EINSTEIN (e-Journal)
Jurnal Hasil Penelitian Bidang Fisika
*Available online http://jurnal.unimed.ac.id/2012/index.php/einsten*
*e-issn: 2407 – 747x, p-issn 2338 – 1981*

# EFFECT OF PARTIAL CEMENT REPLACEMENT RATIO WITH CHICKEN BONE ASH ON COMPRESSIVE STRENGTH AND POROSITY MORTAR

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Submit: April 2026. Approved: May 2026. Published: June 2026.

## ABSTRACT

This study evaluates the effect of partial cement substitution with chicken bone ash on the compressive strength and porosity of mortar. Mortar is a crucial adhesive material in construction that determines the strength and durability of structures. The mortar mixtures were prepared by replacing part of the cement with chicken bone ash at variations of 0%, 3%, 6%, and 9% by weight of the cement according to SNI 03-6825-2002. Cube-shaped mortar samples measuring $5x5x5$ cm were tested for compressive strength after 28 days, and porosity was measured using the gravimetric method referring to Archimedes' principle. The compressive strength test results at 0% variation were 10.45 MPa, at 3% variation were 14.75 MPa, at 6% variation were 12.52 MPa, and at 9% variation were 5.52 MPa. The porosity results for the 0% variation were 2.1%, for the 3% variation were 3.2%, for the 6% variation were 3.2%, and for the 9% variation were 4.8%. It is concluded that high porosity can reduce the material's strength

**Keywords:** Mortar, Chicken Bone Ash, Compressive Strength, Porosity

## INTRODUCTION

The growth of the mortar industry in Indonesia has been significant after 1996, reflected in increased production capacity and continuously increasing levels of demand. Currently, instant mortar products have become one of the most widely used construction materials, both for small-scale construction projects and for large-scale projects. The SNI 03-6825-2002 standard defines mortar as the result of mixing small/fine grained aggregates (for example sand), binding materials (clay, lime, Portland cement), and water in predetermined proportions.

Cement is a material that is very necessary in construction, which has an impact on the price of cement which continues to become more expensive. An alternative to reduce excessive use of cement is by adding additional ingredients, either natural or chemical. (Mega, 2017).

One of the factors that influences the compressive strength of mortar is the level of porosity or the presence of voids in the mortar structure. The higher the porosity, the lower the compressive strength of the mortar, and vice versa. Apart from that, the water cement factor (FAS) also plays an important role in determining the compressive strength of mortar (Annisa et al., 2021).

Efforts that can be made are using waste materials as additional or construction materials which not only have an impact on reducing waste management costs and preventing

environmental pollution. Bones consist of non-living parts and living parts consisting of osteocytes (bone cells). Non-living bones consist of organic and inorganic substances. About 50% of bones consist of calcium phosphate Ca3(PO4)2, which is an ionic compound consisting of Ca2+ and PO42- ions, and about 4-8% bicarbonate ions. Polysaccharide proteins, glycoaminoglycans and collagen are the organic substances. Until now, animal bone waste has not been utilized thoroughly, this is because bones are generally spatial in nature, so the use of bones also requires the type of bone and its condition. Animal bones consist of 30–35% organic collagen components as well as 95% protein and 65–70% inorganic components.

Animal bone is a natural material rich in apatite which consists of around 65-70% calcium phosphate inorganic substances, especially hydroxyapatite with the chemical composition Ca10(PO4)6OH2. Factor analysis shows that apatite contains around 56.3% phosphate and 36.8% calcium. (Abarasi Hart et al., 2022). Chicken bones contain quite high amounts of calcium oxide (CaO), namely around 56.28%. CaO content is also found in semen. When chicken bones are burned to ash, the compound Ca10(PO4)6(OH)2 is produced which is expected to act as a binding agent like semen. This is because semen produces the compound CaO.SiO2.H2O (C-S-H) which has a function as a binder. (Nida'ul & et al, 2022).

