in the strength of concrete as well as a resultant obtainment of lightweight concrete[15]. According to Khushpreet Singh, Baggash Ash can be used as an effective replacement for Rice Husk Ash and good strength of Geopolymer concrete can be obtained[16]. As very little work has been done on utilization of Recycled Coarse Aggregate in combination with Quarry Stone Dust, this work has been focused and oriented towards incorporation of those two materials to offset the usage of cement, thus reducing pollution and also for utilization of locally available aggregates. Also tests were performed on durability of the prepared concrete in an acidic environment.

Materials and Methods

Class F, Flyash was used in the current investigation which was obtained from Rayalaseema Thermal Power Plant (RTPP), Muddanur, A.P. The specific gravity of the procured flyashwas 2.24 and its fineness is 360 m^2/kg. Recycled Coarse Aggregate (RCA) of mean size 20mm was used as a partial substitute to the conventionally used aggregate in the present study. Natural River Sand obtained from a nearby river in Anantapur District and locally available Quarry Dust were used as fine aggregates. The specific gravity and fineness modulus properties of fine aggregate were found to be as shown in Table.1

Table.1: Properties of fine aggregate materials

Characteristics	**Natural River Sand**	**Quarry Dust**
Specific Gravity	2.58	2.66
Fineness Modulus	2.64	2.32

Alkaline liquid was prepared by mixing sodium silicate & sodium hydroxide solutions. Sodium silicate solution (water=55.9%, SiO_2=29.4%, Na_2O = 13.7% by mass) was purchased from ASTRRA chemicals and sodium hydroxide (NaOH) flakes were (97%-98% purity) purchased from a local supplier. Potable water which does not contain any amount of sugar, salt, oil, organic, acid, alkali materials or other substances was used for mixing & curing. The water used had a pH value 7.2

Geopolymer concrete was prepared by mixing together fine aggregate, coarse aggregate, sodium silicate and Sodium Hydroxide of 12 Molarity. Recycled Coarse Aggregate (RCA) and Quarry Dust (QSD) were used as partial substitutes in 0, 20, 40, 60, 80 and 100 percentages in place of conventional aggregates, one after the other, to arrive at the optimum dosages of substitution and tested for compressive strength after 7, 14, 28 and 90 days of ambient curing. Durability tests were also conducted by exposing the prepared geopolymer concrete blocks of 40% QSD substitution and 100% RCA substitution in a 5% HCl acidic environment for 30, 60 and 90 days and their compressive strengths were evaluated.

Results and Discussion

Geopolymer concrete which was prepared by mixing Fine aggregates, Coarse aggregates, Sodium Silicate and 12M Sodium Hydroxide and cured for various time intervals exhibited various values of compressive strengths and the same are presented and discussed in this section.

Initially, conventional coarse aggregates were used unaltered whereas QSD was partially substituted in place of conventional fine aggregates in incremental percentages of 0, 20, 40, 60 , 80 and 100 and the variation in compressive strengths with various ambient curing periods with variations of %RCA are presented in Fig.1-6 respectively.

Figure1. Compressive strength of geopolymer concrete with replacements of QD in % and ambient curing periods with 0% RCA substitution.

