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| **RESEARCH ARTICLE**

Mechanical Properties of Lightweight Concrete Incorporating Perlite, LECA, and Supplementary Materials

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| ABSTRACT

Lightweight structural materials are increasingly essential in modern construction, particularly in seismic-prone regions, as they reduce self-weight while maintaining mechanical reliability and improving earthquake resilience. This study investigates the mechanical behavior of lightweight concrete mixtures produced using expanded perlite and Light Expanded Clay Aggregate (LECA), combined with stone powder and microsilica to enhance matrix densification, with Ordinary Portland Cement (Type I) and potable tap water used across all mixes. Four lightweight mixtures—C350L40P15, C300L60P5, C400L40P15, and C400L50P10—were designed and compared with a reference concrete. Results showed substantial reductions in compressive strength (35.4%–54.2%), with C400L40P15 achieving the highest value of 26 MPa. Indirect tensile strength decreased by 16.3%–32.5%, yet mixtures with higher perlite content demonstrated notable improvements, achieving up to 19.4% greater strength compared with lower-perlite. Flexural tensile strength declined by 28.6%–41.3% relative to the reference, with C400L40P15 again showing the best performance (4.5 MPa). The elastic modulus exhibited the largest reductions (54.3%–65.7%) due to lower density, though it increased with higher cement content and reduced water-to-cement ratio. Overall, the findings indicate that optimized perlite content, controlled density, and the incorporation of stone powder collectively enhance the tensile, flexural, and stiffness properties of lightweight concrete, highlighting its potential for structural applications in earthquake-prone areas where reduced density is crucial for improving seismic performance without severely compromising mechanical strength.

| KEYWORDS

Lightweight Concrete, Mechanical Properties, LECA, Perlite, Superplasticizer

| ARTICLE INFORMATION

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1. Introduction

One of the fundamental challenges in design and construction of reinforced concrete structures particularly high-rise buildings and bridges is their self-weight which is considerable in construction implement and safety[1]. Since structural weight directly affects dynamic response and vibration absorption capacity, reducing the effective weight of the structure is of great engineering significance [2]. The use of lightweight concrete instead of conventional concrete offers an effective solution to this challenge. Lightweight concrete typically has a density ranging from 300 to 1900 kg/m^3, whereas the density of normal-weight concrete falls within 2200 to 2500 kg/m^3. One common method of producing lightweight concrete is the replacement of normal-weight aggregates with lightweight aggregates. Among these materials, light expanded clay aggregate (LECA) has gained particular importance due to its low weight, adequate compressive strength, and favorable behavior in self-compacting concrete.

LECA not only helps to decrease the unit weight of concrete but also enhances its thermal and elastic properties. Research has also proven that Leca-Lightweight Concrete can save energy in buildings and steel on construction sites which leads to reducing CO2-emissions by 30-45%. Nevertheless, the low compressive strength and its susceptibility to cracking are still challenges that should be taken into consideration in designing mixes [3]. The mechanical properties of the zeolite-clay-lightweight concrete strongly depend on the addition of pig iron slag and polypropylene fibers, they improve both compressive strength and crack resistance behavior[4]

Generally, the use of light weight construction materials in concrete also has many advantages, by which it may reduce the dead load of buildings, foundation size and increase usable space with smaller sized structures members that provide better thermal and acoustic insulation as well as fire resistance combating to a certain level [5]. Lightweight materials can be either natural or manmade. They could be natural materials (pumice, volcanic tuff, perlite and vermiculate) or artificial lightweight creativities (flyash, slag produced in blast furnaces expanded clays and expanded perlites). Of these, expanded clay is one of the most popular manufactured LWA materials because its production process is controllable and product properties uniform, strong as well [6]. properties of geopolymer materials and structures derived from clay sources have considerable impact on this concrete type[7].

