A Study on Investigation for Effectiveness of Natural Minerals with Silica-Component as Admixture for Concrete

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요 약

본 연구는 콘크리트용 혼화재로서 우리나라에 풍부한 천연 실리카 질 광물을 이용하여 콘크리트의 강도증진 가 능성 및 유용성과 경제적인 효율성에 대해 검토한 것이다. 제반 실험을 통해 얻어진 결론을 요약하면 다음과 같다.

① 최적의 제오라이트 치환율은 단위 시멘트량당 5~10% 정도로 나타났으며, 그 때의 강도 증진율은 무첨가 콘크리트 값에 비해 대체적으로 40% 정도의 강도증진 효과를 얻었다.

② 최적의 이암 치환율은 단위 시멘트량당 10~15% 정도로 나타났으며, 그 때의 강도 증진율은 무첨가 콘크리트 값에 비해 대체적으로 10% 정도의 강도증진 효과를 얻었다.

이러한 검토로부터 우리는 혼화재로서 콘크리트의 강도성능의 향상을 목적으로 기존의 실리카 흄, 플라이 애쉬 등의 대체품으로 천연 실리카 광물을 활용할 수 있다는 결론을 얻었다.

Abstract

In this study, when natural mineral with Silica component(Zeolite & Mudstone) abundant in Korea are used as an admixture for concrete, the possiblity of strength increase, effectiveness and economical efficiency of the concrete is investigated.

Through the experiments, the results obtained are summarized as follows.

① The optimum replacement ratio of Zeolite appeared to be 5~10% of unit-cement content. The strength increase was approximately 40%, compared with those of the plain concrete, in the above range of the optimum replacement ratio.

② The optimum replacement ratio of Mudstone appeared to be 10~15% of unit-cement content. The strength increase was approximately 10%, compared with those of the plain concrete, in the above range of the optimum replacement ratio.

From this investigation, it is concluded that the natural Zeolite and Mudstone is useful as an admixture in order to increase the strength of the concrete and as a kind of substitute for existing Silica Fume, Fly ash, and so on.

keywords : zeolite, mudstone, compressive strength, strength increase.

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1. Introduction

Recently, according to the tendency of highstoried, long-spaned and many-variegated structural form, the concrete has come to occupy a more important place as a structural material, and it is required to make high strength concrete corresponding with various performance[5].

In order to make the high strength concrete, first of all, utilizing admixtures can be considered Nowadays, many types of admixture has been investigated and developed to increase the strength of the concrete all over the world[2].

However, in Korea these admixtures are imported from other countries.

Therefore, it is desirable to investigate and develop this kind of admixture in the near future.

The purpose of this study is to investigate for the possiblity of strength increase of the concrete, effectiveness and economical efficiency, in the case that the natural minerals such as Silica component(Zeolite and Mudstone) are utilized as an admixture of the concrete[3].

These kinds of material are abundant in Korea and can be utilized as a substitute for Silica Fume.

2. Properties of material used for the experiment

2.1 Admixture

(1) Zeolite and Mudstone

The samples were collected in the Pohang area, KyungPook, and after pulverizing crude rock and sieving the finer component than the size of No. 200 sieve was used.

(2) Silica Fume

In order to compare with the difference between Zeolite and Mudstone, the same process of the experiment was applied and the results were evaluated comparing with those of Silica Fume(produced in Astria), shown the remarkable performance in the increase of the concrete strength.

2.1.1 Chemical Composition and Specific gravity

(1) Specific gravity

The test results showed that the values of specific gravity of Zeolite and Mudstone are 2.2 and that of Silica Fume is 2.19.

(2) Chemical Composition

Zeolite and Mudstone consist mainly of Silica and Alumina of 85~90%, possessing pozzolan reaction, and 97% in the case of Silica Fume.

From this fact, it is considered that Zeolite and Mudstone are very similar material to Silica, an excellent admixture, in the chemical composition and expected to show similar performance.

Table 1 Chemical composition and specific gravity of admixture

Kinds	Chemical Composition(%)												Specific gravity
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	TiO_2	Mn_2O_3	P_2O_5	Igloss	
Zeolite	67.57	15.48	4.70	1.47	2.01	0.07	1.92	2.38	0.4	0.12	0.04	3.84	2.22
Mudstone	80.96	9.58	5.47	0.0	0.65	0.03	1.16	0.44	0.59	0.05	0.09	0.98	

(Notice) The test was performed by Dong Yang Central Research Institute

2.1.2 Properties of Paste partially-replaced by admixture

(1) Setting Time

The test of setting time was conducted based on the procedure of KS L 5108, for cement paste and the other pastes replaced partially by each admixture. The results of the test showed that partially replacing each admixture has little effect on the setting time.

Table 2 Setting time of paste partially —Replaced by Admixture

Kinds	Setting Time(h-m)				
	0%	5%	10%	15%	20%
A	4−15	8−15	7−33	6−28	6−02
B		6−43	6−02	5−52	7−30
C		9−00	7−20	6−28	5−55

A : Paste partially-replaced by Mudstone

B : Paste partially-replaced by Zeolite

C : Paste partially-replaced by Silica Fume

(2) Heat of hydrate

The degree of temperature rising due to the heat of hydration was investigated for the cement paste and the other pastes with partially-replaced by admixtures.