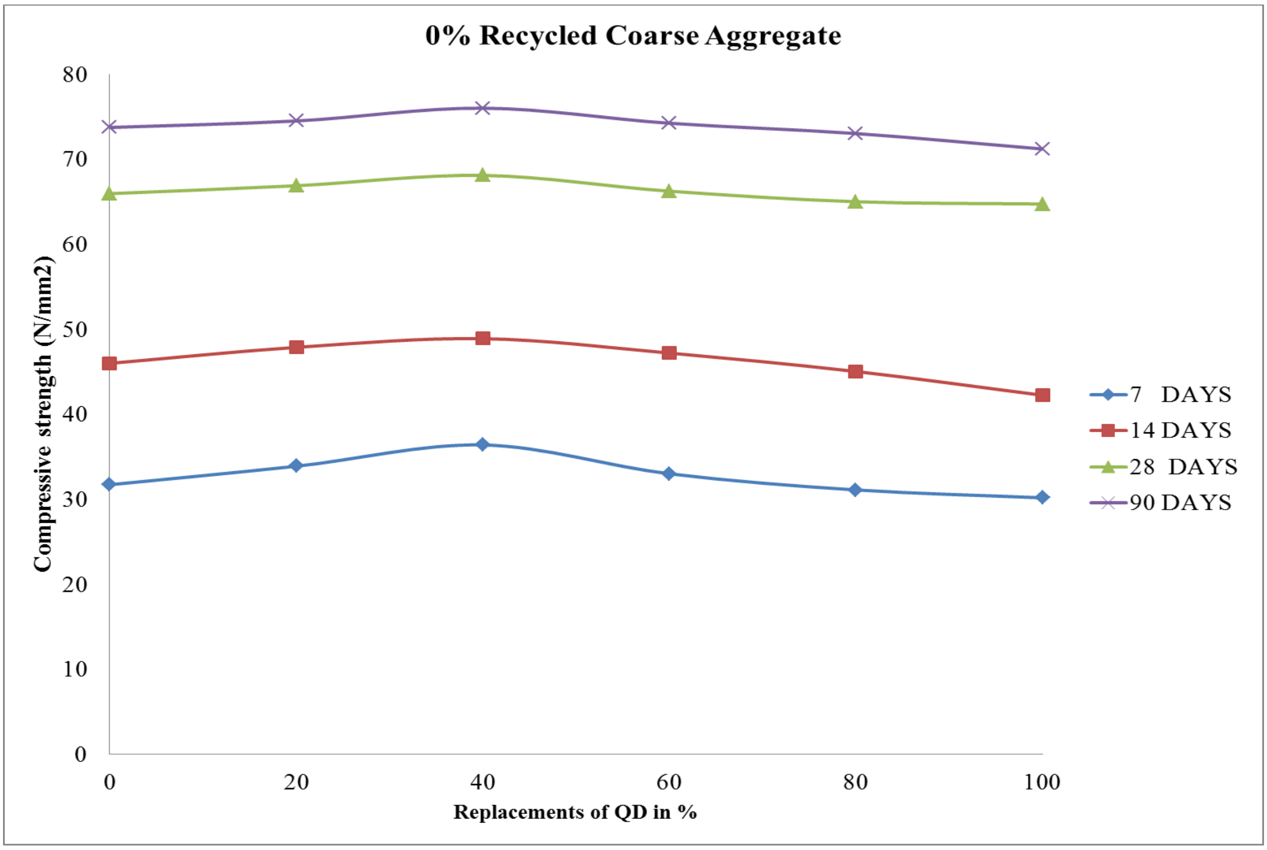


Figure 2. compressive strength of geopolymer concrete with replacements of QD in % and ambient curing periods with 20% RCA substitution.