Mohammad Aslam produced a lightweight concrete incorporating blast furnace slag and oil palm fibers, achieving a compressive strength of 42.5 MPa and a density of 1856 kg/m³. Romseis investigated the influence of high-density polyethylene (HDPE) and low-density polyethylene (LDPE) plastic waste on the mechanical properties of lightweight concrete and succeeded in producing concrete with a density of 1950–2050 kg/m³ and a compressive strength exceeding 40 MPa at 28 days. Demirboğa conducted an experimental study on the effects of expanded perlite and mineral additives on the compressive strength of lightweight concrete, reporting that mineral additives can enhance the strength of perlite-based lightweight mixtures [8]. Alexandre Boes examined self-compacting lightweight concrete produced with local lightweight aggregates in the Iberian Peninsula and concluded that stable and workable self-compacting lightweight concrete with compressive strengths between 37.4 and 60.8 MPa can be achieved [9]. Demirboğa and Gul evaluated the effect of silica fume on the density of lightweight concrete [10]. Newlan, in a study on bridge deck concrete mix designs, recommended the replacement of 10% of the cement weight with microsilica as an optimal option [11]. Ebrahim demonstrated that substituting expanded perlite for pumice reduces the thermal conductivity of hardened concrete samples [12]. You-It's investigations further indicated that the mechanical and thermal behavior of lightweight concrete is significantly influenced by the type of aggregate and mixture proportions [13]. Syed Henigal, Ali, and Abdulsalam emphasized that lightweight concrete intended for structural applications must achieve a 28-day compressive strength exceeding 17 MPa [5]. Additionally, Subramanian examined the use of titanium dioxide–coated pumice for seawater bacterial removal and concluded that this type of reactor is efficient and practical for water and wastewater treatment [14]. Chandra and Berntsen also noted that natural lightweight materials such as pumice, volcanic tuff, and volcanic ash originate from the fragmentation of volcanic or sedimentary rocks [15]. Finally, Al-Zarif evaluated the performance of dual lightweight concrete systems reinforced with GFRP bars under various earthquake intensities and heights, reporting that such systems can reduce structural damage by up to 25% under controlled seismic conditions [16].

2. Materials and Methodology

2.1 Materials

In this research, potable tap water, which was clear, odorless, and tasteless, was used for mixing and curing all concrete specimens. The binder employed was Ordinary Portland Cement (Type I) from Ghori Cement Plant, with its chemical properties detailed in Table.1 Expanded perlite was incorporated as a lightweight aggregate due to its very low bulk density and low thermal conductivity, with its chemical properties provided in Table 1 and samples illustrated in Fig.1.d and Fig.1. e.

To enhance workability, a polycarboxylate-based superplasticizer (ADIUM 132) was used in both normal-weight and lightweight concrete mixes. Its view is shown in Fig.1.c and its physical properties are given in Table.3. Stone powder was added at a 5% cement replacement level to fill surface pores, and its effect on mechanical properties was investigated; its characteristics are given in Table.1. Microsilica (Silica Fume) was utilized to increase paste cohesiveness and strength in lightweight mixes, with its chemical composition listed in Table.1 and a sample presented in Fig.1.b Regarding natural aggregates, crushed gravel passing through a 12.5 mm sieve and retained on a 9.5 mm sieve was used alongside natural sand with a particle size of 0-5 mm and a fineness modulus of 2.6. The particle size distribution curves of sand and LECA are presented in Fig.2.

Table1. Chemical Compositions

Chemical composition	CaO	SiO2	Al2O3	Fe2O3	MgO	k2O	Na2O	Cl	Traces	SO3	P2O5	SiC	Other oxides
Cement	64	21.97	4.69	3.53	2.04	0.85	0.34	0.001	-	2.5	-	-	-
Microsilica	0.49	93.6	1.32	0.3	0.97	1.01	0.31	-	-	0.1	0.16	0.5	
LECA	2.46	66.05	16.57	7.1	1.99	2.69	0.69	-	-	0.03	0.21		0.84

Perlite	0.9	73.8	13.9	0.9	0.3	4.3	4.70	-	0.20	-	-	-	-
stone	55.4	0.5	0.5	-	-	-	-	-	43.1	-	-	-	-

The primary lightweight aggregate, Light Expanded Clay Aggregate (LECA), was produced by firing clay at temperatures exceeding 1100 °C; its chemical analysis is in Table.1, a sample is in Fig.1.a, and its physical properties are in Table.2.

Table2. Physical Properties of LECA

Lightweight aggregate (LECA)	Average uncompacted specific gravity kg/m3	Average compacted specific gravity kg/m3	Density	Water Absorption (%)
First specimen	736	768	1350	10.2
Second specimen	-	-	1240	9.4
Third specimen	-	-	1100	9.6

Table3. Physical Properties of ADIUM-132

Color	Dark brown
Density	1.04-1.010kg/l
PH	5.50 ± 1.00
Maximum chloride content	Chloride free
Maximum alkali content	≤2% by weight


(a)

(b)

(c)

(d)

(e)

Fig.1. a) LECA, b) Microsilica Powder, c) Adium132, d) Fine-grained (1-3mm) Perlite, e). Coarse-grained(3-5mm) Perlite

