Effect of Zeolite on the Compressive Strength of Concrete with Different Types of Cement

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Abstract. Concrete is a material component in coastal area construction. With the increasing demand for concrete for construction purposes, there have been various innovations in concrete mixtures to improve the quality of the concrete, including the compressive strength value of concrete. In the concrete mixture, the researchers also add additive to the concrete mixture, one alternative is natural zeolite which is widely found in the earth. Research by testing concrete samples with variations of the zeolite mixture 0%, 15%, and 25% uses cement type V. The test results are then compared with the results of other studies using different types of cement. Comparative studies of zeolite concrete test with different types of cement show that the optimum proportion of zeolite is around 10% to 20% of the weight of cement to get the best compressive strength value.

1. Introduction

Concrete is one of the main materials in coastal area construction. Currently, the demand for construction for concrete materials is increasing, so various innovations in concrete mixes have emerged intending to improving the quality of the concrete, including the value of the compressive strength of concrete. In addition to the basic ingredients in the form of sand, cement and aggregate, the researchers also added additional ingredients to the concrete mixture. One alternative is a zeolite type c*lipnotilolite* which is a natural material. The addition of zeolite is expected to improve the function of cement as a binder in a concrete mixture because it has the similar building blocks as cement. The addition of zeolite material in the concrete mixture is expected to increase the strength and quality of concrete compared to ordinary concrete. This concrete with zeolite added material has been studied by researchers including Jujjuri [1] stated that the addition of 15% zeolite to the binder mixture improved the compressive strength of the concrete but for concrete with 30% zeolite content they obtained a 25% reduction in strength even by adding superplasticizers which were not used in the control mixture. Ahmadi B and Shekarchi M [2] observed that an increase in the compressive strength of concrete up to 20% zeolite was used instead of portland cement but this was achieved by increasing the amount of superplasticizer in the mixture containing zeolite. B Uzal and L Turanlı [3] reported a mortar compressive strength similar to that of 55% zeolite in a binder with 100% Portland cement mortar but again, this could only be achieved using superplasticizers. Emam E [4]observed compressive strength of concrete at 10% cement replacement level by 26%, whereas 25 to 40% replacements have caused a modest reduction in strength at the same age ranged from 4 to 16% (untreated) and 34.7 to 47.3% (calcined) respectively at 28 and 56 days.

Shahrabadi [5] observed results of compressive strength tests showed that replacement of natural Zeolite instead of cement significantly increased compressive strength in comparison with control

specimens, in all environments. Adding 20% natural Zeolite increased the compressive strength to its highest values about 60-85% higher than control specimens.

These studies used several different types of cement to produce different strength effects from each other. The research carried out this time is to use type V cement, which is a Portland cement type for the use of concrete that has high resistance to sulfates with the aim that the concrete has reliability in an environment that is affected by sulfates such as in the sea [6] and [7].

2. Material

The main ingredients of concrete are Portland cement, fine aggregate and coarse aggregate. In concrete, additives are added which are mixed into the concrete or mortar, before or during the stirring. Additives are used to modify the properties and characteristics of concrete or mortar for example to be easily worked, save, or for other purposes [8] and [9]. Concrete additives can be divided into chemical admixtures and mineral additives.

2.1 *Zeolite*

Mineral zeolite can be classified as a pozzolanic material because zeolite contains silica up to 62.75%. Zeolite is one of the pozzolanic materials with alumino-silicate chemical bonds that occurs in nature with a high cation exchange capacity, high absorption, and hydration-dehydration properties. There are nine zeolite minerals that are often found as follows: *analcim, chabazit, klinoptilolite, heulandite, erionit, ferrierit, laumontit, modenit and phillpsit*.

The zeolite used in this study came from Tasikmalaya, West Java, Indonesia. The test results on the zeolite mineral composition carried out at the Laboratory of Coal and Mineral Technology Center can be seen in Table 1.

