Eleventh East Asia-Pacific Conference on Structural
Engineering & Construction (EASEC-11)
"Building a Sustainable Environment"
November 19-21, 2008, Taipei, TAIWAN

EXPERIMENTAL STUDY ON THE USE OF NATURAL ZEOLITES AS PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

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ABSTRACT : Study on the use of natural zeolite as partial replacement for cement in concrete has been carried out in China and in other countries since early 1980. However, very few information has been reported in Indonesia on this subject, although the availability of the natural zeolite in the country is abundant. So far, natural zeolite is only utilized in the agricultural sector. In this research, natural zeolite has been used to partially substitute the ordinary Portland cement (OPC) in concrete. The presence of silicon dioxide in natural zeolite was expected to increase the concrete strength through reaction with the calcium hydroxide from the hydration of OPC. However, results from the investigation revealed that the compressive strength, the tensile splitting strength and the modulus of elasticity of concrete containing natural zeolite decreased with the increase of natural zeolites content.

KEYWORDS: Natural Zeolites, Partial Replacement of Cement, Concrete, Pozzolanic Reaction, Strength

1. INTRODUCTION

Natural zeolite is a crystalline hydrated aluminosilicate and alkaline earth cations having an infinite, open and three dimensional structures. This low-cost natural mineral is generally easily mined by the surface methods. Huge beds of zeolite-rich sediments were discovered in the United States, China and in many other parts of the world since the late 1950s [1].

Natural zeolites are useful industrial mineral with exciting surface and structural properties. It has been used widely for various purposes in industrial, agricultural, environmental and biological technology. And because of this multitude uses, it is often called magic rock [1].

In concrete industry, natural zeolites have been used as lightweight aggregate, mineral admixture and partial replacement for cement through pozzolanic reaction. Expanded zeolitic tuff is widely used as lightweight insulating materials or lightweight aggregates in concrete in many Eastern European countries [1].

In China, research on the use of natural zeolites as construction materials has been carried out intensively and extensively, especially since the discovery of a large zeolite mineral deposit in Zhejiang Province in 1972. Since then, a series of new products have been developed by taking advantage of the unique characteristics of the natural zeolites, for example an anti bacteria agent, mineral admixture to reduce the alkali-aggregate reaction, blended cement, cellular concrete, carrier fluidizing agent to improve concrete workability, and humidity-conditioning material. Even in the late 1990s, two new industrial codes for the usage of natural zeolites as construction and building materials have been approved by China Standard Association for construction practice in China. Currently, the

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annual consumption of natural zeolites in China by the construction industries itself is approximately in the amount of 30 millions tons [2].

In Indonesia, natural zeolites are also available abundantly. To date, its usage is restricted mainly in agricultural industries, such as the ingredient for fertilizer and dietary supplement for animals. Whereas for the application in the construction industry, only very few information have been reported [3].

In this study, natural zeolite has been used to partially substitute the use of ordinary Portland cement (OPC) in concrete. The silicon dioxide in natural zeolite was expected to increase the concrete strength through the pozzolanic reaction with the calcium hydroxide from the hydration of OPC.

2. EXPERIMENTAL DETAILS

The mineral zeolites used in this study were of Kuzeo brand. It has a specific gravity of 2100 kg/m^3, pH of 6.7 and surface area of 9500 cm^2/g. The chemical composition of natural zeolites used is shown in Table 1. Zeolites were used to partially replace the use of OPC in the amount of 0% (as the control mixture), 3%, 5% and 10% by mass. No pre-treatment was applied to the natural zeolites before its usage, and no other admixture was added.

Table 1: Chemical Composition of Natural Zeolites

Oxides	SiO2	Al2O3	Fe2O3	CaO	MgO	K2O	K2O	P2O5	MnO
Mass (%)	60-64	18-21	4-5	4-6	2-3	2-3	0.8-1.0	0.1-0.5	0.3-1.0

Locally available crushed coarse aggregate of granite type was used, together with river sand with the fineness modulus of 1.85. The OPC used was of type I. Mixture proportion was prepared for 35 MPa target strength at 28 days with the target slump of the fresh concrete in between 75-100 mm.

Tests were performed on the concrete cylinders, diameter 150 mm and of 300 mm height, at the age of 3, 7, 14 and 28 days for compressive and tensile splitting strength, as well as for the measurement of the modulus of elasticity. All tests were performed in accordance to relevant Indonesian and or ASTM standards. All specimens were cured by immersing it in the water until the day of testing. Each data presented in the following Figures and Tables is the mean value of five test results.

3. RESULTS AND DISCUSSION

3.1. COMPRESSIVE STRENGTH

Compressive strength tests were conducted for concrete specimens at the age of 3, 7, 14 and 28 days. The results are shown in Table 2.