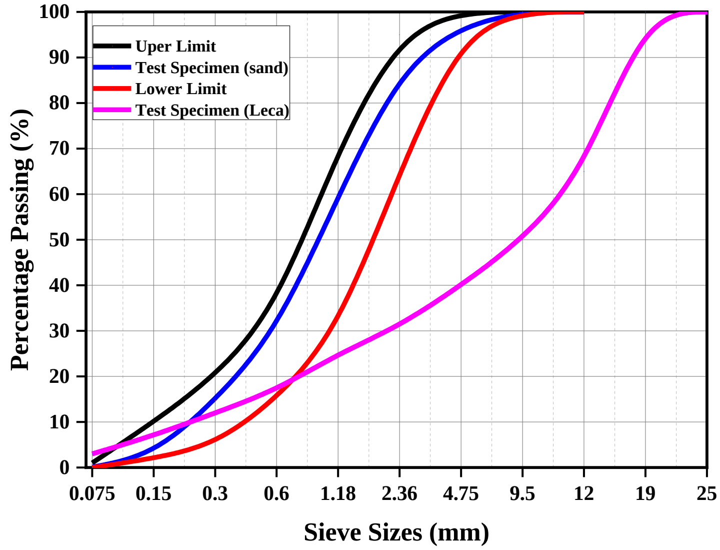


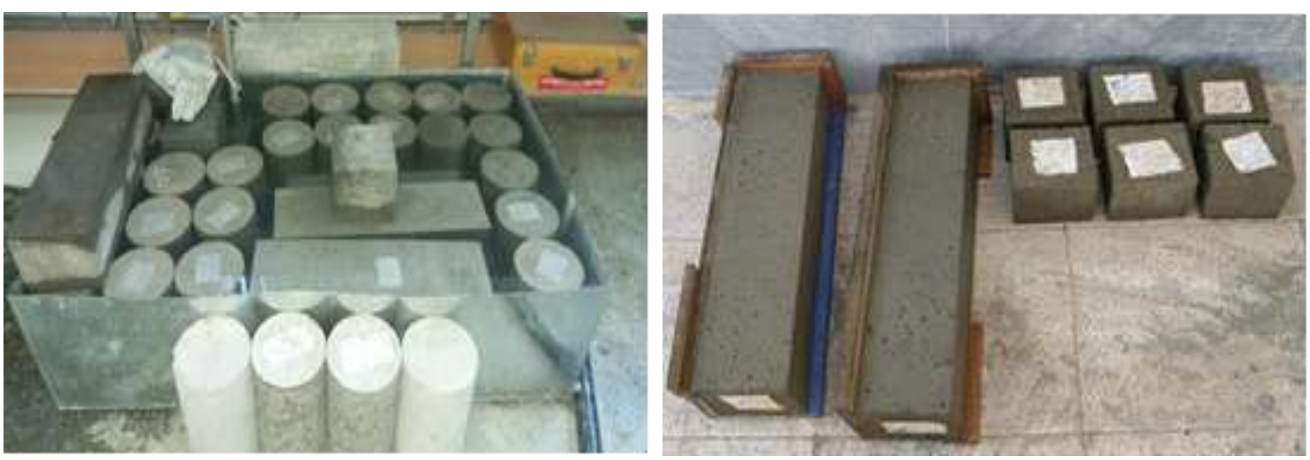
Fig.2 particle size distribution curves of sand and LECA

2.2 Preparation and Experimental Procedures

2.2,1 Concrete Mixing and Curing Procedures

The concrete mixtures were prepared in accordance with ASTM C192[17]. All constituent materials were weighed based on the required experimental volume, and the aggregates were used in a saturated surface-dry (SSD) condition. The mixing process was conducted in three stages to ensure uniformity. First, the dry materials were mixed for 3–5 minutes without water to achieve initial homogeneity. In the second stage, cement, limestone powder, fine aggregate, microsilica, and 50% of the superplasticizer, together with two-thirds of the mixing water, were added and mixed for 4 minutes. In the third stage, coarse aggregates were introduced along with the remaining water and the rest of the superplasticizer, and mixing continued for an additional 2 minutes. The fresh concrete was then cast into oil-coated molds, including 150×150×150 mm cubes, 100×200 mm cylinders, prismatic molds, and 150×300 mm cylinders.

The cube and prismatic specimens were cast in two layers, whereas the 150×300 mm cylindrical specimens were cast in three layers; each layer was compacted using a vibration table for 20 seconds. After casting, the specimens remained in the molds for 16–24 hours before being demolded carefully to avoid damage. Subsequently, all specimens were cured in a water tank at a controlled temperature of 20 ± 2°C until the time of testing.



(a) (b)

Fig.3. a) Curing and storage of concrete specimens in water tanks at 22°C, b) Fresh lightweight concrete cubes and prisms with Leca–perlite mix,

Table.4 presents the mix designs for conventional and lightweight concretes. In the aforementioned mix designs, the amount of microsilica is fixed at 10% of the cement content, and the superplasticizer is added at 2% of the combined weight of cement and microsilica. The natural coarse aggregates constitute 20% of the total aggregate materials, while the natural fine aggregates account for 80%. Stone powder is maintained at a constant 5% of the fine aggregate content, whereas the quantities of expanded clay (LECA) and perlite vary for each mix. All material weights are expressed in kilograms per cubic meter of concrete. During the preparation of lightweight concrete mixtures, the lightweight aggregates were first soaked in water for 24 hours to achieve saturation. Later, they were used in concrete mixes in a saturated surface-dry (SSD) state to confirm proper mix uniformity and performance.