Tabel 1. Mineral composition of *zeolite*

Oxide	**(%)**
SiO_2	77,7
Al_2O_3	7,88
Fe_2O_3	0,77
K_2O	2,34
Na_2O	1,31
CaO	2,07
MgO	0,48
TiO_2	0,06
LOI	7,20
MnO	0,013
Cr_2O_3	Tt

Zeolite in the concrete mixture is expected to give a pozzolanic reaction so that it will improve the quality of the concrete. This reaction is often referred to as a secondary reaction and this reaction takes place more slowly and has a longer time so that the quality of concrete over the age of 28 days can still increase.

2.2 Aggregate

Tests of concrete materials carried out on fine aggregate and coarse aggregate in this study included testing of specific gravity & water absorption, silt content, sieve analysis, and cavity density. The test results are presented in the following Table 2.

Table 2. Fine agregate test result

No	Test	Result	Limit requirement		Description
1	Mud Content	3%	max 5 %	ASTM C113-03	qualify
2	Bulk Specific Gravity SSD	2.58	2.5 - 2.7	ASTM C 33	qualify
3	Grain modulus	2.76	2.3 - 3.1	ASTM C 33	qualify

Fine aggregate test results that the mud content is 3%, this value is still below the maximum required value of 5%. For the bulk specific gravity test, the value is 2.58, which still meets the requirements because it is below the maximum value of 2.8. The grain modulus test gives a result of 2.76 which still meets the requirements.

Table 3. Coarse agregate test result

No	Test	Result	Limit requirement		Description
1	Mud Content	1%	max 1 %	ASTM C113-03	qualify
2	Bulk Specific Gravity SSD	2.64	2.5 - 2.7	ASTM C 33	qualify
3	Grain modulus	6.69	6 - 7.1	ASTM C 33	qualify

Coarse aggregate testing gives the result that the mud content is 1%, this value meets the requirements. Meanwhile, for the bulk specific gravity test, the value of a coarse aggregate is 2.64, which still meets the requirements because it is below the maximum value of 2.7. The grain modulus test of the coarse aggregate gives a result of 6.69 which is still below the maximum required value of 7.1 (see Table 3).

2.3 Spesific gravity of material

The test results for the specific gravity of Portland cement (PC) and zeolite give the results of 3.2 kg/m^3 for the specific gravity of PC and the specific gravity of zeolite is 2.15 kg/m^3 (Table 4).

Table 4. Spesific gravity test result

No	Material	Unit	Result
1	PC	Kg/m^3	3.20
2	*Zeolite*	Kg/m^3	2.15

2.4 Slump test value

The slump value is used to determine the workability of concrete. From the results of the concrete mixing, each variation of the mixture has a different slump value.

Tabel 5. Slump test result

No	Concrete	Speciment	Slump value (cm)
1	Ordinary	BN	10.00
2	Zeolite 15 %	BZ - 15%	8.50
3	Zeolite 25 %	BZ - 25%	10.00

The slump test value of ordinary concrete produced is 10 cm, concrete with an additional 15% zeolite has a slump value of 8.5 cm and concrete with an additional 25% has a value of 10 cm. The slump value of the concrete is still in the ideal range of 8 cm to 12 cm (see Table 5).

3. Research Methodology and Test Result

3.1 Research Methodology

The materials used in this research are testing of coarse aggregate and fine aggregate used, water, cement used is type V which this for sulfate resistant concrete, mineral zeolite type c*linoptilolite*.

This research was carried out using quantitative experimental methods on concrete test objects. The first test includes testing the basic ingredients for forming concrete, namely coarse aggregate, fine aggregate, cement, and mineral zeolite added materials where the results have been described. After the testing of the material is complete, the next step is to plan the concrete mix design and make the mixture. The slump test of the concrete mixture must comply with the specified requirements [10].

The test object for the compressive strength test of concrete in this study was a concrete cylinder with 15 cm and a height of 30 cm and a concrete cube measuring 20x20x12 cm for the permeability test of concrete. Three variations of the use of zeolite are used, namely concrete with zeolite content of 0%, 15%, 25% of the cement weight.

