# INVESTIGATION OF MECHANICAL CHARACTERISTICS OF LIGHTWEIGHT CONCRETE USING ENVIRONMENTALLY FRIENDLY LIGHTWEIGHT AGGREGATES

*by* Lisa Oksri Nelfia

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

**Indonesian Journal of Urban and Environmental Technology**
**https://www.e-journal.trisakti.ac.id/index.php/urbanenvirotech**
urbanenvirotech

# INVESTIGATION OF MECHANICAL CHARACTERISTICS OF LIGHTWEIGHT CONCRETE USING ENVIRONMENTALLY FRIENDLY LIGHTWEIGHT AGGREGATES

**Lisa Oksri-Nelfia[1*], Nazifa Sekarningtyas[1], Agung Sumarno[2], Astri Rinanti[3], Ouali Amiri[4,5]**

[1]Department of Civil Engineering and Planning, Faculty of Civil Engineering and Planning, Universitas Trisakti, Jakarta, Indonesia
[2]Research Center for Biomaterials, BRIN, Cibinong, 16911, West Java, Indonesia
[3]Department of Environmental Engineering, Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Jakarta, Indonesia
[4]Polytech'Nantes, Nantes Université, 44603 Saint-Nazaire, France
[5]Nantes Université, Ecole Centrale Nantes, CNRS, GeM, UMR 6183, F-44000 Nantes, France

*Corresponding author: lisa@trisakti.ac.id

**ABSTRACT**

**Aim:** This study aims to investigate the mechanical properties of lightweight concrete using lightweight aggregate and analyze the impact of silica fume on enhancing its compressive strength. The main objective of this study was to improve the value of industrial waste by utilizing GGBFS as a substitute for cement. Four alternative compositions have been used to produce samples of lightweight concrete. The coarse aggregate is substituted with 100% lightweight expanded clay aggregate, whereas the fine aggregates are replaced with 100% vermiculite and 100% polystyrene bead waste. A combination of 20% GGBFS and 10% silica fume is employed for cement replacement. The materials used throughout this study consist of aluminum powder and superplasticizer. The workability, compressive strength, tensile strength, and specific gravity of concrete will be determined by testing. The waster curing will be carried out on cylindrical concrete specimens 200 mm in height and 100 mm in diameter. Experimental results showed that the concrete mixture consisting of 80% cement and 20% GGBFS as binders, along with lightweight expanded clay aggregate as coarse aggregate and vermiculite as the fine aggregate, exhibits the highest compressive strength compared to other lightweight concrete mixtures.

**MANUSCRIPT HISTORY**

- Received April 2024
- Revised June 2024
- Accepted June 2024
- Available online October 2024

**KEYWORDS**

- Environmentally friendly
- Iron slag
- Light aggregate,
- Lightweight concrete,
- Waste

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

## 1. INTRODUCTION

One problem in a developed and developing country is the limited land to accommodate industrial waste in a large capacity. As a result, industrial waste accumulates and damages the environment (Meshram *et al.,* 2023). In China, industrial waste continuously increased from 1998 to 2018 and is expected to double by 2025 (Kanwal, Zeng, and Li, 2023). In Japan, in 2014, industrial waste contributed about 393 million tons, or about 89.9% of total waste (Amemiya, 2018). Hazardous industrial waste containing heavy metals can cause environmental pollution in isolated final disposal areas (Singh *et al.,* 2015). In Indonesia, waste produced by industry contributes to hazardous waste of around 229,907 tons every year (Widyatmoko, 2018); the amount of limited waste management centers with international standards results in industrial waste having the potential to pollute the environment and interfere with health (Widyatmoko, 2018). Landfill disposal is still an option for treating municipal solid and industrial waste. Even when better management, such as material recycling and energy recycling, needs to be introduced. This reduces waste and adds value to waste products (Widyatmoko, 2018). Environmental problems are caused by industrial waste and those that occur in the industrial process. In the field of construction, concrete contributes significantly to environmental problems because it is the second most widely used artificial substance in the world after water (Xuan, Poon and Zheng, 2018). The causes of concrete being one of the materials that contribute to environmental pollution include the extraction of natural minerals such as gravel and sand, carbon emissions from the transportation of resources and products, the amount of energy, water, and resource consumption during cement production and concrete manufacturing, and the emergence of large amounts of waste when the service life of the structure has expired (Pellegrino, Faleschini and Meyer, 2019; Mohamad *et al.,* 2021). Cement is an essential component in manufacturing concrete used in the construction world. One of the efforts to reduce waste from cement production is to reduce the use of Portland cement using substitute materials or substitute cement with other industrial waste so that, at the same time, it can reduce environmental problems due to Portland cement production and provide added value to construction waste (Seco *et al.,* 2012). Rice husk ash, which is one of the solid wastes produced by the agricultural industry, can be used as a substitute for cement in making concrete, and it was found that the use of rice husk ash as a material to replace cement contributes positively to

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

the compressive strength of concrete (Patah and Dasar, 2022). Ground granulated blast furnace slag (GGBS) is an industrial waste of iron production. GGBS is a pozzolan material that can be used as a cement or cement substitution substitute (Turu'allo, 2015).