2.2.2 Determination of Compressive Strength of Concrete

Checking the compressive strength of specimens is one of the most crucial experiments, as it is closely related to various material properties. In order to find out the compressive strength of hardened concrete, both cube and cylindrical specimens are widely used. In this study, cubic samples measuring 150 × 150 × 150 mm were prepared and tested according to ASTM C109[18]. The compressive strength tests were controlled using an ELE automatic testing machine with a loading capacity of 2500 kN. Because standards typically define the characteristic strength of concrete based on cylindrical samples, the results achieved from cubic specimens were altered to equivalent cylindrical strength following the relevant code conditions. Fig.4 demonstrates the compressive strength testing machine. Compressive strength is calculated using equation 1.

$$\sigma = \frac{P}{A} \qquad (1)$$

σ: compressive strength in (MPa)
P: Applied load in (N)
A: Cross-sectional area of the specimen in (mm^2)

Fig.4 Compressive Strength Testing Machine

Table4. Selected mix designs incorporating perlite and LECA aggregates

Specimen Number	$\frac{W}{(c+Ms)}$	Various percentages of different lightweight aggregates replacing sand Total mixture (kg)	Cement (kg)	Water (kg)	Natural sand (kg)	Gravel (kg)	Superplasticizer (kg)	Microsilica Ms) (kg)	Stone powder (kg)
1	0.35	Normal concrete (Reference) -	400	158.4	898.5	898.8	8.8	40	-
2	0.30	15%Perlite+40%LECA 311.17	350	174.0	600	370	7.7	35	58
3	0.35	5%Perlite+60%LECA 358.34	300	172.4	510	360	7.7	35	56
4	0.30	15%Perlite+40%LECA 295.76	400	195.0	570	351	8.8	40	55
5	0.40	10%Perlite+50%LECA	400	176.0	485	340	8.8	40	53

2.2.3 Indirect Tensile Test

The specimens' tensile strength was determined using the indirect tensile (splitting) test by cylindrical samples measuring 200 × 100 mm, according to ASTM C496[19]. It is a crucial parameter affecting the failure of structural elements. As stated by such standard, the tensile strength is gotten by splitting the cylindrical specimen, which is placed horizontally in the testing machine and loaded linearly along its height. The tensile strength, T, is considered in (MPa) using Equation 2. It should be added that the tensile strength reported agrees with specimens tested in 28 days.

$$F = \frac{2P}{\pi LD} \qquad 2$$

P: Maximum applied load in newtons (N)
L: length or height of the specimen in (mm)
D: Specimen diameter in (mm)

2.2.4 Determination of Elastic Modulus

Elastic modulus is a principal material property that signifies the resistance of a body to deformation (strain). In this study, cylindrical specimens measuring 300 × 150 mm were tested in using ASTM C469 [20] code to find out the elastic modulus of concrete.

By load applying, the number of deformation cycles was registered at increases of 0.002 strain, and the corresponding change in the specimen length was measured in (mm). Figure 4 illustrates the appliance used for elastic modulus testing. The elastic modulus was considered using the following procedure.

The linear elastic range of concrete was determined, which in this study was considered as
Fc = 0.25Fc' It should be noted that this range must be less than 0.5 Fc'.
The applied load on the cylindrical specimen was calculated using equation 3.

$$P = Fc \times A \qquad 3$$

The strain (ε) was determined using the equation 4.

$$\varepsilon = (x \times 0.002)/150 \qquad 4$$

The elastic modulus (E) was calculated using equation5 of Table.5.

$$E = Fc/\varepsilon \qquad 5$$

Fc denotes the concrete stress within the linear elastic range.

2-2-5: Determination of Tensile Strength of Concrete Induced by Flexure

The tensile strength of concrete under flexural loading was determined in accordance with ASTM C78[21] using specimens measuring 100 × 100 × 500 mm. A simple concrete beam was placed on two supports, and a two-point loading system was applied at a distance of L/3 from each support. The load, P, was gradually increased until the beam fractured. A two-point loading apparatus was used for this test, as illustrated in Fig.5. The tensile strength of the specimen was calculated based on the tensile stress induced by bending, denoted as fr that is calculated from equations 6 and 7.

$$M_{max} = \frac{PL}{3} \qquad 6$$

Mmax: Maximum moment of the beam in (N x mm)

$$Fr = \frac{M_{max}}{I} * \frac{h}{2} = \frac{2PL}{bh^2} \qquad 7$$

Fr: Tensile Strength in MPa
h: Height of the beam in (mm)
b: Width of the beam cross-section in (mm)