3.2 Permeability Test Result

Permeability testing using a cube sample with dimensions of 20 cm x 20 cm and a height of 12 cm (Figure 1). The permeability test of the concrete was carried out at the age of 28 days using the Apparel Permeability Test tool. The concrete sample is given to give water pressure to the cube specimen. However, this research is intended for concrete in coastal areas, so in the permeability test uses seawater. The standard for applying pressure is 5 kg/cm^2 (or 0.5 N/mm^2) for 3x24 hours. Concrete permeability limitation requirements are based on DIN 1048 -5 [11], it cannot be more than 5 cm [12] after three days or the permeability test is completed.

Figure 1. Permeability Testing Equipment.

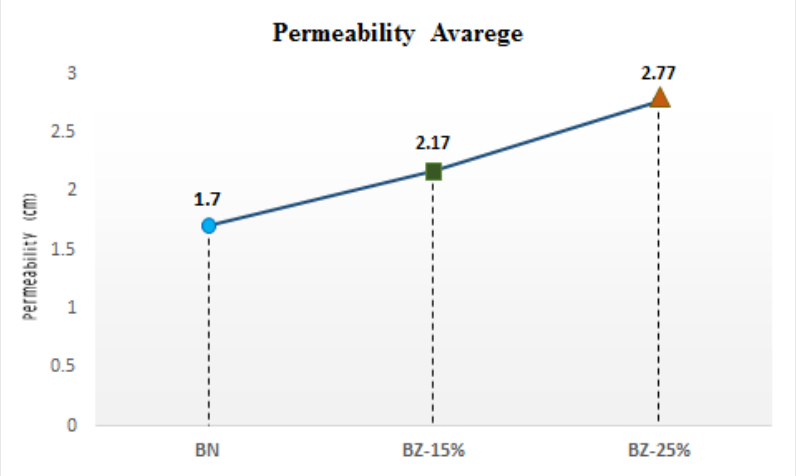

Figure 2. Permeability Test Result.

3.3 Compressive Strength Test Result

Concrete samples made with several variations, namely ordinary concrete without zeolite (BN) with the quality of the concrete design mix is fc '35 MPa, concrete added with zeolite 15% (BZ-15%) and concrete with 15% zeolite (BZ-25%). All concrete mixtures do not use plasticizers. The compressive strength test was carried out when the specimens were 15, 28, and 36 days old by using a Compression Testing Machine, from the results of these tests we obtained results that the average compressive strength value of concrete without zeolite had a slightly higher value than concrete with added zeolite. However, at the age of 36 days of concrete, the value of concrete BZ-15% is close to the value of concrete without zeolite (BN), while for BN-25% from the beginning of the formation of concrete until the age of 36 days, the value of compressive strength remains below the concrete without zeolite (BN). The value of BN and BZ-15% has exceeded the compressive strength of the design concrete, which is 35 MPa, while BZ-25% has not reached the expected value.

Figure 3. Compressive Testing Machine.

Table 6 shows the results of testing concrete specimens at the age of 15 days, wherein ordinary concrete (BN) the average compressive strength of concrete achieved is 36 MPa. This value is higher

than the concrete with the addition of zeolite, namely BZ-15% and BZ-25% which only reached the average compressive strength values of 29.81 MPa and 18.58 MPa.

Table 6. Compressive Strength at 15 Days

No	Speciment	Average fc' (Mpa)
1	BN	36.60
2	BZ-15%	29.81
3	BZ-25%	18.58

The compressive strength of concrete increased at 28 days and 36 days, as shown in Table 7 and Table 8. At 36 days of age, the compressive strength of ordinary concrete BN reached 39.31 MPa, the compressive strength of concrete BZ-15% is 38.66 MPa. This value is close to the value of ordinary concrete. While at BZ-25% the average compressive strength value achieved is only 28.23 MPa.

Table 7. Compressive Strength at 28 Days

No	Speciment	Average fc' (Mpa)
1	BN	38.32
2	BZ-15%	34.41
3	BZ-25%	26.73

Table 8. Compressive Strength at 36 Days

No	Speciment	Average fc' (Mpa)
1	BN	39.31
2	BZ-15%	38.66
3	BZ-25%	28.23

The stages of increasing the compressive strength of concrete from 15 days to 36 days are shown in Figure 2.

