Retraction

Retracted: Empirical Investigation on Compressive Strength of Geopolymer and Conventional Concretes by Nondestructive Method

Advances in Materials Science and Engineering

This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] B. Ravali, K. B. G. Krishna, D. R. Kanth, K. J. B. Chari, S. V. Prabhu, and R. Ramesh, "Empirical Investigation on Compressive Strength of Geopolymer and Conventional Concretes by Nondestructive Method," *Advances in Materials Science and Engineering*, vol. 2021, Article ID 9575964, 10 pages, 2021.

Research Article

Empirical Investigation on Compressive Strength of Geopolymer and Conventional Concretes by Nondestructive Method

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Need of construction is increasing due to increase in population growth rate. The geopolymer concrete is eco-friendly than ordinary concrete. Current experimental investigation was conducted on ordinary and geopolymer concrete using nondestructive testing (NDT) tests like ultrasonic pulse velocity (UPV) test and rebound hammer (RH) test. Cube specimens of dimensions $150\,mm \times 150\,mm \times 150\,mm$ are used to conduct these tests at 7, 14, and 28 days. Proportions considered for concrete are cement-fly ash-river sand (100-0-100% and 60-40-100%), cement-fly ash-robo sand (100-0-100% and 60-40-100%) whereas geopolymer concrete fly ash-metakaolin is taken in proportions of 100-0%, 60-40%, and 50-50%. Alkaline activators (sodium hydroxide and sodium silicate with molarity 12M) were used in preparing geopolymer concrete. The major objective of the current study is to obtain relation between compressive strength of concrete and UPV values.

1. Introduction

Nondestructive testing (NDT) is an approach for reviewing, testing, or analyzing the elements or components on concrete and concrete members. The major purpose of NDT is to evaluate integrity and quality of concrete members without causing any damage to its functionality and integrity [1]. Acoustic Tap Testing was one of the methods of NDT used earlier to nineteenth century, to detect cracks in railroad wheel [2]. NDT is majorly used to test the structural components of a structure for ensuring safety and serviceability. Certain factors like resolution in both vertical and lateral directions and signal to noise ratio impact NDT [3].

Distinct NDT methods are used in Civil Engineering. NDT surface hardness methods are used to identify the material's strength characteristics. Indentation method and rebound hammer method are the two groupings used to identify concrete surface hardness [4]. Rebound or Schmidt hammer is another nondestructive testing equipment. It is used for finding the concrete or rock strength and elastic property. The rebound number is measured spring-loaded mass. Impacting the hammer on smooth concrete block or rock surface at right angles, the rebound number is obtained.

In the recent past, the use of fly ash offers with cement replacing material gains significant importance for reducing the pollution [5]. It becomes one of the ingredients of concrete. Measurement of strength of concrete through

UPV was introduced in USA in the mid-1940s. UPV is one of the NDT methods useful to test quality, homogeneity, and compressive strength of concrete through regression equation. The UPV test consists of transmission of mechanically generated pulses through electro-acoustic transducers. Applied pulse generates longitudinal waves, whose velocity can be determined by transducers. The velocity of waves determined by UPV is correlated to elastic modulus, strength, and so on.

Rebound or Schmidt Hammer. The RH is another NDT equipment. It is used for finding the concrete or rock strength and elastic property. The rebound number is measured spring-loaded mass. Impacting hammer on smooth concrete block or rock surface at right angles, the rebound number is obtained.

Depending on age of concrete, water-cement ratio, properties, and type of aggregate and cement influence UPV values [6]. In addition to these factors, reinforcement which was embedded in the path of pulse also shows significant effect on UPV values [7]. As there are various NDT methods used by industries of civil and structural engineers, there exists an ample amount of literatures related to NDT. The major intent of this paper is to obtain UPV and rebound values of conventional, geopolymer concretes and to develop the relation between compressive strength and UPV values.

2. Materials and Methods

2.1. Cement. 53 Grade OPC (specific gravity = 3.10) is utilized in this experimental study. Based on the data, IS 8112 : 1989 [8], the chemical composition of cement is represented in Table 1.

2.2. Fly Ash (FA). FA is one of the coal combustion products which consists of fine particles collected from boilers with flue gases. FA was collected from the thermal power plant, Kondapalli, Krishna district, Andhra Pradesh, India. Composition of fly ash is presented in Table 1.

2.3. Fine Aggregate. River Sand. River sand is naturally obtained material from river bank. It is widely used in normal construction works. The fineness modulus of river sand is 2.75 and conforming to zone III according to IS 383 : 1970 [9].

Robo Sand. Robo sand is a waste obtained from crushed aggregates. It is also known as artificial sand. 3.62 is the fineness modulus of robo sand. According to IS 383 : 1970 [9], this robo sand conforms to Zone III. Robo sand properties are represented in Table 2.