Fig.5 Apparatus for Determining Flexural Tensile Strength

3. Results and Discussion

3.1 Compressive Strength

The specimens' compressive results are presented in Table 5 and Fig.6. Results demonstrate that the incorporation of lightweight aggregates—perlite and expanded clay (LECA)—significantly affected the mechanical acting of the mixtures. The reference specimen showed 28-day compressive strength of 48MPa, while the strengths of specimens (C350L40P15, C300L60P5, C400L40P15, and C400L50P10) were (19, 17, 26, and 25) MPa, equivalent to reductions of (39.5%, 35.4%, 54.2%, and 52.1%) relative to the reference mix. The specimen C350L40P15, achieved 19 MPa strength of 28-day, which is 10.5% higher than that of C300L60P5 (17 MPa), proving that increased perlite content boosts compressive strength.

similarly, specimen C400L40P15 approached 26MPa strength, representing increases of 26.9% and 34.6% compared to C350L40P15 and C300L60P5, respectively, while specimen C400L50P10 recorded 25MPa, showing a 3.8% reduction compared with C400L40P15, but still 24% and 32% higher than C350L40P15 and C300L60P5, respectively.

findings collectively verify the positive effect of perlite on compressive strength development [22]. The ratios of 7-day to 28-day compressive strength for C350L40P15, C300L60P5, C400L40P15, and C400L50P10 were 77%, 81%, 79%, and 67%, respectively. While the tensile-to-compressive strength ratio in ordinary concrete is generally around 10%, the values obtained in this study ranged from 13.67% to 17.23%. To balance the lack of fine particles in lightweight concrete mixtures, 5% stone powder was blended into all mixtures, resulting in smoother fracture surfaces and significantly reduced voids, which indicates improved matrix continuity and lower porosity. As a result, specimens containing stone powder showed better compressive and flexural strengths compared with those without stone powder due to decreased void content and improved matrix densification.

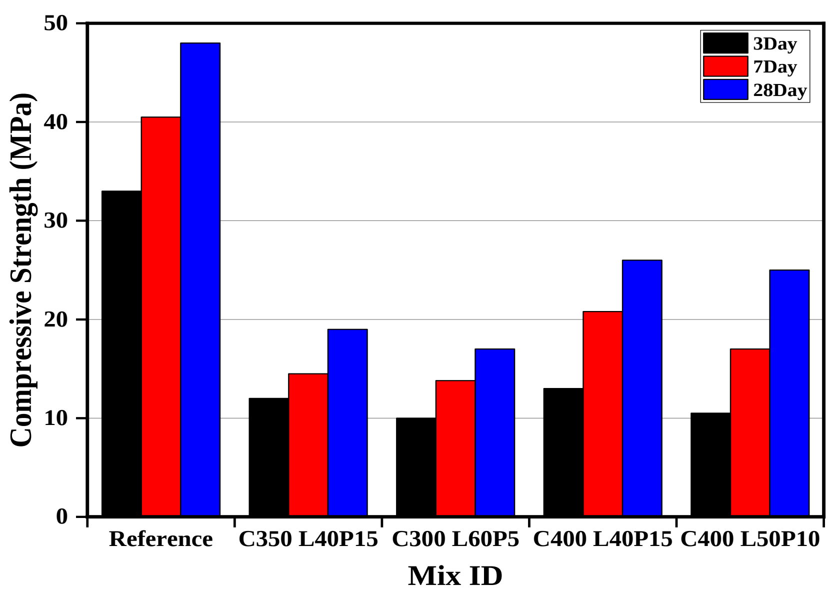


Fig.6 Compressive Strength Result

3.2 Indirect Tensile Strength

After 28 days of curing based on the designated mix designs, indirect tensile strength of the specimens was evaluated, and the related results are presented in Table 5 and Fig.7. The inclusion of lightweight aggregates, including perlite and LECA, showed a significant influence on the tensile performance of the specimens. Reference specimen showed 28-day tensile strength of 4.3 MPa, whereas the tensile strengths of samples (C350L40P15, C300L60P5, C400L40P15, and C400L50P10) were (3.1, 2.9, 3.6, and 3.5) MPa, respectively, showing decreases of 27.9%, 32.5%, 16.3%, and 18.6% compared to the reference. The tensile strength of sample C350L40P15 enclosing 15% perlite and 40% LECA was 3.1 MPa, representing a 6.4% increase compared with C300L60P5 (2.9 MPa), implying that the higher perlite content contributed to improved tensile performance. Generally, development in perlite content resulted in a noticeable enhancement in tensile strength. specimen C400L40P15 reached a tensile strength of 3.6 MPa, showing increases of 13.9% and 19.4% over C350L40P15 and C300L60P5, respectively, primarily due to the higher cement content. Tensile strength of specimen C400L50P10 was 3.5 MPa, which corresponds to a 2.8% decline compared to C400L40P15 but 11.4% and 17.1% improvements relative to C350L40P15 and C300L60P5, respectively, to the increased perlite content.