The results of research (Nida'ul & et al, 2022) use chicken bone ash as a weight substitute for cement in making concrete. Where the percentage of chicken bone ash used by researchers was 2.5% and 5%. The results of this research were in a positive direction where the results of the characteristic compressive strength test of concrete increased by 2.5% resulting in 3.08% of the compressive strength of conventional concrete and for a percentage of 5% it also resulted in an increase of 5.14%. So chicken bone ash really has an effect as a partial replacement for cement because the CaO content in chicken bone ash is found in the cement content

## RESEARCH METHOD

### Research Tools

This research method is in the experimental research category, the location for making mortar test objects to testing compressive strength and porosity at the Material Testing Laboratory at the Faculty of Engineering, Medan State University. The furnace process was carried out at the Integrated Laboratory, University of North Sumatra and structural testing at the Mathematics and Natural Sciences Laboratory, Yogyakarta State University.

The materials used to make mortar test objects based on SNI 03-6825-2002 are Portland cement (Semen Padang) 250 gr, sand 700 gr, water 121 gr and chicken bone ash with variations of 3% (22.5 gr), 6% (45 gr), 9% (67.5gr) all for purposes / 3 samples.

Tools used are scales, mortar mold measuring 5x5x5 cm, gloves, mask, scoop spoon, rojokan tool, mixer, receptacle, 200 mesh sieve, furnace machine and xrd testing equipment.

The process of making a mortar test object mixed with chicken bone ash, namely

1. Material collection process (field cement, sand, air, chicken bone ash)
2. The process of making chicken bone ash is done by calcining it for 4 hours at a temperature of 800c, after being in the furnace, it is then ground and sieved with a 200 mesh size until the fineness of the chicken bone ash is the same as cement.
3. The process of mixing ingredients that have been confused is based on SNI 03-6825-2002
4. After that, we carry out the mixing process until we put it in a cube mold measuring 5x5x5 cm
5. We wait 1 day for the sample to become a test object, and we take it out of the mold then we put it in a bucket to carry out the soaking period according to the days we designed, but I gave this research a lifespan of 28 days
6. After 28 days, the mortar test specimens are ready for the compressive strength test process
7. The best samples are sent to do xrd testing to see whether they are amorphous or crystalline.

Table 1. Composition of mortar mixture with chicken bone ash

| Abu Tulang Ayam | Kode Sampel | Komposisi | | | |
|---|---|---|---|---|---|
| | | Semen(g) | Pasir (g) | Abu Tulang Ayam (g) | Air (g) |
| 0 % | $A_1$, $A_2$, $A_3$ | 250 | 700 | 0 | 121 |
| 3 % | $B_1$, $B_2$, $B_3$ | 227,5 | 700 | 22,5 | 121 |
| 6 % | $C_1$, $C_2$, $C_3$ | 205 | 700 | 45 | 121 |
| 9 % | $D_1$, $D_2$, $D_3$ | 182,5 | 700 | 67,5 | 121 |

## RESULT AND DISCUSSION

### Mortar compressive strength testing

After testing the compressive strength of all test objects using compressive testing machine, strength of the mortar are obtained as in the table 2.

Table 2. Test results for compressive strength of mortar aged 28 days

| Variasi Konsentrasi | Kode Sampel | Luas Permukaan Rata-Rata ($m^2$) | Beban Tekan Rata-Rata (KN) | Kuat Teka Rata-Rata (MPa) |
|---|---|---|---|---|
| 0% | $A_1$, $A_2$, $A_3$ | 0,015 | 26,11 | 10,45 |
| 3% | $B_1$, $B_2$, $B_3$ | 0,015 | 36,87 | 14,75 |
| 6% | $C_1$, $C_2$, $C_3$ | 0,015 | 31,53 | 12,62 |
| 9% | $D_1$, $D_2$, $D_3$ | 0,015 | 13,80 | 5,52 |

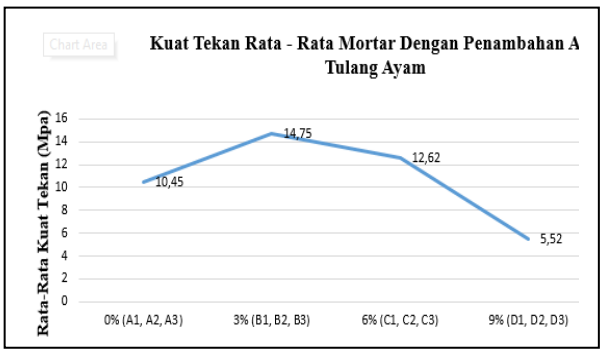


**Figure 1.** Compressive strength test graph for mortar aged 28 days

Average compressive strength of 10.45Mpa. Mortar mixed with chicken bone ash at a concentration of 6% was 12.62 Mpa and mortar mixed with chicken bone ash at a concentration of 9% experienced a decrease in compressive strength of 5.52 Mpa. The addition of chicken bone ash to the mortar greatly affects the compressive strength, where when the addition of chicken bone ash to the mortar is more than 3%, the compressive strength will decrease, but it is still suitable for use up to a variation of 6% because it still exceeds the normal compressive strength value, above 6% not suitable for use because it will reduce the compressive strength value.