2.4. Coarse Aggregate. Coarse aggregate is collected from quarry site. 20 mm and 10 mm aggregates are used in this experiment conforming to Zone III as per IS 10262 : 2009 [10]. In this experiment, 60% of 20 mm and 40% of 10 mm aggregates are used. Table 3 represents properties of coarse aggregates.

TABLE 1: Cement and fly ash chemical composition.

Component	% of cement	% of FA
Loss ignition	1. 8	2.0
SiO_2	20. 4	60.54
Fe_2O_3	3. 2	5.87
Al_2O_3	3. 9	26.20
CaO	63	1.91
MgO	2. 4	0.38
$K_2O + Na_2O$	—	1.02
SO_3	3	0.23

TABLE 2: River sand and robo sand properties.

Property	River sand	Robo sand
Fineness modulus	2.65	3.56
Specific gravity	2.68	2.7
Silt content	0.8%	—

TABLE 3: Test values for coarse aggregate.

Property	Test value
Specific gravity	2.79
Water absorption	0.45%
Aggregate impact value	21.70
Aggregate crushing value	20.60
Combined flakiness and elongation value	22.10

2.5. Metakaolin. The dehydroxylated variety of clay mineral kaolinite is termed metakaolin. It provides high strength to concrete [11]. The disordered kaolinite and ordered kaolinites are converted into dehydroxylates at temperatures of 530–570^{0}C and 570–630^{0}C. A light pinkish metakaolin was employed here whose specific gravity is 2.45.

2.6. Alkaline Activators. For the preparation of geopolymer concrete, chemicals called sodium hydroxide and sodium silicate were used.

Sodium Hydroxide. Generally, sodium hydroxide (NaOH) is available in flakes and pellets. Sodium hydroxide flakes are used in this experiment.

Sodium Silicate. Generally, it is available in gel state and is known as water/liquid glass.

2.7. Solution Preparation. Solution NaOH was prepared 24–48 hours priorly. Due to its presence in form of flakes, NaOH pellets were dissolved properly in water for preparation of sodium hydroxide solution. Experimental property studies of solutions can provide significant thermodynamic information under various temperature and pressure circumstances. Oxygenated compounds like alkaline and alcohols have become a very important additive in mix binders for liquids and solids [12–16]. In order to prepare one litre of 12M NaOH, 480 grams of NaOH was dissolved in water at room temperature, approximately 28 ± 2°C. The molarity equation can be written as follows:

$$M = \frac{n}{v}, \tag{1}$$

where M is the molarity, n refers the moles of solute, and v is the litre of solution.

Molarity = moles of solute/litre of solution $12M = 12$ molarity

= $12 \times$ molecular weight

= 12×40

= 480 gm.

2.8. Mix Design. IS 456 : 2000 [12] is used for mixing of conventional OPC concrete. Ratio of water to cement used for concrete mixing is 0.35 which is obtained by designing M25 grade concrete. 2400 Kg/m^3 is the density of concrete which is considered for calculation of quantities of materials. According to 10262 : 2009 [10], absolute volume of coarse as well as fine aggregates is 70% in density of concrete whereas remaining 30% is of geopolymer binders like ash, meta-kaolin, and alkaline activators. The mix proportions are represented in Tables 4 and 5.

2.9. Mixing and Casting. Mixing and casting of geopolymer concretes are kind of conventional concrete. After mixing, the concrete is cast in 150 mm × 150 mm×150 mm moulds. The casting is finished by placing concrete in the three layers. A tamping rod is employed for tampering of each layer (25 times) [9, 17].

2.10. Curing. Ambient curing is the curing method adopted for geopolymer concrete. For ordinary concrete, curing is done by placing cubes into a water bath for 7, 14, and 28 days. After curing period completion, specimens are tested.

2.11. Testing

Ultrasonic Pulse Velocity Test Procedure. Basic principle of the UPV test is measuring pulse of longitudinal vibrations that are passing through concrete. The travel time of UPV wave travelling through the concrete will be measured. Velocity of wave depends on geometry and elastic property of material. BS-4408 part-5, ASTM C 597-71, and BIS 13311 (part 1): 1992 [18–20] provided recommendations for utilization of this method.

The compressive wave velocity for homogeneous concrete is evaluated by using the following equation:

$$V = \sqrt{\frac{kE_d}{\rho}}, \tag{2}$$

where $k = 1 - \gamma/[(1 + \gamma)(1 - 2\gamma)]$, E_d is the dynamic elasticity modulus, and ρ is the dynamic Poisson's ratio.

Elastic stiffness and mechanical strength are the two influencing factors of UPV. Variations in mix proportions influence pulse velocity. To assess compressive strength, quality of concrete and calibration charts are to be established.