Another effort that can be made to reduce environmental pollution is to replace or reduce the use of natural materials, such as fine aggregates and coarse aggregates, with industrial waste materials or artificial light aggregates. In terms of waste, plastic waste is still a significant concern due to the inability of plastic to decompose. Polystyrene is a type of plastic often used as industrial and household waste. Light aggregate is an aggregate that has a maximum content weight of 1100 kg/m$^3$. Examples of natural lightweight aggregates are pumice, scoria, and tuff, while examples of artificially light aggregates are clay, diatom-aces, perlite, and vermiculite. (SNI 03-3449, 2002; Abdulrasool *et al.,* 2022). Lightweight Expanded Clay Aggregate (LECA) is also a class of lightweight aggregate, which has a variety of sizes, so it is suitable as a substitution material for fine aggregate and coarse aggregate. Using LECA as a concrete constituent material can provide high segregation resistance. The more the LECA content in concrete increases, the more the specific gravity of concrete decreases. Using LECA as a combined aggregate can reduce the density of concrete to a lower level than if LECA was only a fine aggregate or coarse aggregate. In using LECA as aggregate, the more significant the reduction in the specific gravity of concrete, the more significant the decrease in mechanical strength. The thing to note is that using LECA as a combined aggregate can reduce the mechanical strength of concrete even more. (Rashad, 2018).

The use of polystyrene beads and vermiculite can be a solution for the substitution of fine aggregates. Due to the lightweight nature of vermiculite, the use of vermiculite as a fine aggregate can reduce the specific gravity and compressive strength of concrete. However, vermiculite can increase resistance to high temperatures and water absorption (Mo *et al.,* 2018). Using LECA, polystyrene beads, and vermiculite reduces specific gravity and the compressive strength of concrete. Thus, other materials are needed to increase the compressive strength of concrete. Based on (Srivastava *et al.,* 2014) Using silica fume in concrete at certain levels can significantly increase its compressive strength. In addition to an increase in compressive strength, silica fume can also increase concrete workability.

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

Incorporating lightweight aggregate into concrete will result in concrete that has a low specific gravity. Normal concrete has a specific gravity of 2200-2500 kg/m$^3$ (SNI 03-2834,2000) . In comparison, structural lightweight concrete has a specific gravity of less than 1850 kg/m$^3$ (SNI 03-3449, 2002). The specific gravity of concrete affects the weight of the building, which affects the size of the foundation. The greater the building load carried by the foundation, the bigger the foundation will be, or the number of foundation points will be increased; however, if the load carried is small, then the size of the foundation will be reduced. Also, the number of foundation points will decrease (Sajedi and Shafigh, 2012).

Currently, the foaming agent in concrete increases its porosity. Common foaming agents in concrete are air-entraining additives, aluminum powder, and foam. The use of foam requires a generator to pump foam into the concrete during the mixing process. Another way to use a *foaming agent* is to add a certain level of aluminum powder to the concrete mixture (Hou *et al.,* 2021).

In this study, GGBFS was used as a cement substitute to increase the added value of waste. Based on (Wuman, 2014), incorporating GGBFS or metal smelting waste as a substitute for cement at a certain level can increase the compressive strength of concrete. The GGBFS used is waste from PT. Krakatau Steel (Persero) Tbk is then processed and produced by PT. Krakatau Semen Indonesia (KSI). The purpose of this study was to investigate the effect of making floating concrete using GGBFS as a cement substitute, LECA as coarse aggregate, and vermiculite and polystyrene beads as fine aggregate on the mechanical strength of lightweight concrete, including concrete compressive strength, workability, and tensile strength of concrete.

## 2. RESEARCH METHODOLOGY

### 2.1 Materials

Binders used in this study include cement, iron slag, and silica fume. The cement used in this study is ordinary Portland cement (OPC), with a specific gravity of 3.10. The iron slag has a specific gravity of 2.79. The silica fume used has a specific gravity of 2.2.