Test specimens were prepared of Water/cement(or cement+admixture) ratio to be 40% and the replacement ratio of admixtures to be 20%.

The dimension of mould(product of Schiropol, 18mm diameter) is 24×24×18cm and the four sides of mould were insulated.

The temperature of paste was measured in the room temperature(24±1℃) by using a data logger connected with K-thermo couple which is embedded in the centeral part of mould.

From the results of experiment, the maximum temperature appeared to be 109.2℃(10 hours after moulding) in the case of the cement paste and 85.4, 95.8, 84.8℃ for the paste replaced by Zeolite, Mud-stone, Silica Fume, respectively.

And the time reaching the temperature was retarded 4~6 hours in case of using partially-replacing admixtures.

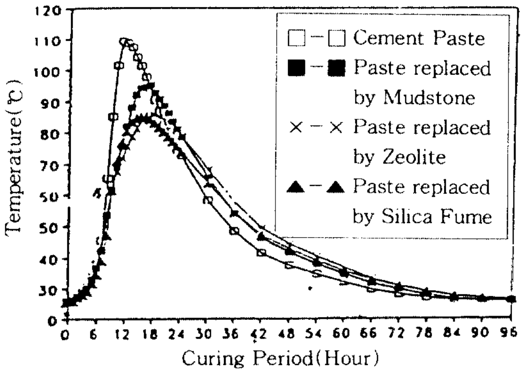


Fig. 1 Temperature rising of past by heat of hydrate

(3) Properties of crystallization in the chemical reaction creature by X-Ray Diffratogram

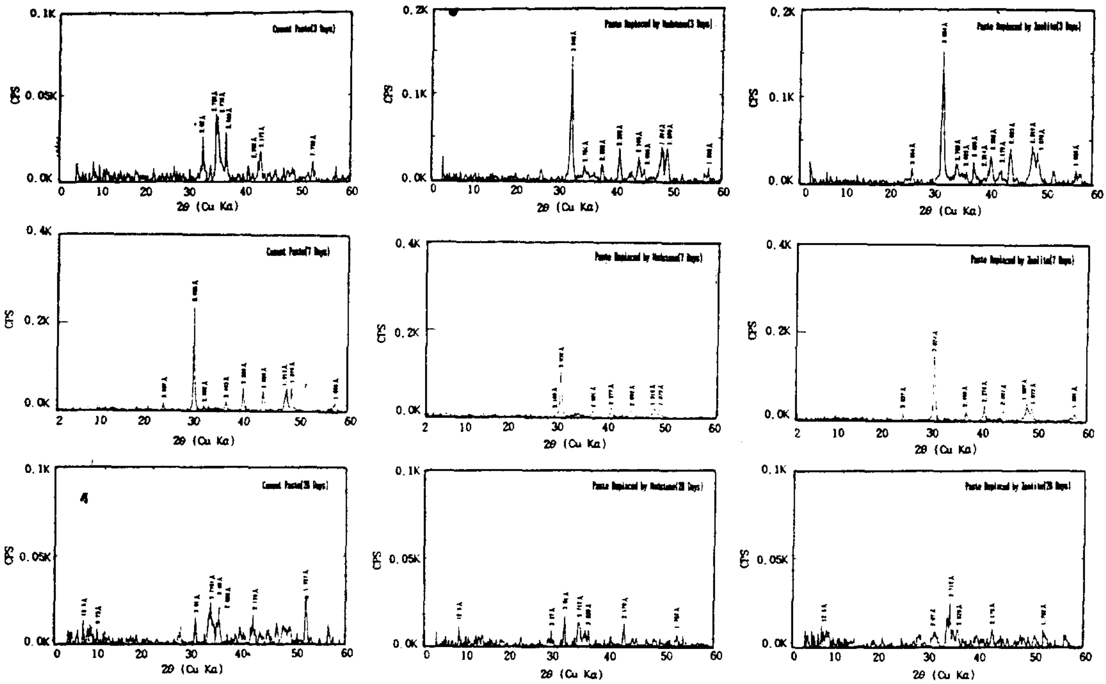
The X-Ray Diffratogram of the cement paste and the paste replaced 10% of cement by admixture is shown in Fig 2.

The peak content of Calcium Silicate and Mono Sulphate which is insoluble hydrate in the cement paste is lower than the case of replacing the paste by the admixture.

This phenomenon appeared to be remarkable in paste replaced by Zeolite and Mudstone.

Also the peak content of $Ca(OH)_2$ separated from the hydration process of the cement showed the low degree in the case of the paste replaced by Zeolite and Mudstone(Fig 3).

Thus, it showed that the reaction between the admixture and $Ca(OH)_2$ was being very active.