Table 4: Mix proportions for GPC.

Mix no.	Mix proportion
GPC 1	100% + 0%MK
GPC 2	60% + 40%MK
GPC 3	50% + 50%MK

Table 5: Mix proportions for OPC.

Mix no.	Mix proportion
1	100% + 0%FA+100%RS
2	60% + 40%FA+100%RS
3	60% + 40%FA+0%RS

According to BIS 13311 (part 1): 1992 [15, 18, 19], quality of concrete can be determined by using velocity of ultrasonic pulse waves. Velocity of waves is determined initially. Based on velocity of wave travelling through the concrete specimen, quality of concrete can be identified and is represented in Table 6.

Rebound Hammer or Schmidt Hammer Test Procedure [9]. The rebound hammer with plunger is considered and impacted against concrete surface. Generally, there are different kinds of rebound hammers which are available depending on applications. The impact energy may vary from 0.07–3 kg-m. Number which is obtained from the rebound index is calibrated to compute compressive strength.

The concrete surface on which this rebound test is conducted should be smooth, clean, and dry. Sand paper or stone can be used to rub rough surfaces present on concrete. From edges and discontinuity shapes, the hammer should be impacted 20 mm long. Concrete surface should be maintained perpendicular to the rebound hammer. For each concrete surface, numbers of observations are to be taken. Average of those observations results in strength of concrete. Test procedure for determining rebound values is as per ASTM C-805-85 [21] and BIS 13311 PART 2 [22].

According to BIS 13311 (part 2): 1992 [22], quality of concrete can be determined by using the rebound number. The rebound number is determined initially by impacting the rebound hammer. Based on the number, quality of concrete can be identified and is represented in Table 7.

3. Results and Discussion

Evaluation tests for finding the concrete strength were conducted with various supplements of cement after completion of curing periods. UPV testing machine and rebound hammer are the equipment used for compressive strength evaluation [15, 20, 22].

3.1. For Ultrasonic Pulse Velocity Test. Table 8 contains UPV values of OPC after curing (7, 14, and 28 days). A graph was plotted by considering concrete mix on abscissa and UPV values as ordinates. And the obtained graph is represented as Figure 1.

Table 6: Grading of concrete using pulse velocity [8].

UPV (km/sec)	Quality of concrete
Above 4.5	Excellent (E)
3.5–4.5	Good (G)
3–3.5	Medium (M)
Below 3	Poor (P)

Table 7: Grading of concrete using the rebound number [8].

Rebound number	Concrete grading
Above 40	Very good (VG)
30–40	Good (G)
20–30	Fair (F)
Below 20	Poor (P)

Table 8: UPV values for OPC.

Concrete mix	UPV (km/s)		
	7 days	14 days	28 days
Mix 1	4.731	4.913	5.245
Mix 2	4.913	5.068	5.372
Mix 3	3.452	3.816	4.275
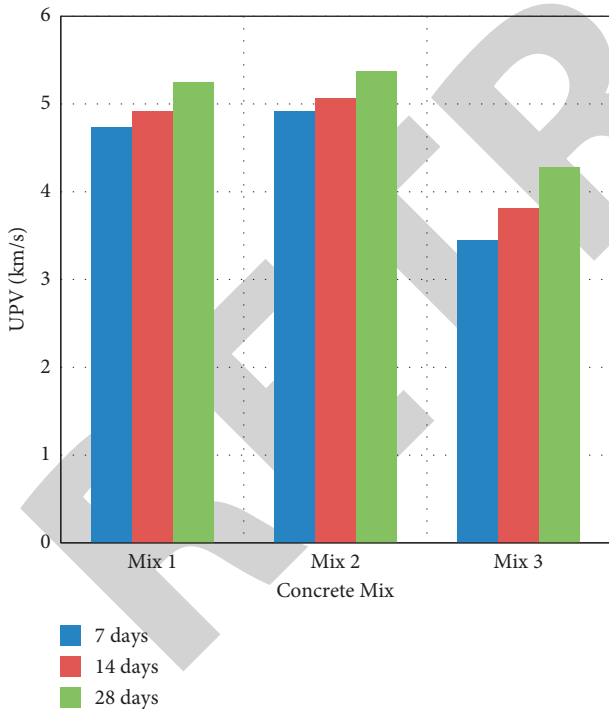
Figure 1: UPV values for OPC for different mix proportions.

Figure 1 represents a plot between UPV values for OPC for different concrete mixes. And it was noticed that UPV values are increasing for increasing curing period. UPV values of Mix 3 are decreasing at all ages (7, 14, and 28 days).

Table 9 represents UPV values for GPC concrete of all the three mix proportions after 7, 14, and 28 days of curing.