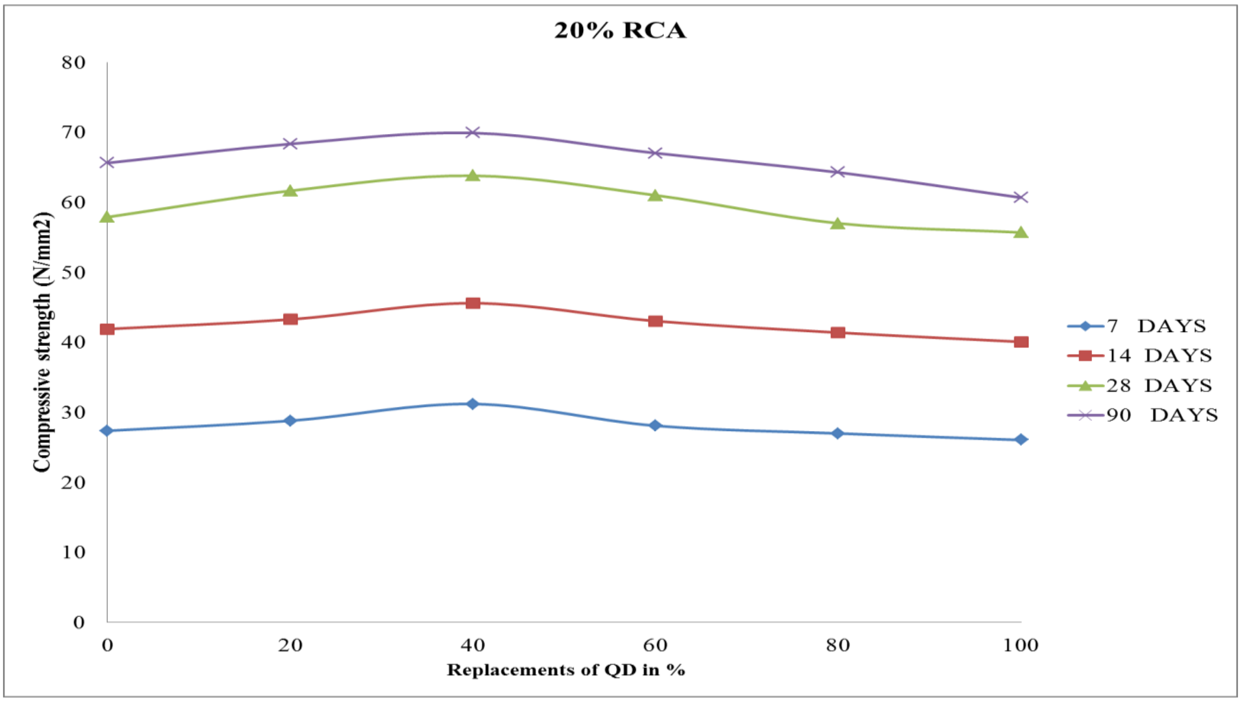


Figure 3. compressive strength of geopolymer concrete with replacements of QD in % and ambient curing periods with 40% RCA substitution.