Generally, the results ratify that increasing perlite has a positive influence on tensile strength, and that higher density mixtures show increases in both compressive and tensile strength because of the established correlation between these two mechanical properties[23].

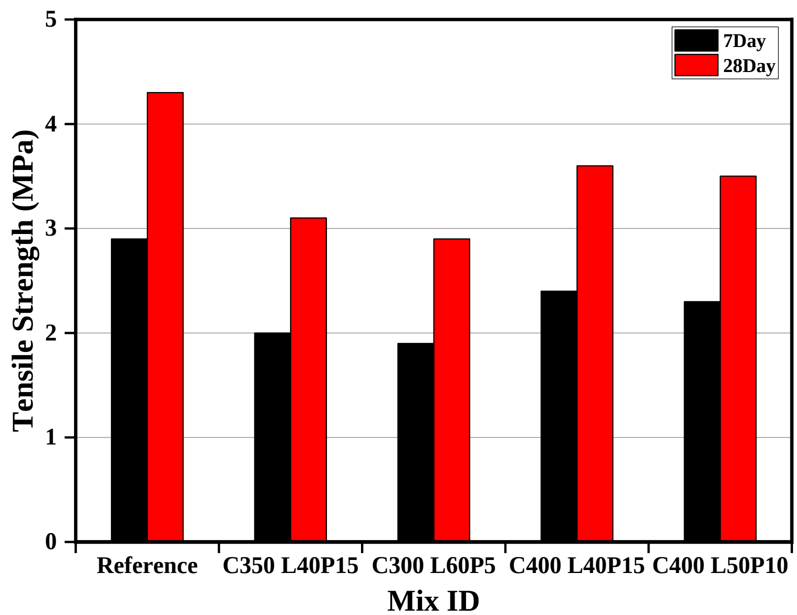


Fig.7 Tensile Strength Result

3.3 Flexural Tensile Strength

After 28 days of curing, the flexural tensile strength of the specimens was evaluated according to the selected mix designs. The relevant results are presented in Table 5 and Fig.8. The water-to-cement ratio showed a significant effect on flexural tensile action of the concrete mixtures.

The reference specimen exhibited 28-day flexural tensile strength of 6.3MPa, while the strengths of samples (C350L40P15, C300L60P5, C400L40P15, and C400L50P10) were (3.9, 3.7, 4.5, and 4.3)MPa, respectively, in relevance to reductions of 38.1%, 41.3%, 28.6%, and 31.7% compared to the reference specimen.

Sample C350L40P15, showed flexural tensile strength of 3.9 MPa, representing a 5.1% increase compared to C300L60P5 (3.7 MPa), denoting that the lower water-to-cement ratio in this mixture contributed to increased flexural tensile capacity. Generally, decreasing the water-to-cement ratio had an outcome of noticeable accompaniment in flexural tensile strength. Sample C400L40P15 reached a flexural tensile strength of 4.5 MPa, indicating increases of 13.3% and 17.8% relevant to C350L40P15 and C300L60P5, respectively, attributable to the combined influence of higher cement content and a decreased water-to-cement ratio. In opposition, sample C400L50P10 showed a flexural tensile strength of 4.3 MPa, which is 4.4% lower than C400L40P15 due to its higher water-to-cement ratio; however, it still showed growth of 9.3% and 14% in relevance to C350L40P15 and C300L60P5, respectively, primarily due to its higher cement content.