Table 9: UPV values for GPC.

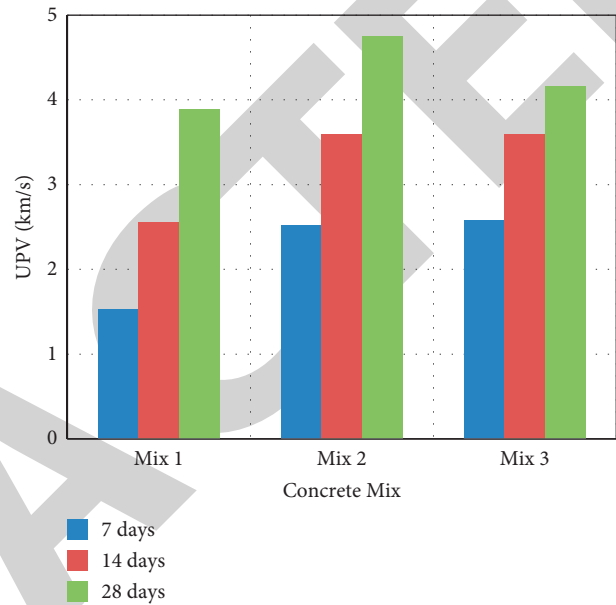| Concrete mix	UPV (km/s)		
	7 days	14 days	28 days
GPC 1	1.534	2.556	3.884
GPC 2	2.523	3.596	4.756
GPC 3	2.573	3.592	4.165

Figure 2: UPV value for GPC for different proportions.

Table 10: Rebound number for OPC.

Concrete mix	Rebound no.		
	7 days	14 days	28 days
Mix 1	33	25	26
Mix 2	36	28	29
Mix 3	38	31	30

A graph was plotted by considering GPC mix on abscissa and UPV values as ordinates. And the obtained graph is represented as Figure 2.

A plot between UPV values for OPC for different mix proportions is represented in Figure 2. From this figure, it was observed that UPV values increase for increasing curing period. UPV values of Mix 3 are decreasing at all ages (7, 14, and 28 days).

3.2. For Rebound Hammer Test. Table 10 represents the rebound number for different mix proportions of OPC. These values are taken after the curing period (7, 14, and 28 days).

Figure 3 represents a plot between rebound numbers for OPC for different mix proportions. And it is being noticed that rebound values are decreasing with increase in the curing period. A rebound value of Mix 3 is greater when
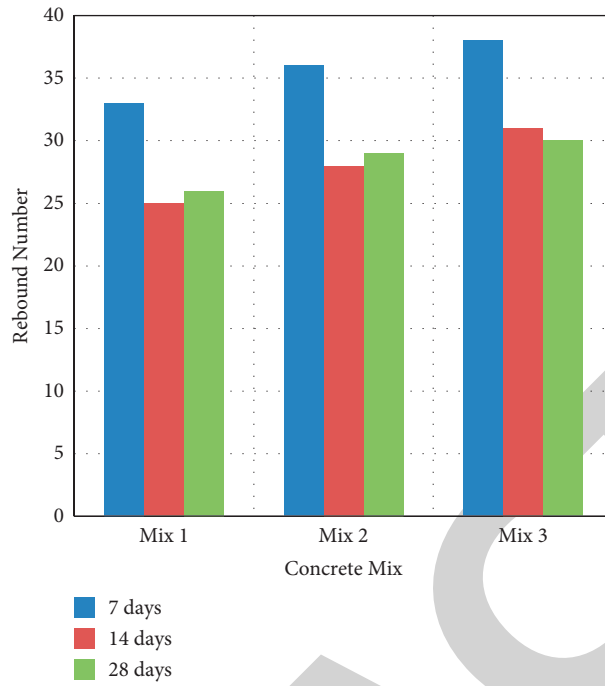
Figure 3: Rebound number for different proportions of OPC.

Table 11: Rebound number for GPC.