The coarse aggregate used in this study for concrete control came from the Sudamanik quarry with a maximum diameter of 20 mm, and the fine aggregate of 0-5 mm used came from the MBS quarry. The result obtained from the specific gravity of coarse aggregate is 2.55, while the specific

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

gravity of fine aggregate is 2.52, with a fineness modulus of 3.10. In comparison, the aggregates used as substitutes for natural aggregates are LECA, vermiculite, and polystyrene beads based on the results of sieve analysis tests that have been carried out. The LECA used in this study met the gradation 5-12.7 mm. Requirements contained in SNI 2461, (2014) and include well-graded aggregates. LECA will be used as a substitute for coarse aggregate; based on (SNI 2461, 2014), the maximum grain density of light aggregate for coarse aggregate is 880 kg/m$^3$. From the results of testing, the weight of the contents of LECA obtained a result of 504 kg /m$^3$, and the results can be used as seen on Table 1.

**Table 1** Material properties

| Materials | Type/Properties | Specific Gravity (gr/cm$^3$) |
|---|---|---|
| Cement | Ordinary Portland Cement (OPC) | 3.10 |
| Iron Slag (GGBFS) | | 2.79 |
| silica-fume | Sika-Fume | 2.20 |
| Coarse Aggregate | Maximum Diameter of 20 mm | 2.55 |
| Fine Aggregate | Fine Modulus of 3.10 | 2.52 |
| LECA | Maximum Diameter of 12.7 mm | 0.504 |
| Vermiculite | Passing Sieve No. 5 | 0.284 |
| Polystyrene Beads | Passing Sieve No. 8 | 0.014 |
| Water | Tap water | 1 |

After testing the sieve analysis, it was found that the vermiculite passed sieve No. 5. Vermiculite will be used as a substitute for fine aggregate, based on the maximum grain density of light aggregate for fine aggregate is 1120 kg/m$^3$ (SNI 2461, 2014). The test results on the weight of the contents of vermiculite were obtained at 284 kg m$^3$ so that the results could be used. Concrete with polystyrene beads can be used as structural elements, protective layers, and insulation concrete. Polystyrene beads have a very light fill weight, which leads to segregation and poor mixture distribution in concrete that uses polystyrene beads. The polystyrene Beads to be used passed sieve No. 5 and were restrained in sieve No. 8. The result of the experiment was that the content weight and percentage of the solid volume of polystyrene beads was 14 kg/m$^3$ (Sayadi *et al.,* 2016) .

The chemical composition of OPC type 1 and the GGBFS was determined using the EPSILON 5 analyzer from Panalytical using X-ray Fluorescence (XRF). The results are shown in Table 2.

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

The findings show that the primary chemical constituents of GGBFS (iron slag) include silica, alumina, calcium, and iron.

**Table 2** Chemical properties of iron slag (GGBFS)

| Chemicals | GGBFS (%) |
|---|---|
| $SiO_2$ | 35.93 |
| $Al_2O_3$ | 14.74 |
| $Fe_2O_3$ | 1.02 |
| CaO | 44.71 |
| MgO | 0.28 |
| $SO_3$ | 0.55 |
| $K_2O$ | 0.29 |
| $Na_2O$ | 0.02 |
| $TiO_2$ | 0.33 |
| $Mn_2O_3$ | 0.14 |
| LOI | 1.98 |
| IR | 0.32 |

The concrete mix design refers to The ACI regulation 213R-03, "Guide for Structural Lightweight-Aggregate Concrete," in Table 3. Each concrete mixture is made into 12 concrete samples. Furthermore, the notation for each mixture and the details of the mixture used in this study are as follows (an illustration of the mixture can be seen in Figure 1).

a. Control Concrete or BK is concrete that uses 100% cement, split as coarse aggregate, sand as fine aggregate, and 1% superplasticizer.
b. V100 is concrete with 80% cement and 20% GGBFS binders, LECA as coarse aggregate, vermiculite as fine aggregate, 1% superplasticizer, and 0.1% aluminum powder.
c. APV is concrete with a mixture of binders 70% cement, 20% GGBFS, and 10% silica-fume, LECA as coarse aggregate, vermiculite as fine aggregate, 1% superplasticizer, and 0.15% aluminum powder.
d. PB100 is concrete with a mixture of binders 80% cement and 20% GGBFS, LECA as coarse aggregate, polystyrene beads as fine aggregate, 1% superplasticizer, and 0.1% aluminum powder.
e. APPB is concrete with a mixture of binders 70% cement, 20% GGBFS, and 10% silica-fume, LECA as coarse aggregate, polystyrene beads as fine aggregate, 1% superplasticizer, and 0.15% aluminum powder.