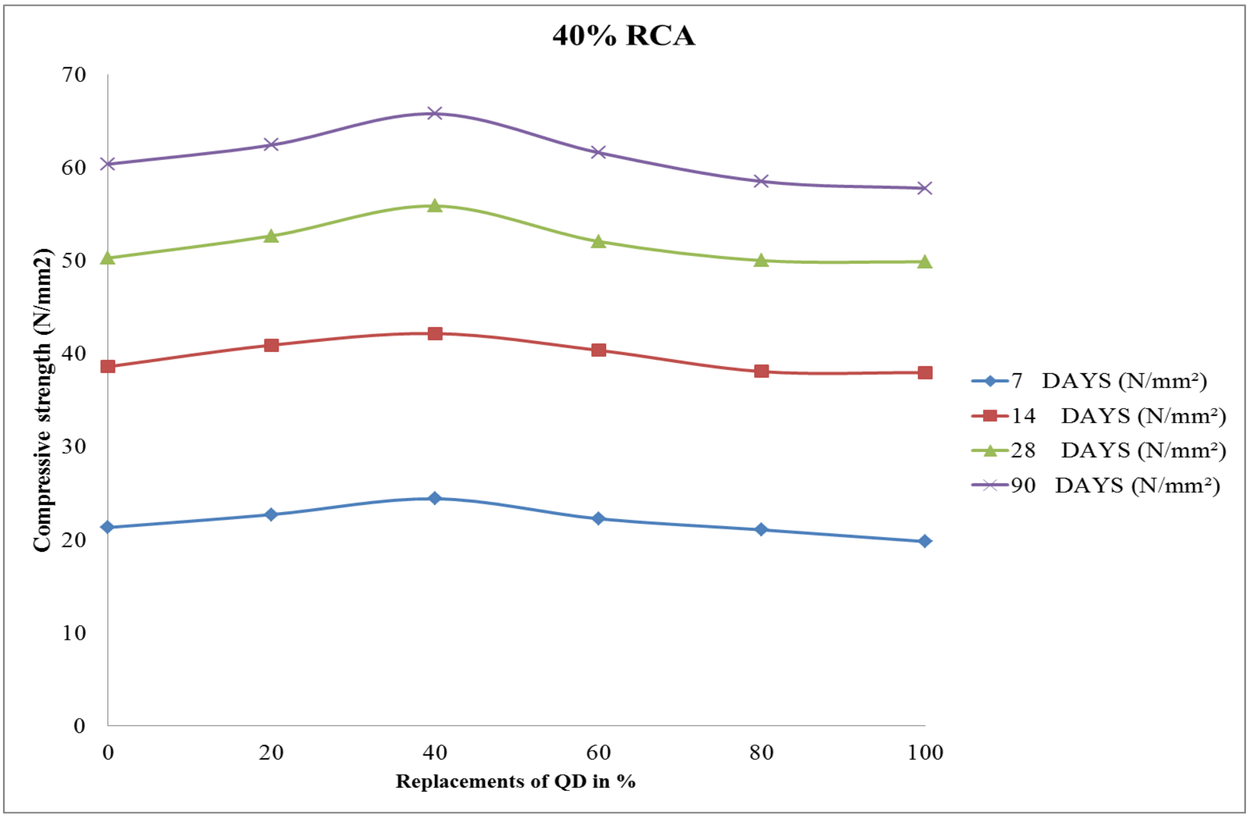


Figure 4. compressive strength of geopolymer concrete with replacements of QD in %and ambient curing periods with 60% RCA substitution.

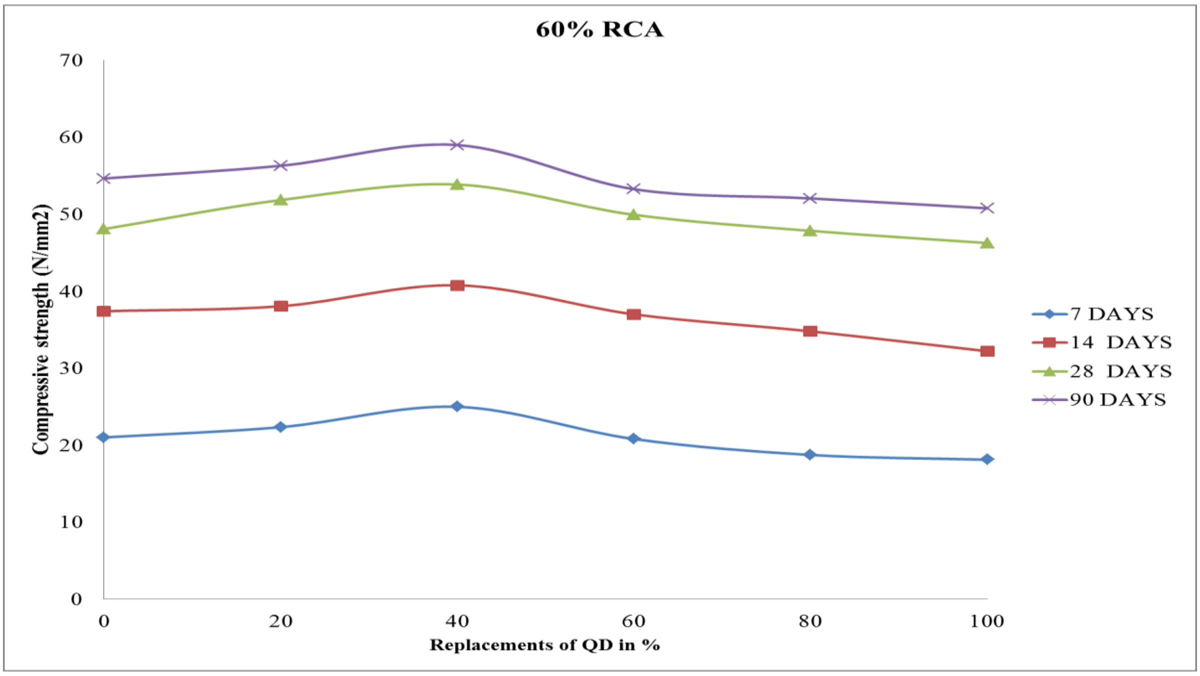


Figure 5. compressive strength of geopolymer concrete with replacements of QD in % and ambient curing periods with 80% RCA substitution.