Concrete mix	Rebound no.		
	7 days	14 days	28 days
Mix 1	28	27	26
Mix 2	29	28	28.5
Mix 3	31	31.5	31.25
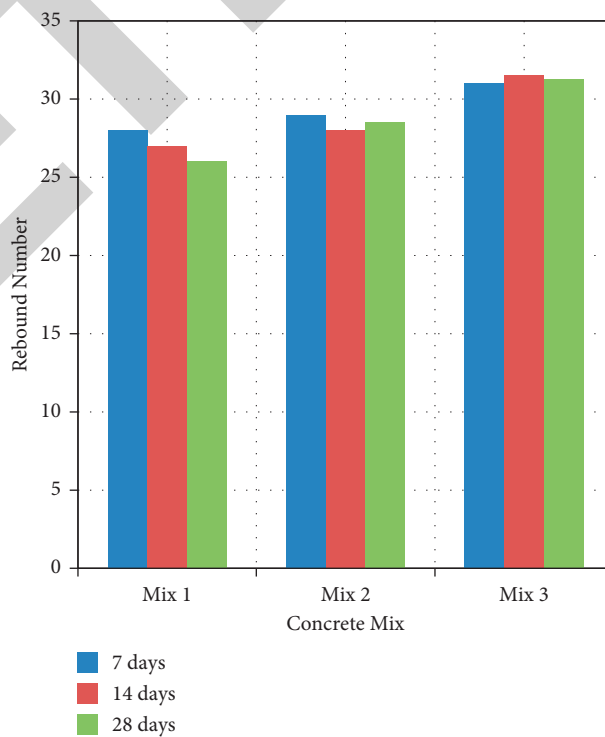
Figure 4: Rebound number for different proportions of GPC.

$$y = 15.21e^{0.216x}$$
$$R^2 = 0.854$$

♦ Compressive strength in MPa
— Expon. (Compressive strength in MPa)
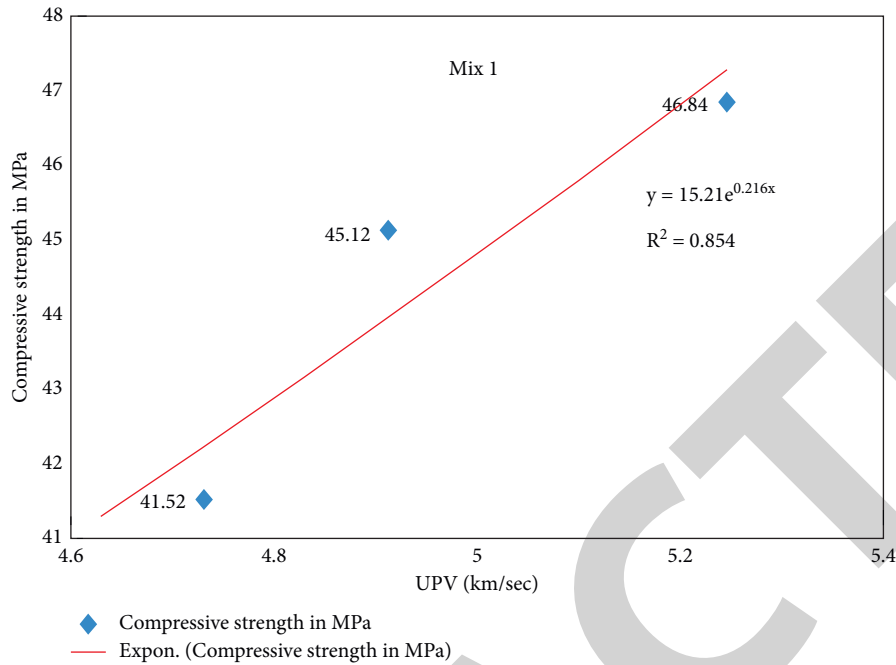
Figure 5: Relation between compressive strength and UPV for Mix 1.

$$y = 0.01481e^{1.4116x}$$
$$R^2 = 0.9886$$

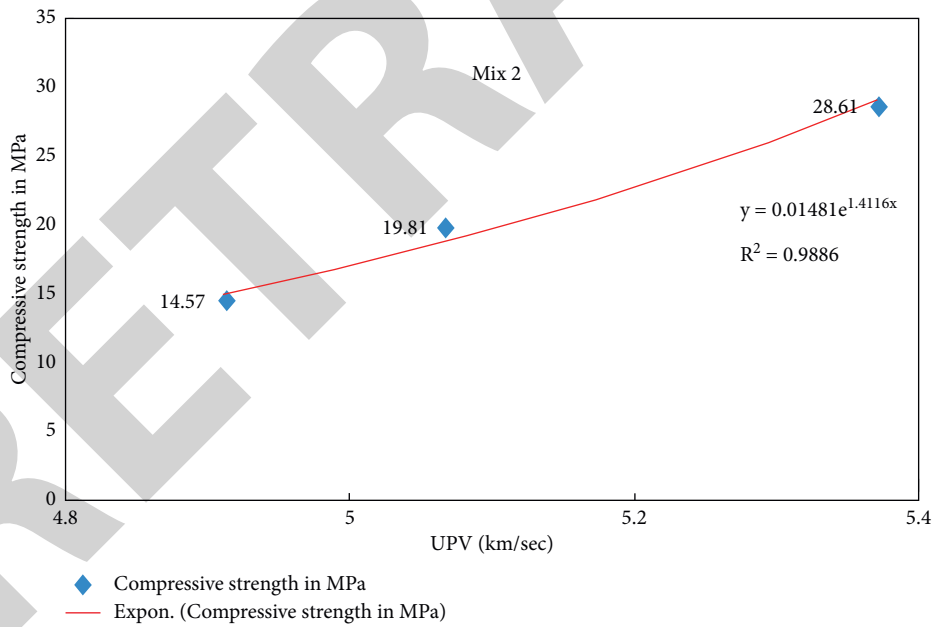♦ Compressive strength in MPa
— Expon. (Compressive strength in MPa)

Figure 6: Relation between compressive strength and UPV for Mix 2.

compared with other mix proportions at all ages (7, 14, and 28 days).