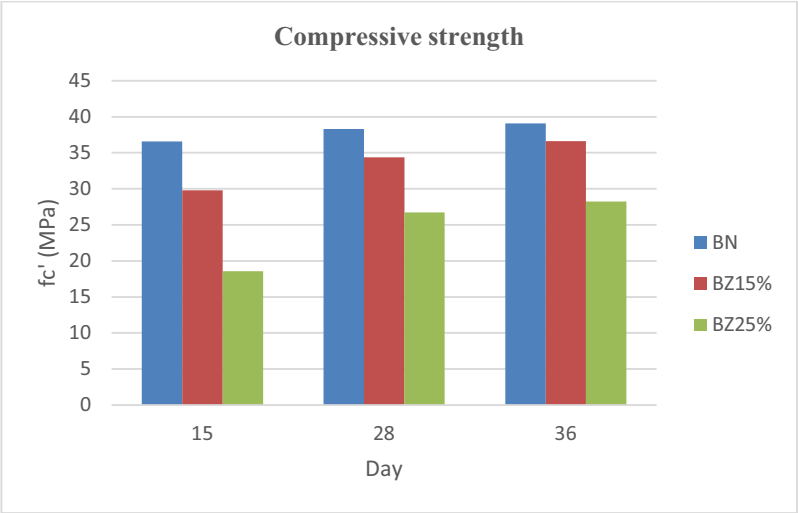

Figure 4. Average Compressive Strength of Concete.

4. Discussion

The results of the compressive strength test based on the age of the concrete in the concrete sample will show an increasing trend which can be formulated in the regression equation. Figure 4 and Figure 5 show that the compressive strength of concrete with 15% zeolite content (BZ 15%) is getting closer to the value of ordinary concrete (BN), even at the age of 50 days, it will exceed the compressive strength of BN which will reach 47.88 MPa. While BZ 25% still shows compressive strength values below BN and 15% BZ until 50 days based on the regression curve. The addition of zeolite as much as 15% into the concrete mixture provides the potential for increasing the compressive strength of cocrete beyond ordinary concrete.

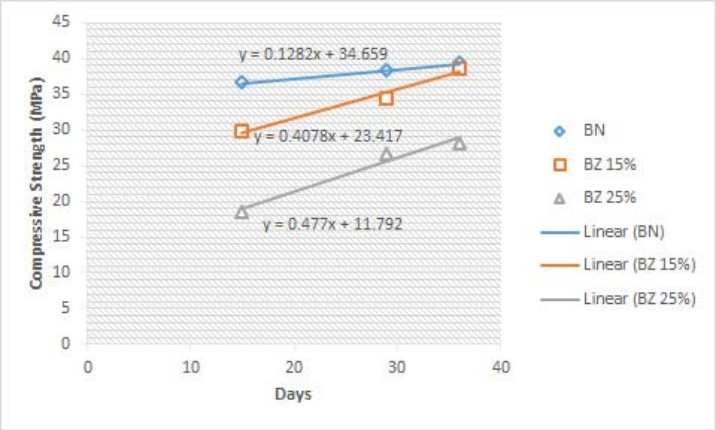

Figure 5. Compressive Strength Regression Graph.

The results of other researchers, namely Ahmadi and Shekarchi [2] who used cement type II showed that concrete with zeolite at the age of 28 days reached 42.2 MPa and concrete with a mixture of 20% reached a value of 42.45 MPa and the results of Emam Essra's research [4] which used cement type I obtained the value of compressive strength of concrete with 15% zeolite at age 28 of 35.6 MPa and concrete with 25% zeolite had a compressive strength of 29.8 MPa (Figure 6).