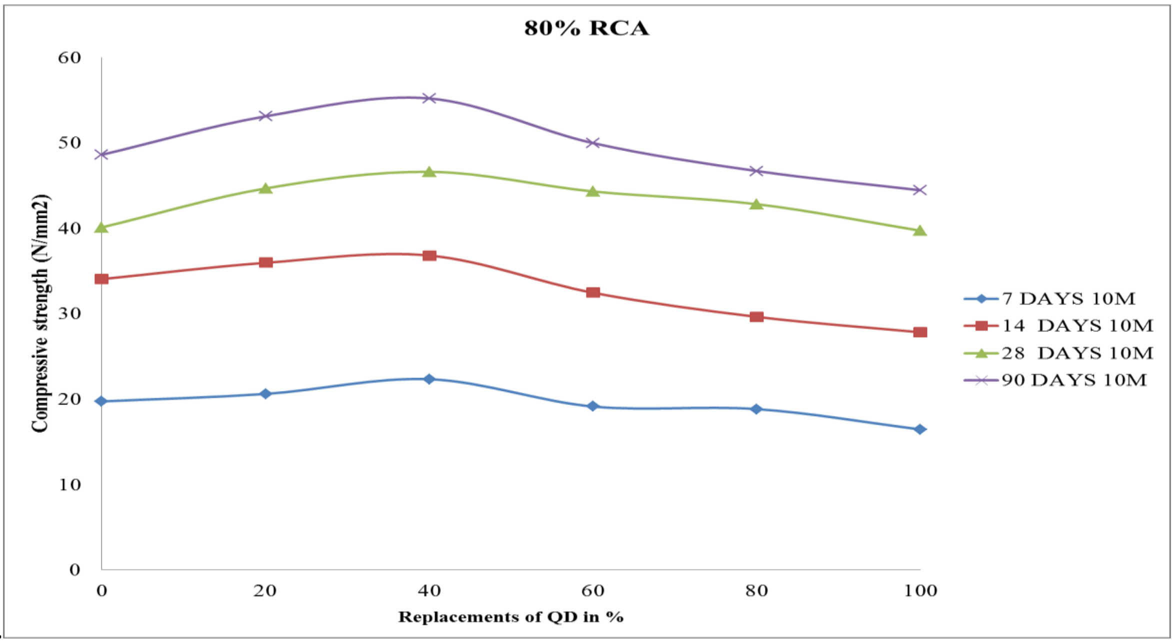
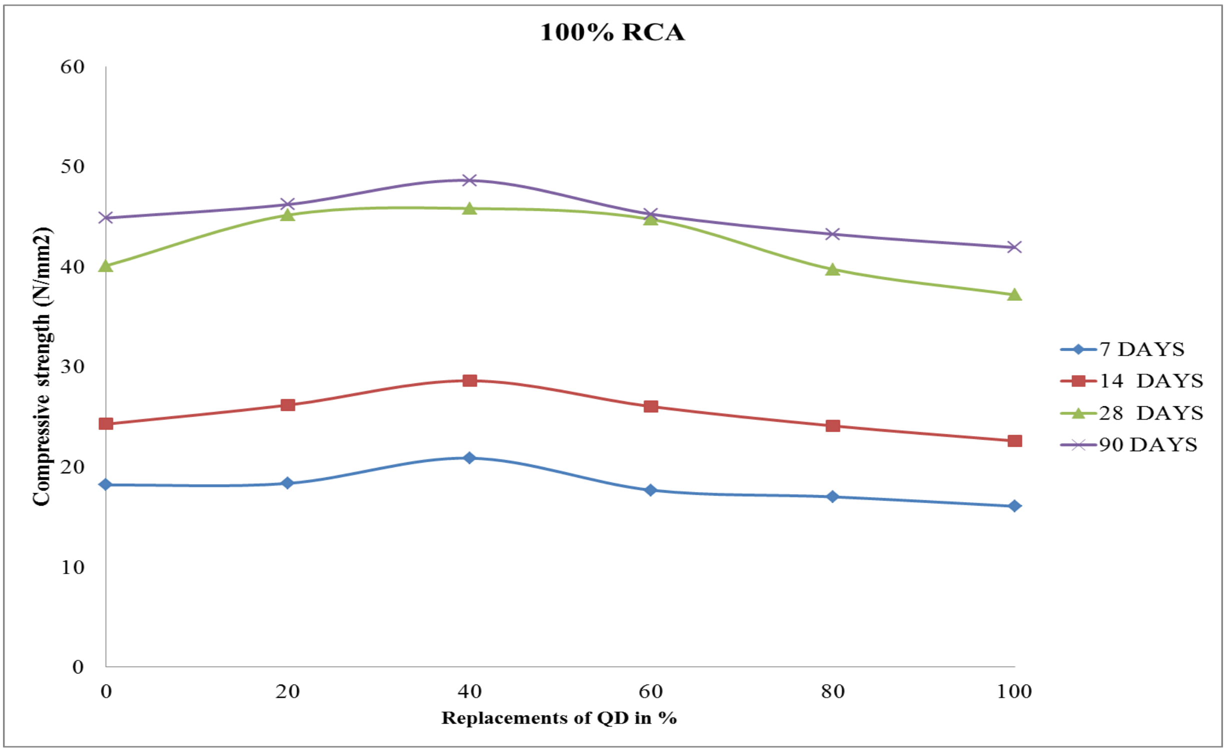
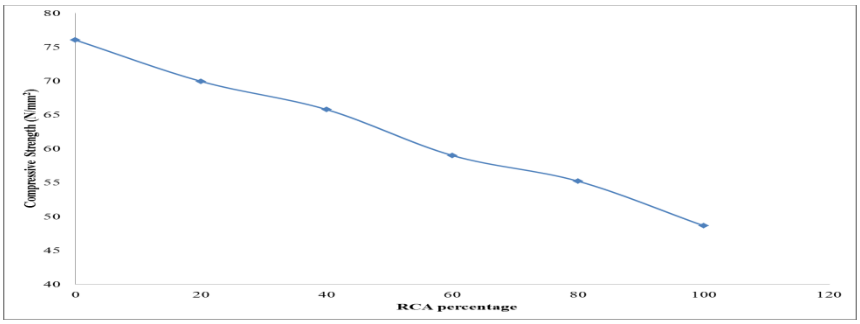