In Table 11, the rebound number for different mix proportions of GPC is represented. These values are taken after the curing period (7, 14, and 28 days).

Figure 4 represents a plot between rebound numbers for GPC for different mix proportions. And it is being noticed that, on increasing the curing period, rebound values are also increasing. Rebound value of Mix 3 is greater when compared with other mix proportions at various ages (7, 14, and 28 days). Along with the above results, relations of compressive strength and ultrasonic pulse velocity values were developed and are represented in Figures 5–12.
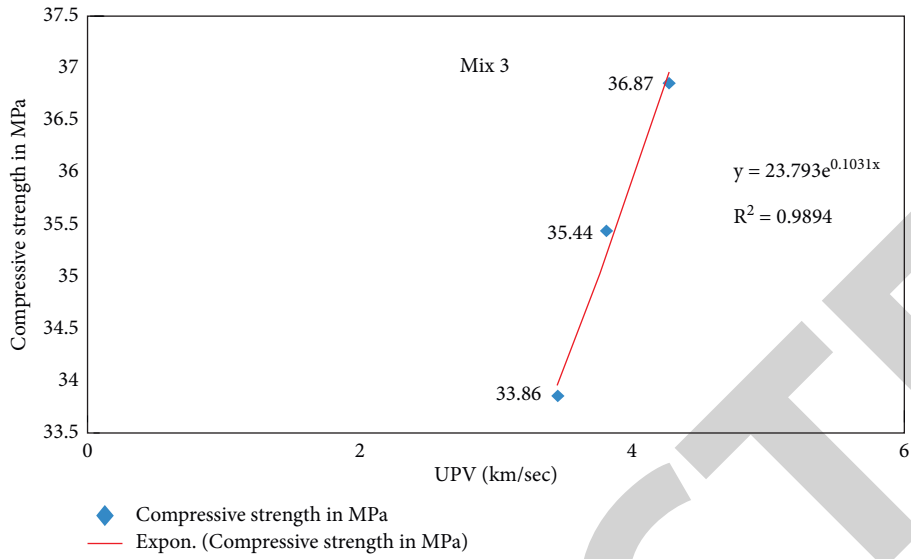
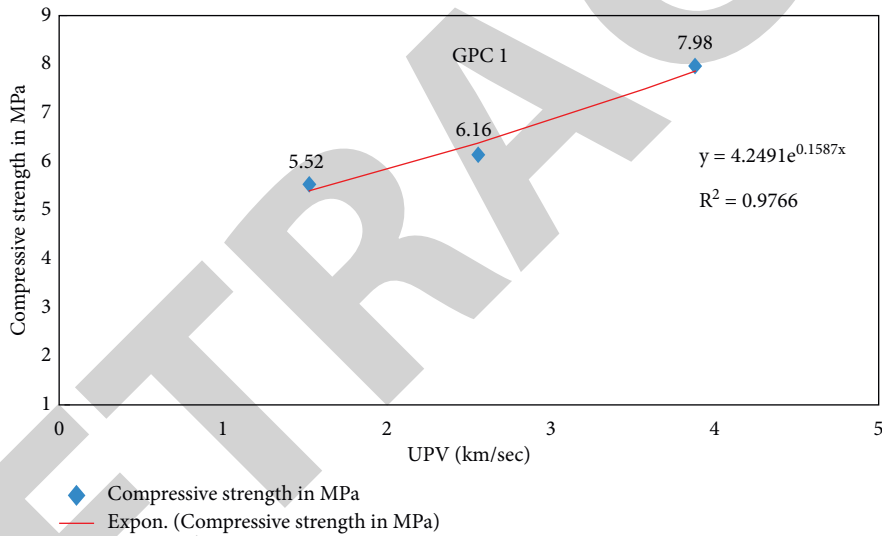FIGURE 7: Relation between compressive strength and UPV for Mix 3.

$y = 23.793e^{0.1031x}$

$R^2 = 0.9894$

FIGURE 8: Relation between compressive strength and UPV for GPC 1.