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

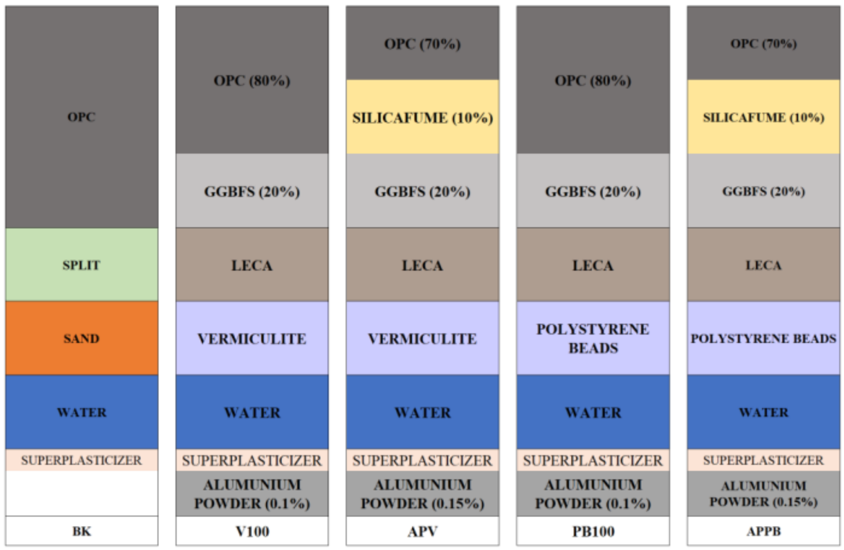


**Figure 1** Composition of concrete mix

**Table 3** The composition of concrete in kg per m$^3$

| Materials | BK | V100 | APV | PB100 | APPB |
|---|---|---|---|---|---|
| Cement | 512.20 | 409.69 | 358.48 | 409.69 | 358.48 |
| GGBFS | – | 102.42 | 102.42 | 102.42 | 102.42 |
| Silica fume | – | – | 51.21 | – | 51.21 |
| Split | 1107.81 | – | – | – | |
| LECA | – | 217.78 | 217.78 | 217.78 | 217.78 |
| Water | 144.87 | 178.22 | 178.22 | 178.22 | 178.22 |
| Natural Sand | 562.04 | – | – | – | – |
| Polystyrene Beads | – | – | – | 2.93 | 2.83 |
| Vermiculite | – | 58.40 | 56.40 | – | – |
| Superplasticizer | 5.12 | 5.12 | 5.12 | 5.12 | 5.12 |
| Aluminum Powder | – | 0.51 | 0.77 | 0.51 | 0.77 |

## 2.2 Experimental Methods

The manufacture of concrete cylinders refers to The SNI 2458:2008; it starts by putting concrete constituent materials, coarse aggregates, fine aggregates, and binders into the mixer. Then proceed with giving water into the mixture, stir for ±1 minute, and continue by inserting a

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

superplasticizer and stirring for ±3 minutes. If the concrete mixture has finished stirring, the mixer is stopped, and the concrete mixture is slump-tested. After completing the slump test, the concrete mixture is fed into a cylindrical mold with 100 mm diameter and 200 mm height dimensions. Then, the mold containing the sample is placed on the vibrating table for ±1 minute, and the surface is given a name. After 24 hours ±, the concrete mold is removed, and curing is carried out by immersing the concrete in water until the specified mechanical characteristics' test life.

## 3. RESULTS AND DISCUSSION

### 3.1 Workability

The slump test standard refers to ASTM C 143-15, "Standard Test Method for Slump of Hydraulic-Cement Concrete." The difference in slump values from the five samples made with a factor of w/(c+p) of 0.348 does not indicate a significant slump result. The addition of silica fume to the concrete composition also does not significantly affect workability. However, the concrete mixture with which silica fume is added becomes stickier and more cohesive, as shown in Figure 2. This is consistent with past research of (Shirdam, Amini, and Bakhshi, 2019; Koksal, Gencel, and Kaya, 2015), which state that silica fume is hardly adequate in its workability.

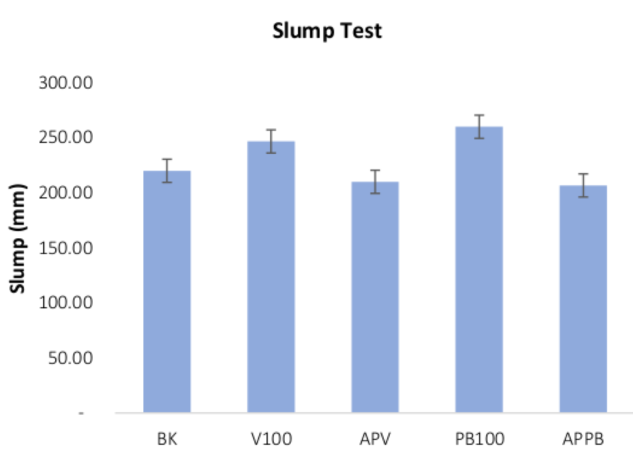


**Figure 2** Slump test result

Doi: https://doi.org/10.25105/urbanenvirotech.v7i2.19715 

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

**Figure 3** Slump test measurement

### 3.2 Compressive Strength

The compressive strength test refers to ASTM C 39-99, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens." Based on the results of compressive strength tests, concrete that uses 100% vermiculite (V100) as fine aggregate has a higher compressive strength than concrete that uses 100% polystyrene beads (PB100) and 50% polystyrene beads and 50% vermiculite (PB50V50).