Figure 6. compressive strength of geopolymer concrete with replacements of QD in % and ambient curing periods with 100% RCA substitution.



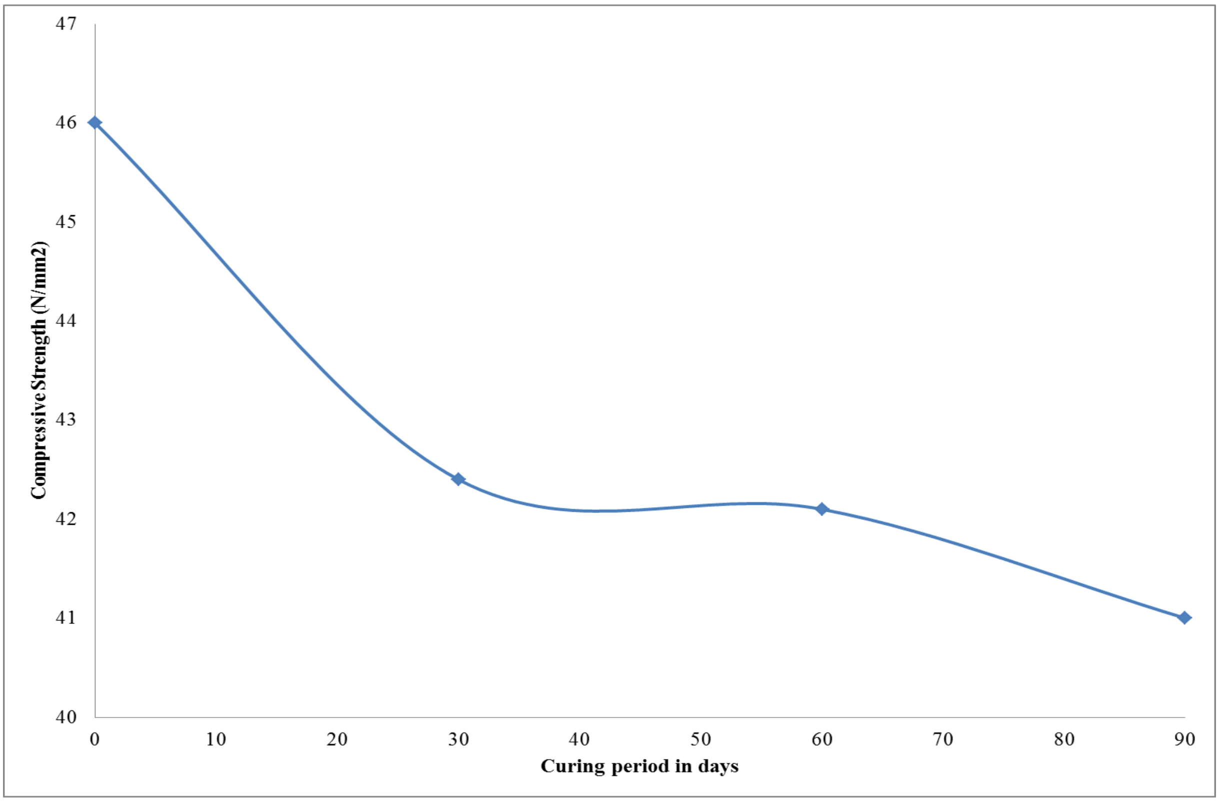
It can be observed from these figures that the compressive strength increases with increase in period of ambient curing. Substitution of QSD in place of fine aggregates had a positive impact on development of compressive strength up to about 40% and there after the compressive strength has shown declining trend. The optimum compressive strength was found at 40% substitution. Similar results were reported when Dolomite Quarry Dust [1]was used partially in place of fine aggregates and therefore the present results are in agreement with the referred values. The main reason for this increase in compressive strength is due to the micro filling ability of QSD thus making a dense concrete. Keeping the optimum QSD level at 40%, the conventional coarse aggregate is replaced with RCA in different percentages ranging from 0 to 100, at 20% increment. The results are plotted in Figure 7

Figure 7. Compressive Strengthsat various percentage RCA at 40% QD



From Figure7, it can be observed that the value of compressive strength gradually falls downto a minimum value of 46N/mm^{2}withsubstitution ofRCA0 to 100%. Therefore, based on design requirements, percentage of RCA can be selected. It can be observed that even at 40% replacement level of RCA, the Compressive strength is more than 60MPa which is quite sufficient for majority concrete works.

Figure 8 compressive strengths of geopolymer concrete containing 40%QSD and 100% RCA for various curing periods in acid environment



Geopolymer Concrete cubes prepared with 40% substitution of QSD and 100% substitution with RCA were tested for their durability, by curing those in an acidic environment for 30, 60 and 90 days and the residual compressive strengths are obtained. The variation of residual compressive strength with the duration of acidic exposure is plotted in Figure 8. It can be observed that with progressive increase in duration of exposure to acidic environment to 90 days, the compressive strength of the geopolymer concrete block, gradually decreased to a minimum of 41 N/mm^2 which is very much similar to the normal concrete behavior.It can be observed that even the minimum strength of 41 MPa is higher than that of M20 concrete which is normally used in general structural applications.

CONCLUSIONS

- The compressive strength of Geopolymer concrete varies in direct proportion with variation in period of ambient curing.

- Replacement of 40% of conventional fine aggregate with Quarry stone dust, yielded an optimal compressive strength value of 76.03N/mm2.