$y = 4.2491e^{0.1587x}$

$R^2 = 0.9766$
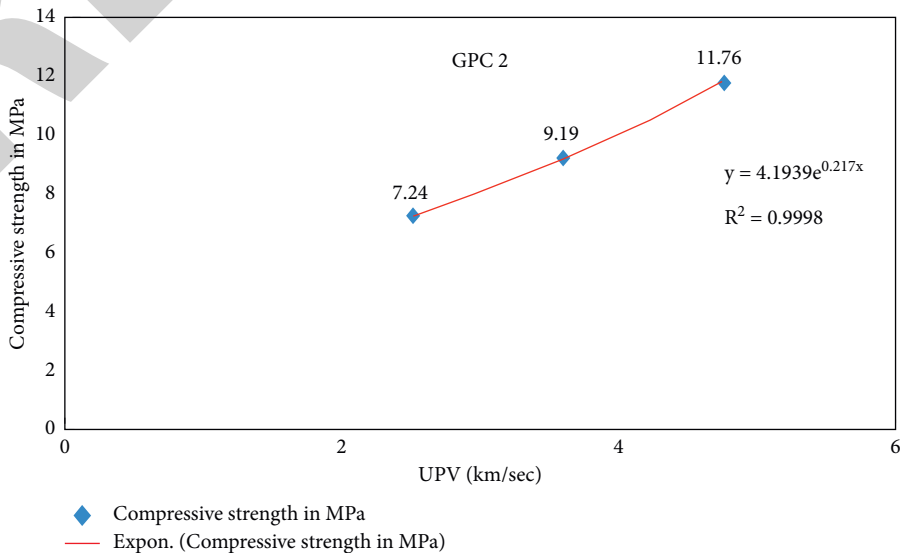
FIGURE 9: Relation between compressive strength and UPV for GPC 2.

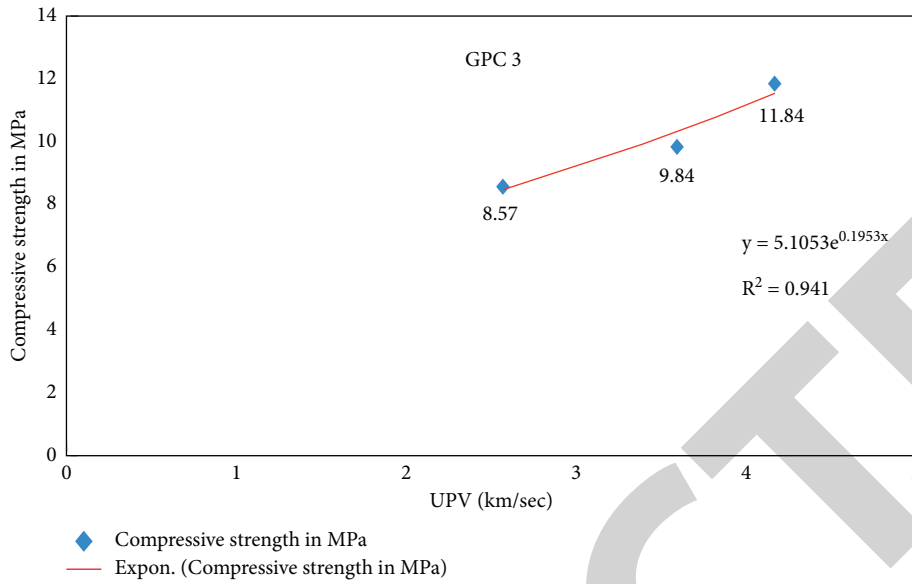$y = 4.1939e^{0.217x}$

$R^2 = 0.9998$

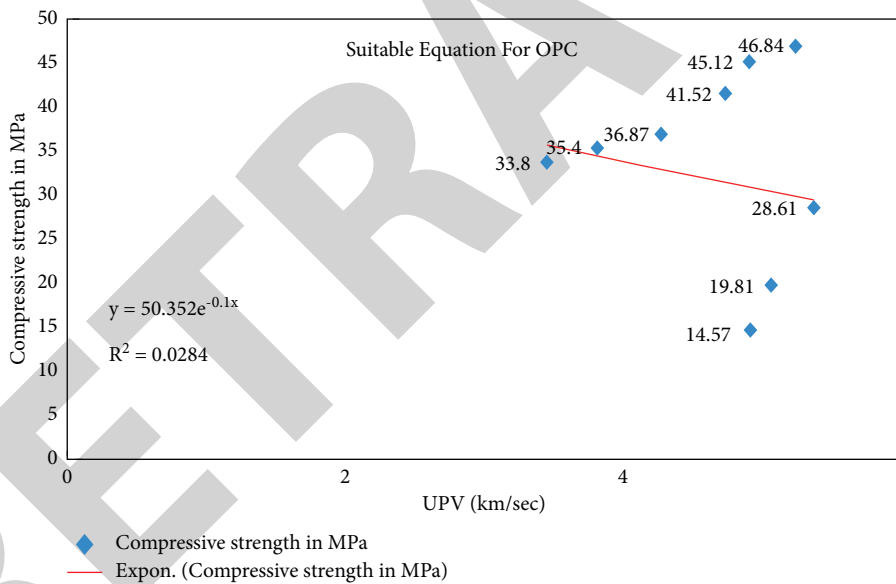Figure 10: Relation between compressive strength and UPV for GPC 3.