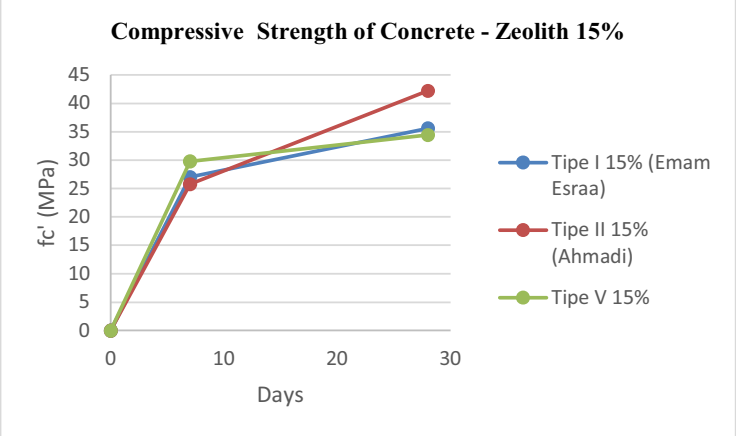

Figure 6. Compressive strength of concrete added zeolite 15%.

Although these results cannot be directly compared to the studies that have been carried out because there are differences in the origin of the material and other added materials such as superplasticizer in the two studies, we can see that the compressive strength value of the mix design can be

achieved with the addition of zeolite 15% to 20%, exceeding the additional percentage of the zeolite, the compressive strength does not reach the design value (see Figure 7).

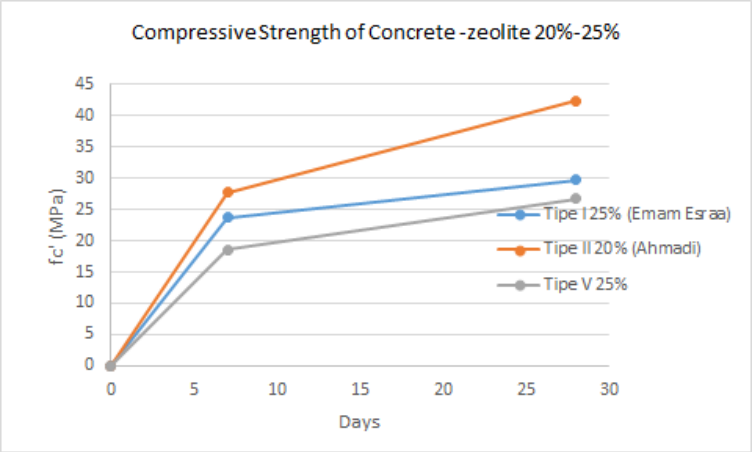

Figure 7. Compressive strength of concrete added zeolite 20% - 25%.

The addition of zeolite to the concrete mixture has an effect on the value of seawater permeability into the concrete as shown from the test results. The average depth of seawater penetration in concrete increases with the addition of the percentage of zeolite. However, the largest permeability value obtained at BZ-25% of 2.77 cm is still below the maximum required value of 5 cm.

From the results of the tests that have been carried out, the optimum value of adding zeolite into concrete should be 15%. In this composition there is a potential increase in compressive strength that can exceed the compressive strength of ordinary concrete, and the permeability value is still lower than concrete with the addition of zeolite by 25% of the cement weight into the concrete.

5. Conclusion

The results of the compressive strength test on ordinary concrete have the compressive strength of normal concrete at 36 days of concrete age of 39.31 MPa and the compressive strength of 15% zeolite concrete of 38.65 MPa, for the concrete with 25%, the compressive strength is 28.23 MPa. Based on comparisons with the results of other studies with variations in different types of cement, it can be concluded that the optimal value of the addition of zeolite to concrete is in the range of 10% to 20%.

For testing the permeability of concrete from the test results obtained ordinary concrete has the lowest water absorption value of 1.73 cm, then 15% zeolite concrete has 2.17 cm water absorption value, and 25% zeolite concrete has an infiltration value of 2.77 cm, this value still meets the requirements for the absorption limit, which is less than ≤ 5 cm, so that the use of zeolite percentage into concrete for use in coastal areas, the most optimum is 15% by weight of cement.

6. Reference

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