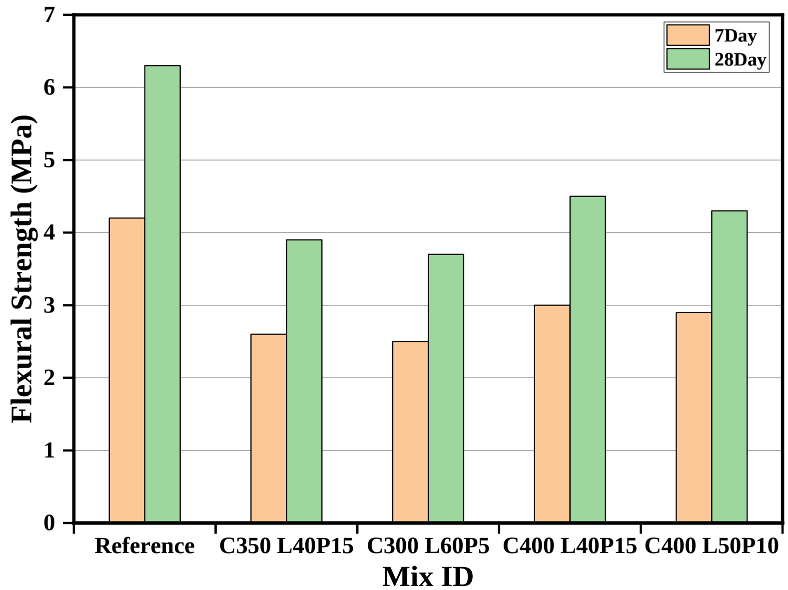


Fig.8 Flexural Tensile Strength Result

3.4 Elastic Modulus

Elastic modulus results of the specimens are showed in Fig.9, resulting that compressive strength and density have a substantial effect on the elastic performance of the mixtures. The reference specimen showed 3.5 MPa elastic modulus, whereas samples (C350L40P15, C300L60P5, C400L40P15, and C400L50P10) showed (1.3, 1.2, 1.6, and 1.5MPa), respectively, indicating (62.8%, 65.7%, 54.3%, and 57%) reductions compared to the reference specimen, primarily because of the lower densities of these mixtures. The elastic modulus of specimen C350L40P15 with (1.3MPa) elastic modulus, was 7.7% higher than C300L60P5 with (1.20 MPa), reflecting its higher density. Similarly, sample C400L40P15 showed an elastic modulus of 1.6MPa, corresponding to increases of 18.7% and 25% in relevance to C350L40P15 and C300L60P5 samples, respectively, attributable to its higher density and compressive strength. The elastic modulus of sample C400L50P10 was 1.5MPa, denoting a 6.25% decrease compared with C400L40P15 by1.6MPa elastic modulus due to its reduced density. However, it still indicated increases of 13.3% and 20% relative to specimens C350L40P15 and C300L60P5, respectively, again exhibited its higher density. Generally, the findings confirm that growth in density of lightweight concrete mixtures has a positive influence on elastic modulus[24].

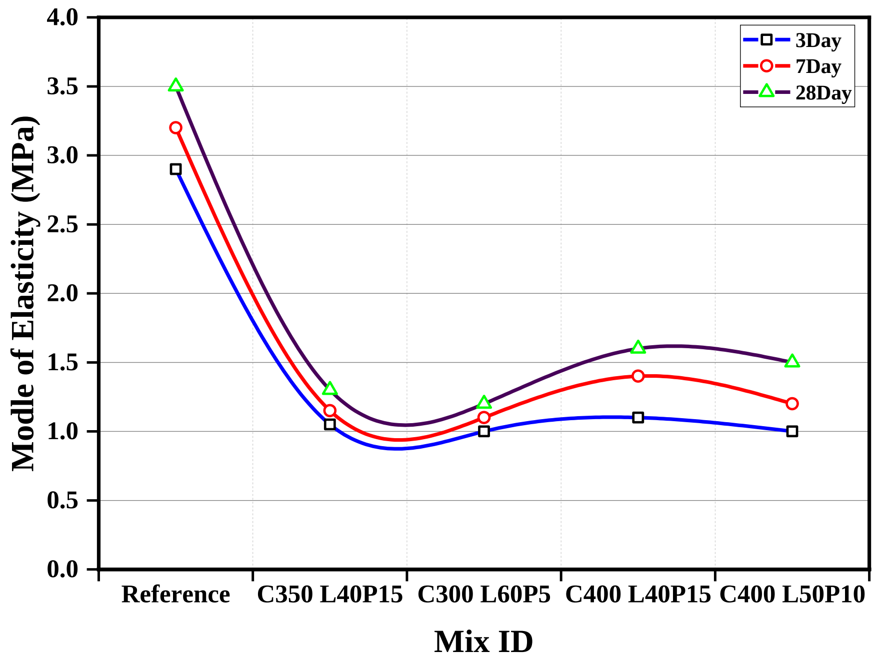


Fig.9 Elastic Modulus Result

3.5 Flexure to Tensile Strength Comparison

The flexural and tensile strengths of the specimens at 7 and 28 days are shown in Figures 9 and 8 and Table.5. Outcomes exhibit that the 7-day flexural strengths of the specimens (Reference, C350L40P15, C300L60P5, C400L40P15, and C400L50P10) were (4.2, 2.6, 2.5, 3.0, and 2.9 MPa), respectively.

When compared to their related 7-day tensile strengths of (2.9, 2.0, 1.9, 2.4, and 2.3 MPa), these values represent increases of (1.4, 1.3, 1.3, 1.2, and 1.3) times, respectively. Similarly, the 28-day flexural strengths of the same specimens were (6.3, 3.9, 3.7, 4.5, and 4.3) MPa, which, when compared with their 28-day tensile strengths of (4.3, 3.1, 2.9, 3.6, and 3.5) MPa, correspond to increases of (1.5, 1.2, 1.3, 1.2, and 1.2), respectively. Overall, the lower flexural strength compared to tensile strength is initially attributed to presence of compressive stresses and the non-consistent arrangement of stresses in flexural test, which results in higher load-bearing capacity in flexural tension zone and finally higher flexural strength in relevance to direct tensile strength[25].