CPS : Intensity of the angle of X-Ray diffraction
2θ : The angle of diffraction

Fig. 2 X-Ray diffractogram

(4) Form of reaction creature by SEM(Scanning Electronic Microscope)

The form of reaction creature for the cement paste and the paste replaced 10% of cement weight by the admixture was investigated.

Photo 1 is photography of each admixture by Scanning Electronic Microscope.

In the case of the paste replaced by Zeolite and Mudstone, the voids of the crystal were decreased, compared with cement paste, by crystallizing due to fiber-shaped Calcium Silicate, second hydrate, and filled up the voids of first hydrate. Also, the structure of first hydrate was changed to the net-shape form(matrix) from the lump-shaped Mono Sulphate combined to neddle-shaped Ettringite.

Thus, it is considered that the increase in compressive strength is due to formating the net-shaped structure, increasing C-S-H shape and C-A-H shape, and due to crystallizing at the same time when replaced with an adequate quantity of Zeolite and Mudstone.

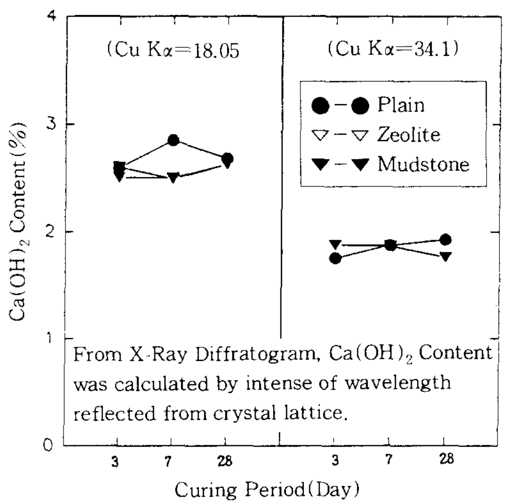
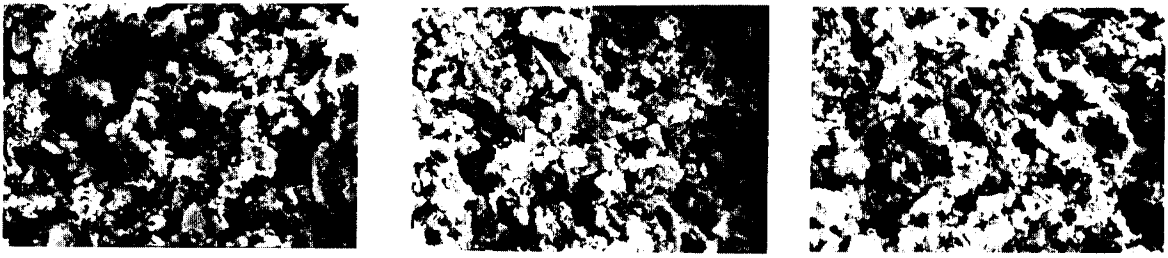


Fig. 3 Change of $Ca(OH)_2$ according to curing period



(Cement Paste) (Paste Replaced by Mudstone) (Paste Replaced by Zeolite)

Photo. 1 Photography of each admixture by SEM (Scanning Electronic Microsope)

Table 3 Chemical composition of cement

Component	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	CaO	K_2O	Na_2O	Ig · loss
Composition Ratio (%)	21.4	7.0	2.9	3.1	1.7	60.8	0.72	0.12	1.2

Table 4 Physical properties of cement

Specific gravity	Blaine's Fineness (cm^2/g)	Setting time (hr-min) Init.	Setting time (hr-min) Final	Soundness	Compressive Strength (Kg/cm^2)		
					3days	7days	28days
3.15	3,140	3-45	7-20	good	210	280	376

2.2 Cement

The portland cement producted by S company was used.

2.3 Aggregate

The type and the source of aggregates are as follows :

Fine aggregate ; river-run sand, Ok-Sung, KyungPook Coarse aggregate ; crushed stones, KyungPook.

Physical properties of aggregate are shown in Table 5.

2.4 Superplasticizer

A superplasticizer(producted by Y company, and the main component is Naphthalene-sulfonated formaldehyde salts) of 1.5%(cement+admixture) was used to improve workability of the mixture.

3. The experiment on mechanical properties of Mortar with admixture

3.1 Outline of Experiment

In order to investigate the effect of the replacement ratio and particle size of admixture

Table 5 Physical properties of aggregate

Kinds (mm)	Specific gravity (SSD)	Max. Size (mm)	Unit Weight (kg/m^3)	Absorption (%)	Air Volume (%)	Solid Volume (%)	Abrasion (%)	Fineness Modulus (%)
Fine aggregate	2.68	4.76	1682	1.63	34.8	65.2	–	2.71
Coarse aggregate	2.74	25	1480	1.26	47.0	53.0	23.8	6.74

of Zeolite and Mudstone on the concrete strength, a series of the replacement ratio and particle size of admixtures was chosen.

Powder-type Mudstone, Zeolite, Silica Hume of 0, 5, 10, 15, 20% of cement weight, respectively, was replaced as an admixture.