The results of research (Nida'ul & et al, 2022) use chicken bone ash as a weight substitute for cement in making concrete. Where the percentage of chicken bone ash used by researchers was 2.5% and 5%. The results of this research were in a positive direction where the results of the characteristic compressive strength test of concrete increased by 2.5% resulting in 3.08% of the compressive strength of conventional concrete and for a percentage of 5% it also resulted in an increase of 5.14%. So chicken bone ash really has an effect as a partial replacement for cement because the CaO content in chicken bone ash is found in the cement content.

### Mortar Porosity

Mortar porosity testing was carried out at a mortar age of 28 days. The porosity test on this mortar is to determine the number of pores or cavities contained in the mortar.

Table 3. Test results for porosity of mortar aged 28 days

| Variasi Konsentrasi Chart Area | Kode Sampel | Massa Basah Rata-Rata (g) | Massa Kering Rata-Rata (g) | Porositas |
|---|---|---|---|---|
| 0% | $A_1$, $A_2$, $A_3$ | 752 | 744 | 2,1 |
| 3% | $B_1$, $B_2$, $B_3$ | 798 | 786 | 3,2 |
| 6% | $C_1$, $C_2$, $C_3$ | 808 | 796 | 3,2 |
| 9% | $D_1$, $D_2$, $D_3$ | 766 | 746 | 4,8 |

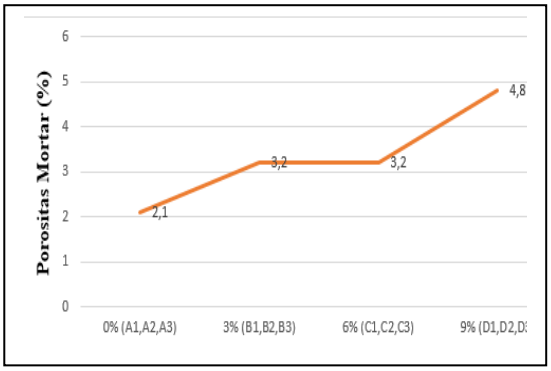


**Figure 2.** grafic for porosityof mortar aged 28 days

## CONCLUSION AND SUGGESTION

### Conclusion

1. The addition of chicken bone ash significantly influences the compressive strength of 28-day-old mortar. The optimal concentration is found at 3%, yielding the highest compressive strength of 14.75 MPa, which is a notable increase from the control/normal mortar (10.45 MPa).
2. Although compressive strength decreases when the concentration exceeds 3%, the mortar remains acceptable and suitable for use up to a 6% concentration (12.62 MPa) because it still outperforms the normal compressive value. However, a 9% concentration causes a drastic drop in compressive strength to 5.52 MPa, making it unsuitable.
3. The inclusion of chicken bone ash increases the porosity of the mortar. The control specimen (0%) has a porosity of 2.1%, which rises and stabilizes at 3.2% for the 3% and 6% concentrations, before peaking at 4.8% at the 9% concentration level.
4. The positive effect of chicken bone ash as a partial replacement for cement is supported by its CaO (calcium oxide) content, which aligns with the elemental composition inherently found in cement.

### Suggestion

1. For practical engineering applications utilizing chicken bone ash as a partial cement substitute, it is highly recommended to limit the mixture concentration to **between 3% and 6%** to ensure structural integrity and enhanced compressive performance.
2. Since adding chicken bone ash increases the number of pores/cavities in the mortar (raising porosity up to 4.8%), future research should investigate methods or supplementary admixtures to minimize porosity, thereby preventing potential issues related to water absorption and long-term durability.
3. Future studies could benefit from exploring narrower percentage intervals between 0% and 5% (e.g., 1%, 2%, 2.5%, 4%) to pinpoint the exact peak of optimal performance more precisely.

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