3.6 Ratio of Tensile to Compressive Strength

To determine the ratio of tensile strength to compressive strength, the compressive strength of cubic specimens was first converted to the equivalent cylindrical compressive strength which is visible in Table.5. For this purpose, the compressive strength of cubic samples with values lower than 25 MPa was divided by a conversion factor of 1.25. For cubic compressive strengths exceeding 25 MPa, specific correction factors were applied; a factor of 1.104 was used for the Reference specimen, and 1.192 for the C400L40P15 specimen. Based on the results of the 28-day compressive and tensile strength tests, the tensile-to-compressive strength ratio for the five specimens ranged from 9.89% to 21.32%. The Reference specimen, which exhibited the highest compressive strength of 43.5 MPa, showed the lowest tensile-to-compressive strength ratio, equal to 9.89.

This outcome indicates that high-strength concrete tends to be more brittle, and increases in compressive strength are not necessarily accompanied by proportional increases in tensile strength[26]. Moreover, the C350L40P15 and C300L60P5 specimens, which exhibit lower compressive strengths of 15.2 MPa and 13.6 MPa, respectively, demonstrated the highest tensile-to-compressive strength ratios. These ratios were found to be 20.39% and 21.32%, respectively .Overall, the results demonstrate that reductions in compressive strength generally lead to relatively higher contributions from tensile strength, primarily due to the presence of lightweight aggregates such as LECA and perlite[27]. It is also evident that the C400L40P15 and C400L50P10 specimens, with moderate compressive strengths of 21.8 MPa and 20 MPa, respectively, fall within the intermediate range of tensile-to-compressive strength ratios. These specimens exhibited values of 16.5% and 17.5%, indicating a more balanced relationship between the compressive and tensile capacities. Accordingly, the results demonstrate that a reduction in compressive strength generally leads to a relative increase in the contribution of tensile strength. This behavior is attributed to the presence of lightweight aggregates such as LECA and perlite, which influence the internal structure of the concrete.

4. Conclusion

The findings of this study show that the incorporation of lightweight aggregates, clearly perlite and light expanded clay aggregate (LECA), affects the mechanical and elastic properties of concrete. Compressive strength outcomes indicated that higher perlite content contributed to improved 28-day strength, while changes in LECA content and whole mixture density directly influenced both compressive and tensile action. Indirect tensile and flexural tensile tests confirmed that mixtures with increased perlite content demonstrated improved tensile capacities, and reductions in water-to-cement ratio further improved flexural performance. The elastic modulus of the mixtures was mainly governed by the density and compressive strength, with higher-density specimens which showed greater stiffness. The insertion of 5% stone powders effectively reduced voids and advanced matrix continuity, contributing to developed strength characteristics. finally, these results highlight the critical interplay between aggregate type, mixture composition, and mechanical properties, showing that careful optimization of lightweight concrete constituents can achieve a balance between reduced density and fair structural performance, making these mixtures suitable for both structural and non-structural applications.

Table5. Various properties of specimens

Specimen number	w/(C+Ms)	Dry unit weight of concrete (Kg/cm3)	3Days		7Days				28Days					$\frac{7day f'c}{28day f'_c}$ (%)	$\frac{7day f_t}{28day f_t}$ (%)	$\frac{7day f_r}{28day f_r}$ (%)	$\frac{28day f_t}{28day f_r}$ (%)	$\frac{28day E}{28day E}$ (%)
			Standard cube compressive strength, f'c (MPa)	Standard cylindrical elastic modulus (Mpa)	Standard cube compressive strength, f'c (MPa)	Standard cylindrical indirect tensile strength, ft (Mpa)	Standard prismatic flexural tensile strength, fr (Mpa)	Standard cylindrical elastic modulus (Mpa)	Standard cube compressive strength, f'c (MPa)	Standard cylindrical indirect tensile strength, ft (Mpa)	Standard prismatic flexural tensile strength, fr (Mpa)	Standard cylindrical elastic modulus (Mpa)	ft/f'c (%)					
1	0.35	2402	33.0	2.9	40.5	2.9	4.2	3.2	48.0	4.30	6.30	3.5	9	84	67.4	66.7	68.3	91.4
2	0.3	1711	12.0	1.05	14.50	2	2.6	1.15	19.0	3.1	3.90	1.3	16.32	76	64.5	66.7	79.5	88.5
3	0.35	1642	10.0	1	13.80	1.9	2.5	1.1	17	2.9	3.70	1.2	17.06	81	65.5	67.6	78.4	91.7
4	0.3	1740	13.0	1.1	20.80	2.4	3	1.4	26.0	3.6	4.50	1.6	13.85	80	66.7	66.7	80	87.5
5	0.4	1698	10.5	1	17.0	2.3	2.9	1.2	25.0	3.50	4.30	1.5	14	68	65.7	67.4	81.4	80

5. Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could influence the reports in this paper.

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