Also, three groups of particle size of 75μm~149μm(Zeolite A and Mudstone A), 45μm~75μm(Zeolite B and Mudstone B), under 45μm (Zeolite C and Mudstone C) was used for each admixture.

The flow test for fresh mortar and the compressive strength test for hardened cement mortar were performed.

Experiment factor and level are shown in Table 6.

Table 6 Experiment Factor and Level

Factor		Level
Grain Size of Admixture	Zeolite	A(75μm~149μm) B(45μm~75μm) C(under 45μm)
	Mudstone	
Replacement Ratio of Admixture		0%, 5%, 10%, 15%, 20%

3.2 Preparation and Curing of test specimens.

Each batch of the mortar was mixed by a mixing drum for 2 minutes after 1 minutes dry

Table 7 Mix proportions and test results of mortar

Kinds of Admixture		Material quantity /Batch(kg /m³) R.R	C	A	S	W	Flow (cm)	Compressive Strength(kg /cm³) 3Days	7Days	28Days	Unit Weight (Kg /m³)
Plain		0%	1,020	0	2,500	494.7	167	194	260	334	1,968
Silica Fume		5%	969	51			158	178	260	357	1,945
		10%	918	102			148	181	246	344	1,915
		15%	867	153			123	202	269	369	1,922
		20%	816	204			134	186	252	359	1,899
Zeolite	A	5%	969	51			160	185	245	325	1,930
		10%	918	102			133	167	209	307	1,915
		15%	867	153			119	148	201	282	1,907
		20%	816	204			118	154	211	301	1,915
	B	5%	969	51			158	209	273	354	1,953
		10%	918	102			136	188	259	344	1,930
		15%	867	153			121	194	261	353	1,938
		20%	816	204			114	159	229	312	1,907
	C	5%	969	51			152	212	284	367	1,960
		10%	918	102			134	219	298	413	1,983
		15%	867	153			111	199	296	378	1,976
		20%	816	204			116	188	259	337	1,922
Mudstone	A	5%	969	51			163	164	227	288	1,915
		10%	918	102			149	180	239	322	1,915
		15%	867	153			117	186	250	327	1,922
		20%	816	204			115	150	213	286	1,892
	B	5%	969	51			167	170	238	322	1,945
		10%	918	102			152	183	256	341	1,938
		15%	867	153			128	161	239	325	1,899
		20%	816	204			117	158	223	301	1,907
	C	5%	969	51			210	210	279	378	1,976
		10%	918	102			191	191	267	362	1,938
		15%	867	153			205	205	292	394	1,991
		20%	816	204			188	188	244	354	1,930

R.R : Replacement Ratio C : Cement A : Admixture S : Sand W : Water mixing for a uniform quality and adding water.

Three specimens were prepared from each batch for a series of the combunation of the experiment factor and the level shown above.

The specimens were molded by using a square-shaped tamping rod in two layers and were cured in a constant temperature water bath (23±2℃) until the required tests were conducted.

3.3 Test Method

The flow tests for the fresh cement mortar were performed in accordance with KS L 5111, and the compressive strength test for the hardened cement mortar by using Universal Testing Machine, hydraulic type, 50 ton capacity, in accordance with KS L 5104.

3.4 Test Results and Discussion

Mixing proportions and test results of mortar are shown in Table 7.

1) Flow value

The results of the flow test for the fresh mortar with different replacement ratio of each admixture are shown in Fig 4.

All the flow values were decreased when replaced by the admixtures, compared with the nonreplaced case, and these decrease ratios are higher in the Zeolite and Mudstone cases than in the case of Silica Fume.

In addition to, the effect of grain size on the flow value is appeared to be insignificant in the cases of Zeolite and Mudstone.