- Replacement of RCA with conventional coarse aggregate in percentages ranging from 0 to 100% reduced the compressive strength from 76.03 N/mm^2 to 48.63N/mm^2. Even at 40% RCA level, the compressive strength is about 60MPa which is quite sufficient for most of the structural applications

- On exposure to a 5% HCl acidic environment, the compressive strength of the prepared geopolymer concrete reduced from 48.63 N/mm^2 to 41 N/mm^2exhibiting a behavior similar to the conventional concrete. However, even the least strength of 41 MPa is higher than the compressive strength of M20 grade concrete which is recommended by IS456-2000 for structural applications.

Hence it is concluded that Geopolymer concrete produced with QSD and RCA can be used in structural concrete works achieving sustainability.

REFERENCES

[1] E. Cohen, A. Peled, G. Bar-nes, Dolomite-based quarry-dust as a substitute for fly-ash geopolymers and cement pastes, (2019) 2–4.

[2] G. Jayarajan, An experimental studies of geopolymer concrete incorporated with fly-ash & GGBS, (2021) 28–29.

[3] S.M.S. Taher, S.T. Saadullah, J.H. Haido, B.A. Tayeh, Case Studies in Construction Materials Behavior of geopolymer concrete deep beams containing waste aggregate of glass and limestone as a partial replacement of natural sand, 15 (2021).

[4] T.V. Madhav, I.V.R. Reddy, V.G. Ghorpade, S. Jyothirmai, Compressivestrength study of geopolymer mortar using quarry rock dust, (2018) 2–4.

[5] A. Islam, U.J. Alengaram, Engineering properties and carbon footprint of ground granulated blast-furnace slag-palm oil fuel ash-based structural geopolymer concrete, (2015) 20–22.

[6] N. Vishnu, R. Kolli, D.P. Ravella, Studies on Self-Compacting geopolymer concrete containing flyash , GGBS , wollastonite and graphene oxide, (2021) 1–2.

[7] T.Z.H. Ting, M.E. Rahman, H.H. Lau, Sustainable lightweight self-compacting concrete using oil palm shell and fly ash, Constr. Build. Mater. 264 (2020) 120590. doi:https://doi.org/10.1016/j.conbuildmat.2020.120590.

[8] V. Pdf, Effect of basalt fiber on metakaolin-based geopolymer mortars containing rilem , basalt and recycled waste concrete aggregates, (2021) 5–7.

[9] S.Y. Rani, M.S. Nusari, S. Poddar, A. Bhaumik, Durability of geopolymer concrete with addition of polypropylene fibre, (2021) 11–12.

[10] P. Nuaklong, P. Jongvivatsakul, T. Pothisiri, V. Sata, P. Chindaprasirt, Influence of rice husk ash on mechanical properties and fire resistance of recycled aggregate high-calcium fly ash geopolymer concrete, (2020) 1–3.

[11] M.A. Kotop, Y.R. Alharbi, A.A. Abadel, A.S. Binyahya, Engineering properties of geopolymer concrete incorporating hybrid, (2021).

[12] N. Bheel, P. Awoyera, I. Ali, S. Ahmed, S. Hussain, K.P. A, Case Studies in Construction Materials Synergic effect of millet husk ash and wheat straw ash on the fresh and hardened properties of Metakaolin-based self-compacting geopolymer concrete, 15 (2021).

[13] S. Kavipriya, C.G. Deepanraj, S. Dinesh, N. Prakhash, N. Lingeshwaran, S. Ramkumar, Flexural strength of Lightweight geopolymer concrete using sisal fibres, (2021) 21–23.

[14] S. Jena, R. Panigrahi, Performance assessment of geopolymer concrete with partial replacement of ferrochrome slag as coarse aggregate, (2019) 1–3.

[15] V. Pdf, Properties of fly ash-based lightweight geopolymer concrete prepared using pumice and expanded perlite as aggregates, (2020) 5–7.

[16] K. Singh, Experimental study on metakolin and baggashe ash based geopolymer concrete, (2021) 1–2.