In 100% polystyrene beads concrete using 10% silica-fume, higher compressive strength results are obtained than in 100% polystyrene beads without silica-fume. The results of this test correspond to those (Wuman 2014) and (Chaitanya and Ramakrishna, 2021), stating that using 10% silica-fume can increase the compressive strength of concrete, as shown in Table 4. Research (Datta, 2020) States that concrete containing silica fume can be of higher quality. This is because silica-fume consists of $SiO_2$ and has fine particles, so the surface zone is enormous. The high content of $SiO_2$ makes silica-fume pozzolan when used in concrete.

Waste-based lightweight concrete is not regulated in Indonesia; hence, this study created a referenced control concrete using a mixture based on the SNI 6468:2000 by replacing conventional coarse aggregate and fine aggregate with lightweight waste aggregate. The BK value result is, therefore, the control concrete value that utilizes 100% conventional aggregate; and by utilizing the same composition for other variations of concrete using different percentages (%) of

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

lightweight waste aggregates, this generates a notable drop in compressive strength compared to the other four mixtures as seen in Table 4.

**Table 4** Results of compressive strength test

| Sample | BK | V100 | APV | PB100 | APPB |
|---|---|---|---|---|---|
| fc' 3 days (MPa) | 38.14 | 5.14 | 4.34 | 2.90 | 3.13 |
| fc' 7 days (MPa) | 42.52 | 7.18 | 5.19 | 3.36 | 3.81 |
| fc' 28 days (MPa) | 51.28 | 7.78 | 5.81 | 4.63 | 5.15 |

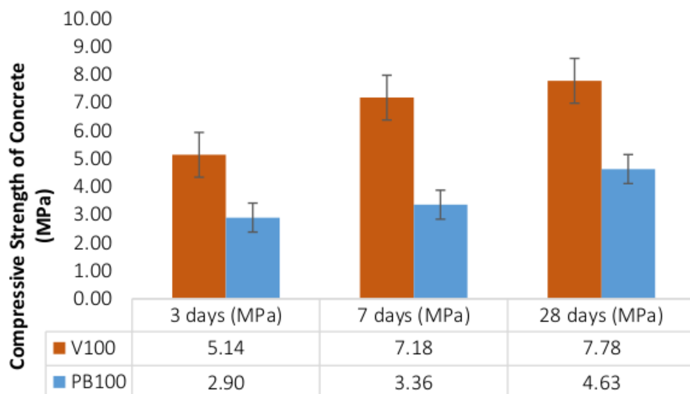


**Figure 4** Compressive strength between V100 and PB100

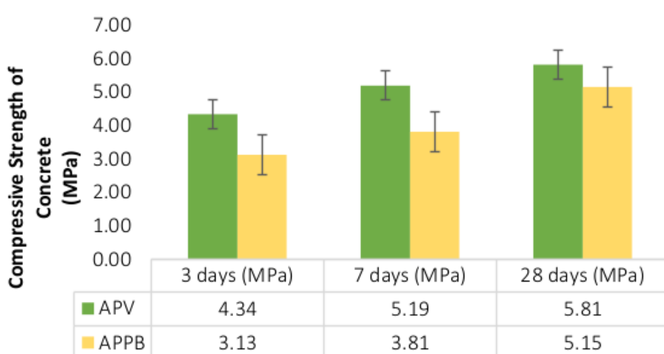


**Figure 5** Compressive strength between APV and APPB

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

Concrete using polystyrene beads has a lower compressive strength than concrete with vermiculite, such as V100 concrete with PB100, which can be seen in Figure 4, and APV concrete with APPB in Figure 5. Previous research Assaad, Michael, and Hanna (2022) states that there is a decrease in concrete strength due to the addition of Expanded polystyrene with an amount of 3-5 kg / m$^3$; this is because it weakens the aggregate in concrete and gives the concrete higher porosity.

### 3.3 Split Tensile Strength

The split tensile strength refers to the ASTM C496-96 “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.” The results of the concrete tensile strength test at the age of 28 days are shown in Table 5. From concrete split strength testing, the tensile strength value of V100 concrete is higher than PB50V50 concrete. The decrease in tensile strength of concrete is directly proportional to the decrease in compressive strength of concrete. Research (Naveenkumar *et al.,* 2021) states that the optimum value of concrete tensile strength and compressive strength of concrete for substituting fine aggregate with vermiculite is 5%.