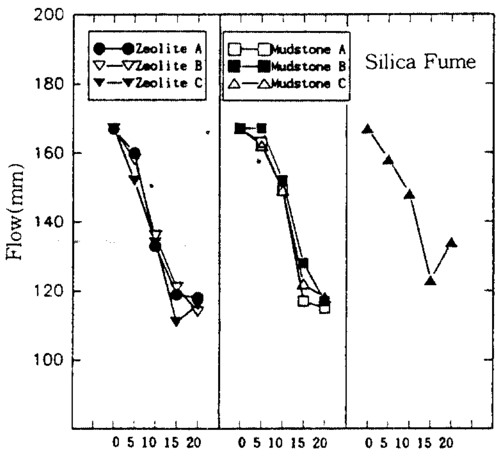


Fig. 4 Replacement ratio and flow relation of mortar

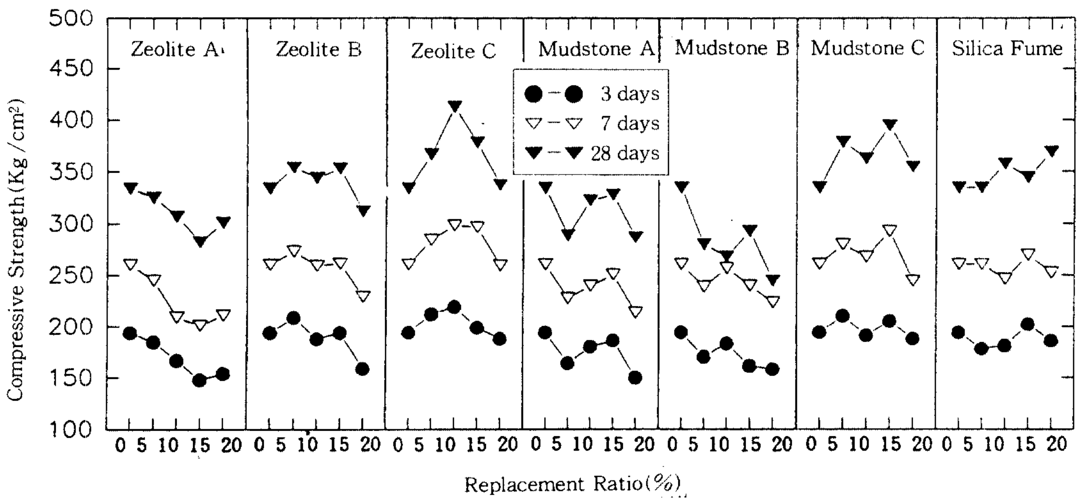


Fig. 5 The relationship between replacement ratio and compressive strength of mortar

2) Compressive Strength

The relationship between the replacement ratios of each admixture and the compressive strength on 28 days for the hardened mortar is shown in Fig 5.

From this figure, the effect of the replacement ratio on the compressive strength of the mortar replaced by Zeolite and Mudstone powder was more remarkable than that of grain size.

In the range of 5~10% replacement ratio, the increase ratios of the compressive strength appeared to be highest and in the case of zeolite C 10% replacement ratio of the compressive strength was increased by 27.3% compared with that of the plain mortar.

The optimum replacement ratio of Mudstone was 15%, and the compressive strength in the case of 15% replacement ratio by Mudstone C was higher 18.0% than that of the plain mortar.

Fig 6~Fig 7 show the relationship between the compressive strength of the mortar with different grain size of the admixtures.

The compressive strength of the mortar replaced by Zeolite A and Mudstone A, the group

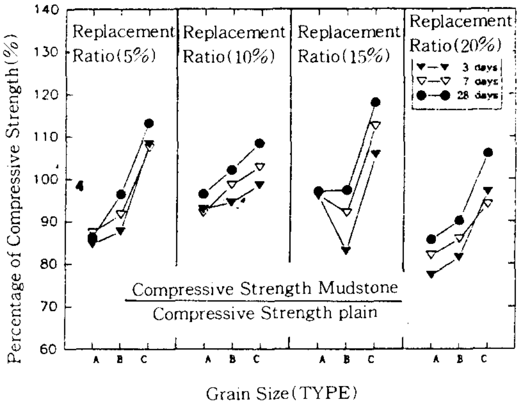


Fig. 6 The Relationship between grain size and compressive strength of mortar(Modstone)

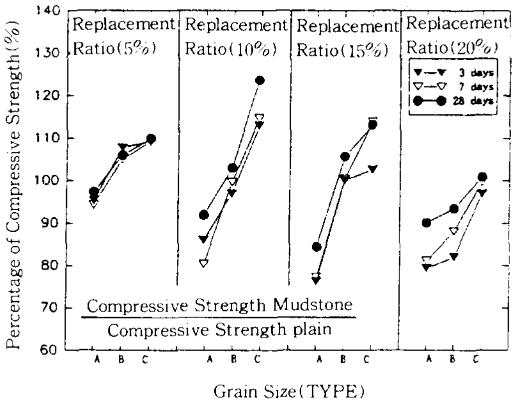


Fig. 7 The Relationship between grain size and compressive strength of mortar(Zeolite)

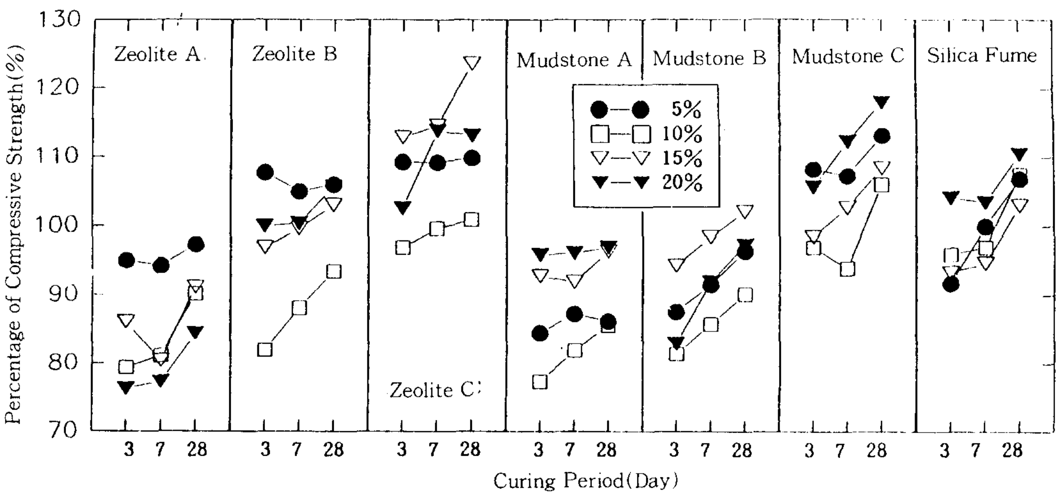


Fig. 8 The relationship between curing period and compressive strength of mortar

with large grain size, is lower than those of plain mortar, and the smaller grain size the more the compressive strength appeared to be increased, compared with that of the plain mortar.