Table 2: Compressive Strength at Various Ages (MPa)

Zeolites	**Compressive Strength (MPa)**			
	3 days	**7 days**	**14 days**	**28 days**
0 %	10.5	14.3	21.2	33.4
3 %	8.3	11.9	19.3	30.2
5 %	7.1	11.7	17.9	28.4
10 %	4.2	9.2	11.8	23.1

From Table 2, it can be seen that with the increase of the zeolites, the compressive strength decreased. For the 10% replacement of cement by natural zeolites, the 28-day strength was only about 70% of the control mixture.

In this study, compressive strength tests were conducted only up to 28 days. There might be possibility that the pozzolanic reaction between the SiO_2 from the natural zeolites and the calcium hydroxides from the hydration of cement takes place in a slower pace than the hydration process of OPC, just like in the case of fly ash, resulted in a lower compressive strength at early age, but higher rate of strength development at later ages.

However, report from another study using the same brand of natural zeolites but different aggregates and cement sources revealed that the strength development rates from 28 to 60-day approximately similar for concrete with and without zeolites, although the strength reduction was only between 10-20% for concrete incorporating zeolites up to 20% at 60 days of age [3]

Studies by Feng et al [4] and Feng and Feng [5] in China reported different outcomes. Using 10% zeolites replacement, the compressive strength increased approximately by 10%. In this case, they added a certain amount of ingredient from Triethanolamine family to enhance the performance of natural zeolites used.

These results suggest that direct partial replacement of Portland cement by natural zeolites does not bring any improvement in compressive strength.

3.2. TENSILE SPLITTING STRENGTH

The tensile splitting strength of concrete is shown in Table 3.

Table 3: Tensile Splitting Strength of Concrete (MPa)

Zeolites	**Tensile Splitting Strength (MPa) at various concrete ages**			
	3 days	**7 days**	**14 days**	**28 days**
0 %	1.7	2.3	2.4	3.0
3 %	1.1	1.6	2.2	2.8
5 %	0.7	1.3	1.8	2.5
10 %	0.5	1.0	1.5	2.3

It can be seen that the tensile splitting strength of concrete incorporating natural zeolites as partial replacement for cement is a fraction of its compressive strength. As the amount of natural zeolites increased, the tensile splitting strength decreased. This tendency is consistent regardless the age of concrete.

3.3. MODULUS ELASTICITY

Modulus of elasticity of hardened concrete was measured in accordance to ASTM C469-87a on concrete cylinders with diameter 150 mm and 300 mm height. Table 4 shows the Modulus of Elasticity of concrete incorporating natural zeolites at various ages.

Table 4: Modulus of Elasticity (MPa)

Zeolites	**Modulus of Elasticity (MPa)**			
	3 days	**7 days**	**14 days**	**28 days**
0 %	18106	19513	20851	28858
3 %	17864	18860	18864	23061
5 %	16971	17410	18426	23585
10 %	17399	17864	19680	22639

As the compressive strength decreased with the increase of natural zeolites content, the modulus of elasticity of concrete at various ages also decreased. This shows that the modulus of elasticity of concrete is a function of its compressive strength. At 28 day, the reduction of modulus of elasticity for concrete with 10% zeolites content is about 20% compared to those of concrete without any zeolites.

3.4. SLUMP AND SPECIFIC GRAVITY

Table 5: Slump and Specific Gravity of Concrete

Zeolites	**Slump (mm)**	**Specific Gravity (kg/m^3)**
0 %	89	2487
3 %	85	2397
5 %	80	2346
10 %	78	2268

The slump of fresh concrete slightly decreased with the incorporation of zeolites. Scanning Electron Microscopy revealed that the particle shape of natural zeolites is cubical with rough surface [3]. This particle shape of zeolites is responsible for the lower workability of fresh concrete. To improve the workability, the use of appropriate superplasticiser is suggested.

On the specific gravity, concrete with natural zeolites tends to have smaller specific gravity with the increase of zeolites content. This can be regarded as the direct influence of smaller specific gravity of natural zeolites as compared to OPC.

4. CONCLUSIONS

From this study, several conclusions were drawn:

- Direct use of natural zeolites as partial replacement for ordinary Portland cement in concrete up to 10% by mass did not improve the concrete compressive strength. In fact, the compressive strength decreased with the increase of natural zeolites content.

- The incorporation of natural zeolites in concrete tends to reduce the slump value of fresh concrete due to its cubical particle shape and rough surface.

- Due to smaller specific gravity of natural zeolites compared to ordinary Portland cement, the specific gravity of concrete incorporating zeolites slightly reduced.

- As in the case of concrete without natural zeolites, the tensile splitting strength and the modulus of elasticity of concrete with zeolites are function of its compressive strength. Thus, concrete with zeolites possesses lower tensile splitting strength and modulus elasticity.

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