**Table 5** Concrete tensile strength test results

| Sample | $F_{ct}$ (MPa) |
|---|---|
| BK | 4.47 |
| V100 | 1.88 |
| APV | 1.15 |
| PB100 | 1.00 |
| APPB | 0.77 |

### 3.4 Specific Gravity

It was found that APPB concrete is the lightest compared to BK, V100, APV, and PB100. This happens because *polystyrene beads* have a lighter content weight than vermiculite. This follows research that uses (Sharma *et al.,* 2017) polystyrene beads as a substitute for sand will get a very light concrete, specific gravity compared to lightweight aggregates with a greater content weight than *polystyrene beads*. Furthermore, research (Assaad, Michael, and Hanna, 2022) states that concrete density decreases with expanded polystyrene because expanded

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

polystyrene has a smaller specific gravity than natural sand, causing a reduction in concrete density.

APPB concrete with a specific gravity of 989.73 kg/m$^3$ is less than the specific gravity of water so that concrete can float. This happens because of a 10% reduction in OPC levels, which is then replaced with silica-fume. The specific gravity of OPC is much higher than the specific gravity of silica-fume. OPC has a specific gravity of 3.10, while silica-fume has a specific gravity of 2.20. In APPB concrete, the specific gravity of concrete is reduced to 59.69% of BK concrete. Increased levels of aluminum powder also reduce the specific gravity of concrete. This follows previous research. (Tayeh *et al.,* 2021) Stating that using aluminum powder results in lower specific gravity.

**Table 6** Concrete specific gravity test results

| Sample | Specific Gravity of Concrete (kg/m$^3$) | Floating Conditions |
|---|---|---|
| BK | 2,455.44 | Not |
| V100 | 1,102.63 | Not |
| APV | 1,052.33 | Not |
| PB100 | 1,026.44 | Not |
| APPB | 989.73 | Yes |

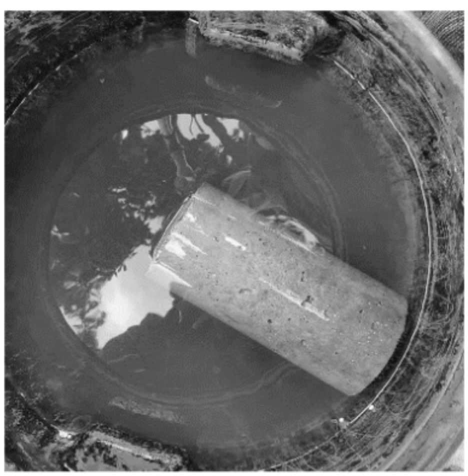

**Figure 6** APPB concrete in floating condition

Doi: https://doi.org/10.25105/urbanenvirotech.v7i2.19715 

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

## 4. CONCLUSION

This study deals with the investigation of fresh and mechanical characteristics of lightweight concrete using environmentally friendly lightweight aggregates; the main conclusions that can be drawn from this study include the following:

1. Concrete with vermiculite produces higher compressive strength than concrete with polystyrene beads. The use of silica-fume as much as 10% as a cement substitute in concrete using 100% polystyrene beads as fine aggregate increases the compressive strength of concrete by 7.60% at three days of age, 13.39% at seven days of age, and 11.26% at 28 days of age but decreases compressive strength in concrete with 100% vermiculite by 15.62% at three days of age, 27.68% at seven days of age, and 25.28% at 28 days of age. For concrete tensile strength, V100 concrete has better tensile strength compared to other lightweight concrete. Using LECA as coarse aggregate and vermiculite and polystyrene beads as fine aggregate does not produce floating concrete with structural qualities. Using 10% silica fume as a cement substitution material has no effect on workability.
2. Concrete using polystyrene beads as fine aggregate produces a lighter specific gravity than concrete using vermiculite. A 10% reduction in OPC levels, followed by substitution with materials with lower specific gravity, can reduce the specific gravity of concrete-increasing the aluminum powder content to 0.15% results in a lighter specific gravity of concrete.

## 5. ACKNOWLEDGEMENT

The author is grateful for the contribution and support from industrial partners PT Jaya Beton Indonesia (JBI), and I-Lab BRIN (National Research and Innovation Agency), Cibinong.

## 6. FINANCING

In 2024, this project received funding from the Research Institute of Universitas Trisakti and the Indonesian Ministry of Research, Technology, and Higher Education through a competitive research grant under the Fundamental Research Scheme, with contract number 832/LL3/AL.04/2024, 170/A/LPPM-P/USAKTI/VI/2024 and 0538/PIPP/FTSP-LPPM/V/2024.