The compressive strength of the mortar appeared highest at the replacement ratio of 5% in the case of Zeolite A and B, and 10% in Zeolite C.

Thus, it is considered that in order to increase the strength the optimum replacement ratio has to be found and the finer particle size of the admixtures to utilize the effect of Micro Filler is desirable to be used.

The relationship between the compressive strength of the mortar and curing period is shown in Fig 8.

The compressive strength at 3 and 7 days are decreased as the replacement ratio increase and grain sizes of the admixture become larger, but the the strength increase in the early days was compensated by using the finer grains of zeolite and mudstone.

Therefore, it is regarded that using finer grains of zeolite and mudstone is desirable when early strength is required.

4. The experiment on strength properties of concrete with admixtures

4.1 Scope of the Experiment

In this experiment,the effect of the replacement ratio of each admixture on the strength properties of concrete was investigated.

Table 8 Experiment Factor and Level

Factor	Level
Replacement Ratio	0, 5, 10, 15(%)
Unit Weight combined material	533,567(kg/m³)
Ratio of Water/Combined material	30(%)

Table 9 Experiment mixing and results

Admixture		Amount of Unit-Combined Material (kg/m³)	Unit Weight(kg/m³)						Slump (cm)	Air Content (%)	Compressive Strength(kg/cm²)				Splitting Tensile Strength (kg/cm²)
Kind	Repplacement Ratio(%)		W	C	A	S	G	SP			3days	7days	28days Dry	28days Wet	
Plain	0%			533	0				22.0	2.4	363	427	454	464	30
Mud Stone	5%			507	27				20.3	2.6	404	439	492	509	35
	10%			480	53				14.9	2.5	252	428	521	531	41
	15%			453	80				5.5	1.9	320	449	460	537	35
Zeolite	5%			507	27				21.5	2.0	421	479	581	641	44
	10%	533	160	480	53	744	931	8	17.0	2.4	455	508	617	640	46
	15%			453	80				8.1	1.7	340	472	526	600	38
Silica Fume	5%			507	27				22.0	2.1	364	440	529	604	39
	10%			480	53				14.1	2.6	418	426	525	529	37
	15%			453	80				9.4	2.0	386	418	464	508	32
Plain	0%			567	0				18.8	2.5	241	320	401	415	27
Mud Stone	5%			538	28				17.5	2.6	290	393	443	461	32
	10%			510	57				12.7	2.4	378	402	456	495	28
	15%			482	85				6.8	2.1	380	423	455	502	32
Zeolite	5%			538	28				18.4	2.2	299	352	392	475	35
	10%	567	170	510	57	720	901	8.5	15.3	2.3	293	439	407	463	35
	15%			482	85				7.7	2.2	238	396	391	424	34
Silica Fume	5%			538	28				18.5	2.2	336	490	490	522	33
	10%			510	57				12.3	2.0	260	410	357	508	35
	15%			482	85				8.7	1.9	228	375	317	457	34

Notice) W : Water C : Cement A : Admixture S : Sand G : Gravel SP : superplasticizer

The experiment factor and level are shown in Table 8.

4.2 Preparation and Curing of Test Specimens

Three pieces of test specimens were prepared to investigate the 3, 7 and 28-day compressive strength of the concrete in accordance with KS F 2403.

The test specimens were cured in a constant temperature water bath(23±2℃).

4.3 Test Method

The tests for Slump, Air content and Compressive strength were performed in accordance with KS F 2402, KS F 2421 and KS F 2405.

Also, the test of Splitting Tensile Strength was followed as the procedure of KS F 2423.

4.4 Experiment Results and Discussion

The mixing proportion and results of this ex-periment are shown in Table 9.

4.4.1 Slump

The values of slump for the concrete replaced by Zeolite, Mudstone, Silica Fume were decreased considerably as the replacement ratio increases and were decreased more significantly in the case of ratio of Silica Fume than those of Zeolite and Mudstone.

This shows to result from absorbing a part of mix-water because Zeolite and Mudstone are porousmaterial and consist of cray minerals.

4.4.2 The properties of compressive strength

1) The relationship between compressive strength and replacement ratio of admixtures

Fig 10 shows the relationship between the replacement ratio of admixtures and compressive strength of the concrete.