Figure 11: Equation obtained for OPC.

There is no specific relation for concrete compressive strength and UPV. From above relations, following equations were determined with respect to mix proportions [16, 20, 23, 24]:

(1) $y = 15.21e^{0.216x}$ (Mix 1)

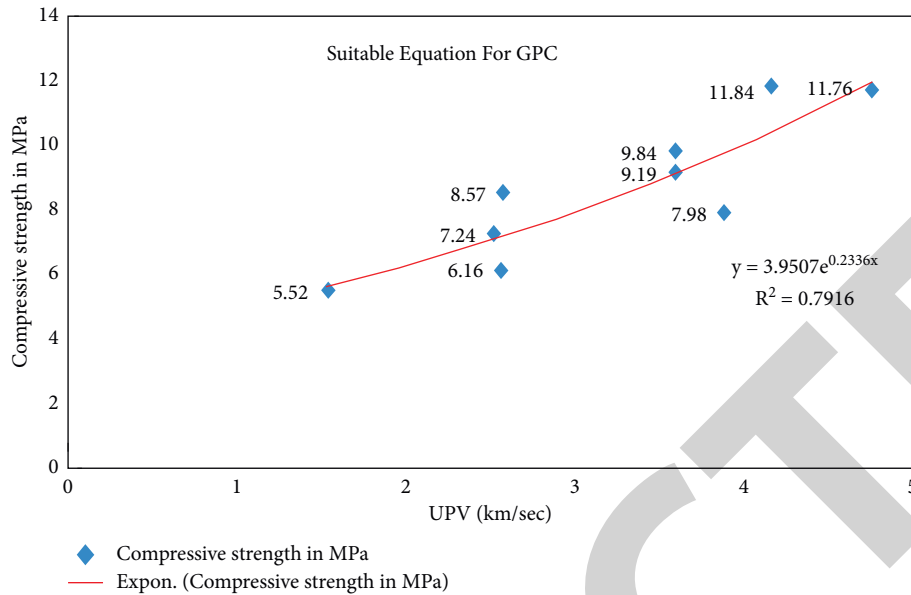(2) $y = 0.014e^{1.411x}$ (Mix 2)

(3) $y = 23.79e^{0.103x}$ (Mix 3)

FIGURE 12: Equation obtained for GPC.

(4) $y = 4.249e^{0.158x}$ (GPC 1)

(5) $y = 4.193e^{0.217x}$ (GPC 2)

(6) $y = 5.105e^{0.195x}$ (GPC 3)

where y is the concrete compressive strength and *x* is the velocity value of concrete.

4. Conclusion

For this present experimental investigation, an equation is determined for comparison of compressive strength and UPV values obtainedare as follows:

(i) The UPV and rebound values increase with increase in the curing period.

(ii) For Mix 2 of OPC concrete, the UPV values increase by 3.8% and 6.42% at 7 to 14 days and 14 to 28 days of curing, respectively. For the same mix proportion, the rebound value increases by 9.1% and 5.5% at 7–14 and 14–28 days of curing, respectively.

(iii) For Mix 2 of GPC, the UPV values increase with 42.46% and 32.31% at 7–14 days and 14–28 days of curing, respectively. For same mix proportion, the rebound increases by 3.57% and 6.89% at 7–14 and 14–28 days of curing, respectively.

(iv) With reduction of fly ash content in GPC, the passing time of longitudinal waves is lesser.

(v) Further investigation of this current study is to develop equations for various mix proportions of both conventional and geopolymer concrete. These are helpful for finding the compressive strength of respective mix proportions.

4.1. Future Scope

Further investigation of this current study is to develop equations for various mix proportions of both conventional and geopolymer concrete. These are helpful for finding the compressive strength of respective mix proportions.

Many industrial by-product combinations can be used for production of geopolymers.

Structural parameters are investigated using geopolymer.

For utilizing geopolymer concrete in large- and small-scale constructions, experimental investigations can be conducted on structural elements.

Life cycle analysis (LCA) of concrete can also be used to identify the durability of geopolymer concrete.

Data Availability

The data used to support the findings of this study are included in the article and are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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