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

## 7. CONFLICT OF INTEREST

There is no financial, personal, authorship, or other conflict of interest on the part of the writers that might influence the study or the findings reported in this article.

## REFERENCES

Abdulrasool, A. T., Mohammed, S. S., Kadhim, N. R., and Mohammad Hussain, W. A. 2022. Sustainable Materials used as Lightweight Aggregate: (An Overview). In: *IOP Conference Series: Earth and Environmental Science*. IOP Publishing Ltd. https://doi.org/10.1088/1755-1315/961/1/012027.

Amemiya, T. 2018. Current State and Trend of Waste and Recycling in Japan Original Reports Open Access. *Int J Earth Environ Sci IJEES*, an open access journal, [online] 3, p.155. https://doi.org/10.15344/2456.

Assaad, J. J., Michael, C. and Hanna, R. 2022. Recycling of Waste-Expanded Polystyrene Concrete in Lightweight Sandwich Panels and Structural Applications. *Cleaner Materials,* [online] 4: 100095. https://doi.org/https://doi.org/10.1016/j.clema.2022.100095.

Broken, D. and Basic, A. 2022. Strength Performance of Concrete using Rice Husk Ash (RHA) as Supplementary Cementitious Material (SCM). *Journal of the Civil Engineering Forum*. 261-276. https://doi.org/10.22146/jcef.3488.

Chaitanya, M. and Ramakrishna, G. 2021. Enhancing the Mechanical Properties of Pervious Recycled Aggregate Concrete using Silicafumes. *Materials Today: Proceedings.* 46(xxxx): 634-637. https://doi.org/10.1016/j.matpr.2020.11.549.

Datta, M. 2020. Experimental Study of Floating Concrete. (June). https://doi.org/10.1166/ASL.

Hou, L., Li, J., Lu, Z. and Niu, Y. 2021. Influence of Foaming Agent on Cement and Foam Concrete. Construction and Building Materials, [online] 280: 122399. https://doi.org/10.1016/j.conbuildmat.2021.122399.

Kanwal, Q., Zeng, X. and Li, J. 2023. Measuring the Recycling Potential of Industrial Waste for Long-Term Sustainability. *Humanities and Social Sciences Communications*. 10(1). https://doi.org/10.1057/s41599-023-01942-1.

Koksal, F., Gencel, O. and Kaya, M. 2015. Combined Effect of Silica Fume and Expanded Vermiculite on Properties of Lightweight Mortars at Ambient and Elevated Temperatures. *Construction and Building Materials.* 88: 175-187. https://doi.org/10.1016/j.conbuildmat.2015.04.021.

Meshram, S., Raut, S. P., Ansari, K., Madurwar, M., Daniyal, M., Khan, M. A., Katare, V., Khan, A. H., Khan, N. A. and Hasan, M. A. 2023. Waste Slags as Sustainable Construction Materials: a

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

Compressive Review on Physical-Mechanical Properties. *Journal of Materials Research and Technology*. 23: 5821-5845. https://doi.org/10.1016/j.jmrt.2023.02.176.

Pellegrino, C., Faleschini, F. and Meyer, C. 2019. Recycled Materials in Concrete. In: Developments in the Formulation and Reinforcement of Concrete. *Elsevier.* 19-54. https://doi.org/10.1016/B978-0-08-102616-8.00002-2.

Rashad, A. M. 2018. Lightweight Expanded Clay Aggregate as a Building Material-An overview. *Construction and Building Materials, [online]*. 170: 757-775. https://doi.org/10.1016/j.conbuildmat.2018.03.009.

Sajedi, F. and Shafigh, P. 2012. High-Strength Lightweight Concrete using Leca, Silica Fume, and Limestone. (May 2014). https://doi.org/10.1007/s13369-012-0285-3.

Sayadi, A. A., Tapia, J. V., Neitzert, T. R. and Clifton, G. C. 2016. Effects of Expanded Polystyrene (EPS) Particles on Fire Resistance, Thermal Conductivity, and Compressive Strength of Foamed Concrete. *Construction and Building Materials.* [online] 112: 716-724. https://doi.org/10.1016/j.conbuildmat.2016.02.218.

Seco, A., Ramirez, F., Miqueleiz, L., Urmeneta, P., García, B., Prieto, E. and Oroz, V. 2012. Types of Waste for the Production of Pozzolanic Materials - A Review, Industrial Waste, Prof. Kuan-Yeow Show (Ed.). [online] In Tech. Available at: <www.intechopen.com/books/industrial-waste/sustainable-construction-with-pozzolanic-industrial-waste-a-review> [Accessed 17 January 2024].