In the case of unit-water content, 160kg, the compressive strength on 28 days were increased by 9.82, 14.44, 15.73% respectively with regard to each replacement ratio of Mudstone, compared with compressive strength of the plain concrete.

Also, the similar results appeared in the case of unit-water content, 170kg, but the rates of increase were 11.08, 19.28, 20.96% respectively.

The maximum strength of the concrete was reveal-ed at the replacement ratio of 15% in Mudstone.

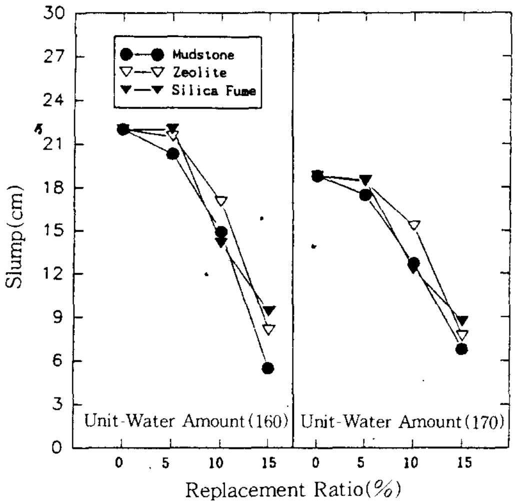


Fig. 9 The relationship between replacement and slump

In the case of unit-water content, 160kg, the compressive strengths on 28 days of the concrete replaced by Zeolite 5~10% were increased by upto 40% compared with the plain concrete, and those of the concrete replaced by Zeolite of 15% were increased by 30%.

Also, in the case of unit-water content, 170kg, the similar features were appeared but the range of the increment was 10~15%.

However, the compressive strength on 28 days of the concrete replaced by Zeolite 15% was increased by 2% compared with that of the the plain concrete.

On the occasion of Silica Hume, the compressive strength on 28 days was appeared highest in the range of the replacement ratio of 5~10% regardless of unit-water content.

2) Curing period and Compressive strength

The relationship between the curing period and the compressive strength of concrete replaced by ad-mixtures is shown in Fig 11.

In the case of Mudstone and Zeolite,the compressive strength ratio on 7 days to 28 days of the concrete replaced by admixtures showed a range of 75~90% in general,and it was decreased a little as the replacement ratio increases in Silica Fume

Generally, the compressive strength ratio on 3 days to 28 days showed a range of presented 50~70% for all mixes.

Especially, in the cases of Zeolite and Mudstone, the compressive strength ratios in 28 days to the plain concrete are higher than those in 3 and 7 days.

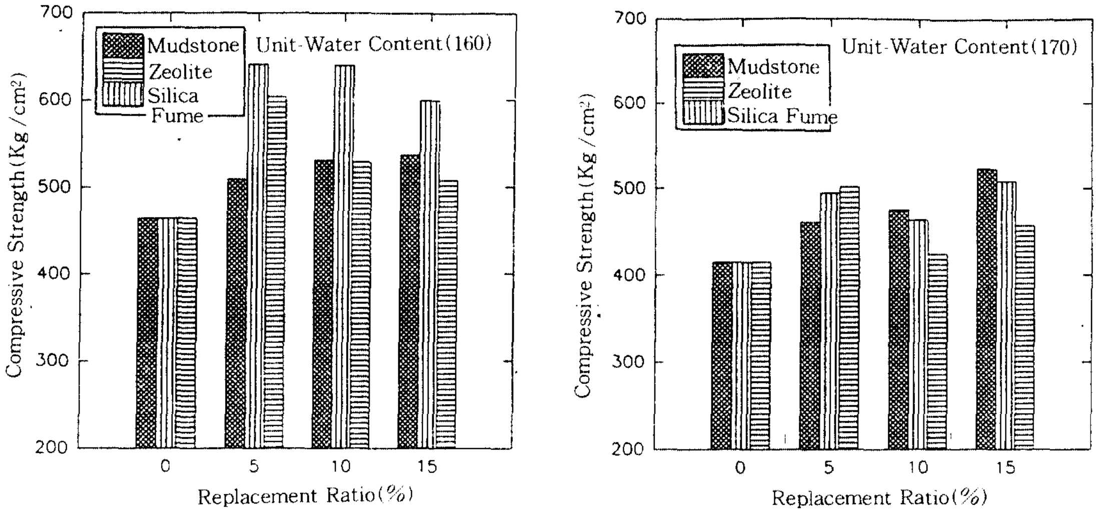


Fig. 10 The relationship between replacement ratio and splitting tensile strength