Sharma, A., Sehrawat, M., Singh, K. and Saraf, M. 2017. Floating Concrete by using Lightweight Aggregates.

Shirdam, R., Amini, M. and Bakhshi, N. 2019. Investigating the Effects of Copper Slag and Silica Fume on Durability, Strength, and Workability of Concrete. *International Journal of Environmental Research.* 13(6): 909-924. https://doi.org/10.1007/s41742-019-00215-7.

Singh, R., Yabar, H., Nozaki, N. and Rakwal, R. 2015. Analyzing Waste Problems in Developing Countries: Lessons for Kathmandu, Nepal through Analysis of the Waste System in Tsukuba City, Japan. *Journal of Scientific Research and Reports*. 8(6): 1-13. https://doi.org/10.9734/jsrr/2015/20346.

SNI 03-2834. 2000. Procedures for Making a Normal Concrete Mix Plan.

SNI 03-3449. 2002. Procedures for Planning the Manufacture of Light Concrete Mixture with Light Aggregate.

SNI 2461. 2014. Specification of Lightweight Agregates for Structural Concrete.

Srivastava, V., Kumar, R., Agarwal, V. C. and Mehta, P. K. 2014. Effect of Silica Fume on Workability and Compressive Strength of OPC Concrete. *Journal of Environmental Nanotechnology*. 3(3): 32-35. https://doi.org/10.13074/jent.2014.09.143086.

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 7, Number 2, page 216-231, October 2024
*Accredited SINTA 2 byMinistry of Research, Technology, and Higher Education of The Republic of Indonesia No. 230/E/KPT/2022 on December 30th, 2022 from October 1st, 2022 to September 30th, 2027*

Tayeh, B. A., Zeyad, A. M., Agwa, I. S. and Amin, M. 2021. Effect of Elevated Temperatures on Mechanical Properties of Lightweight Geopolymer Concrete. Case Studies in Construction Materials, 15(July), p.e00673. https://doi.org/10.1016/j.cscm.2021.e00673.

Trujillo, G. 2015. Using GGBS for Partial Cement Replacement in Concrete: Effects of Water-Binder Ratio and GGBS Level on Activation Energy. *International Journal of Technology*. 6(5): 790-799. https://doi.org/10.14716/ijtech.v6i5.1916.

Widyatmoko, H. 2018. Management of Hazardous Waste in Indonesia. In: *The 4th International Seminar on Sustainable Urban Development.*

Wuman, Z. 2014. Effect of Ground Granulated Blast-Furnace Slag (GGBFS) and Silica Fume (SF) on Chloride Migration through Concrete Subjected. (August 2012). https://doi.org/10.1007/s11431-012-5027-y.

Xuan, D., Poon, C. S., and Zheng, W. 2018. Management and Sustainable Utilization of Processing Wastes from Ready-Mixed Concrete Plants in Construction: A review. *Resources, Conservation and Recycling*. https://doi.org/10.1016/j.resconrec.2018.04.007.

NCRETE_USING_ENVIRONMENTALLY_FRIENDLY_LIGHTWEIG...

ORIGINALITY REPORT

| 13% | 5% | 9% | 6% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | Submitted to School of Business and Management ITB<br>Student Paper | 5% |
| 2 | ijtech.eng.ui.ac.id<br>Internet Source | 2% |
| 3 | "Technologies for Sustainable Buildings and Infrastructure", Springer Science and Business Media LLC, 2024<br>Publication | 1% |
| 4 | dokumen.pub<br>Internet Source | 1% |
| 5 | Alaa M. Rashad. "Lightweight expanded clay aggregate as a building material – An overview", Construction and Building Materials, 2018<br>Publication | 1% |
| 6 | ebin.pub<br>Internet Source | 1% |
| 7 | Submitted to University of East London<br>Student Paper | 1% |

| | | |
|---|---|---|
| 8 | "Sustainable Construction and Building Materials", Springer Science and Business Media LLC, 2019<br>Publication | 1 % |
| 9 | Edward G. Nawy. "Concrete Construction Engineering Handbook", CRC Press, 2019<br>Publication | 1 % |
| 10 | www.hindawi.com<br>Internet Source | <1 % |
| 11 | Bassam A. Tayeh, Abdullah M. Zeyad, Ibrahim Saad Agwa, Mohamed Amin. "Effect of elevated temperatures on mechanical properties of lightweight geopolymer concrete", Case Studies in Construction Materials, 2021<br>Publication | <1 % |
| 12 | icsdc.muet.edu.pk<br>Internet Source | <1 % |
| 13 | jurnal.ugm.ac.id<br>Internet Source | <1 % |

| | | | |
|---|---|---|---|
| Exclude quotes | On | Exclude matches | < 17 words |
| Exclude bibliography | On | | |