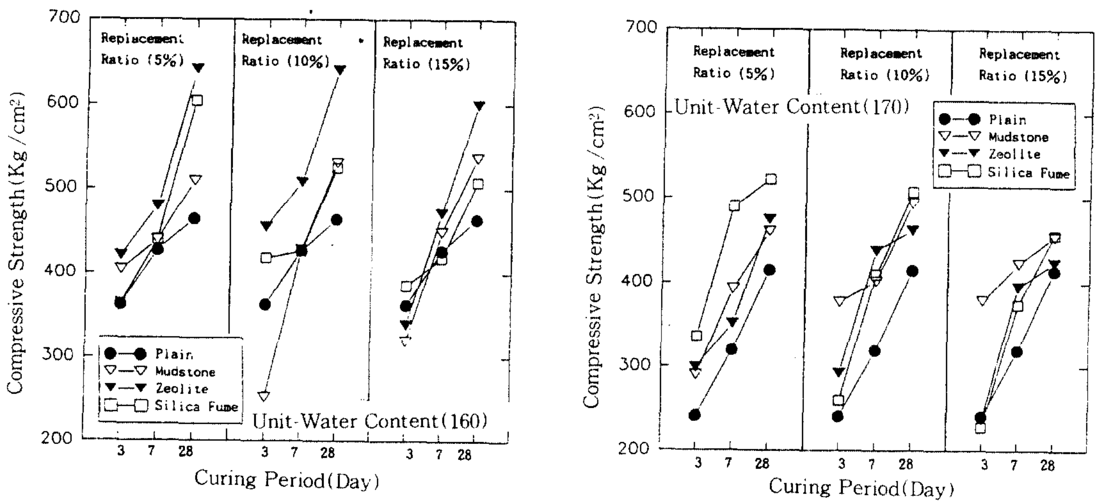


Fig. 11 The relationship between curing period and compressive strength

From this fact, it can be said that in order to increase the long-term strength of concrete, utilizing Zeolite and Mudstone is more economical.

3) Curing condition and Compressive strength

If we compare with compressive strength according to curing condition of concrete replaced by admixture, the compressive strength of wet cured concrete is higher than that of dry-cured concrete regardless of admixture.

The compressive strength of the concrete replaced by admixtures in two different curing conditions, wet and air-dry, were investigated and compared each other.

The compressive strength ratio of a wet cured to air-dry condition is the highest at the replacement ratio of 10% in general.

And this strength increase ratio ranged 5~15% on the whole though a little difference is appeared.

4.4.3 Splitting Tensile Strength

Fig 12 showed the relationship between the replacement ratio of admixtures and the splitting tensile strength. According to this figure, it appeared that the increase ratio of the strength is high in range of the replacement ratio of 5~10%, and the concrete replaced by Zeolite showed a higher strength than the concrete replaced by the other admixture in general.

4.4.4 Stress-Strain Curve

Fig 13 shows stress-strain curves for the concrete with various replacement ratios of admixtures. It can be said from the stress-strain curves that the strains at the compressive strength of the concrete replaced by admixtures are higher than those of the plain concrete. And the secant modulus of stress-strain curve for the concrete replaced by Mudstone was appeared lower than that of plain concrete, but those of the concrete replaced by Zeolite was appeared higher than that of the plain concrete.

From these facts,it is considered that the concrete replaced by Mudstone has better characteristics in deformation, whereas the concrete replaced by Zeolite and Silica Fume is more brittle than the plain concrete.

4.4.5 Elastic Modulus

In this experiment, computation of the elastic modulus was carried out in accordance with

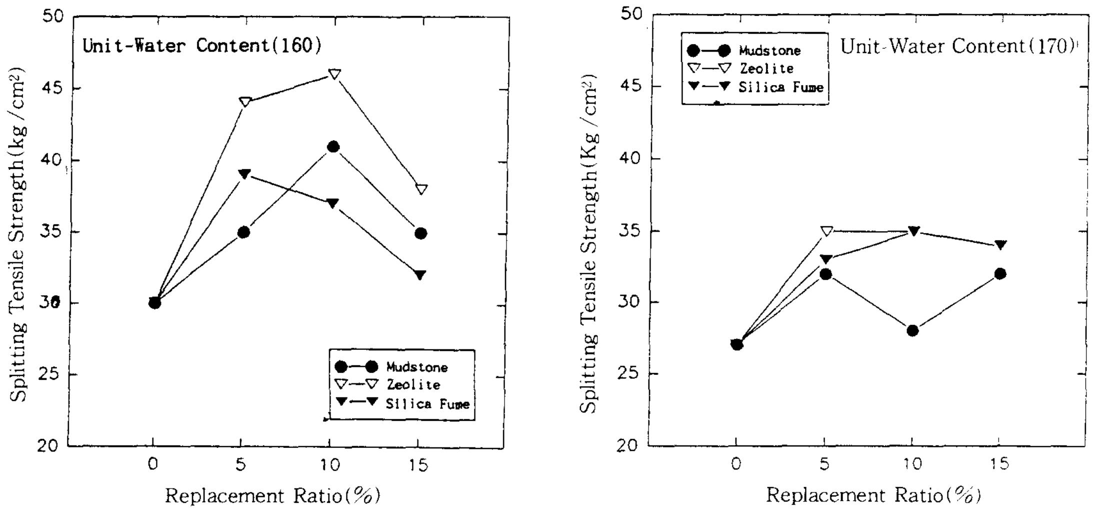


Fig. 12 The relationship of replacement ratio and splitting tensile strength

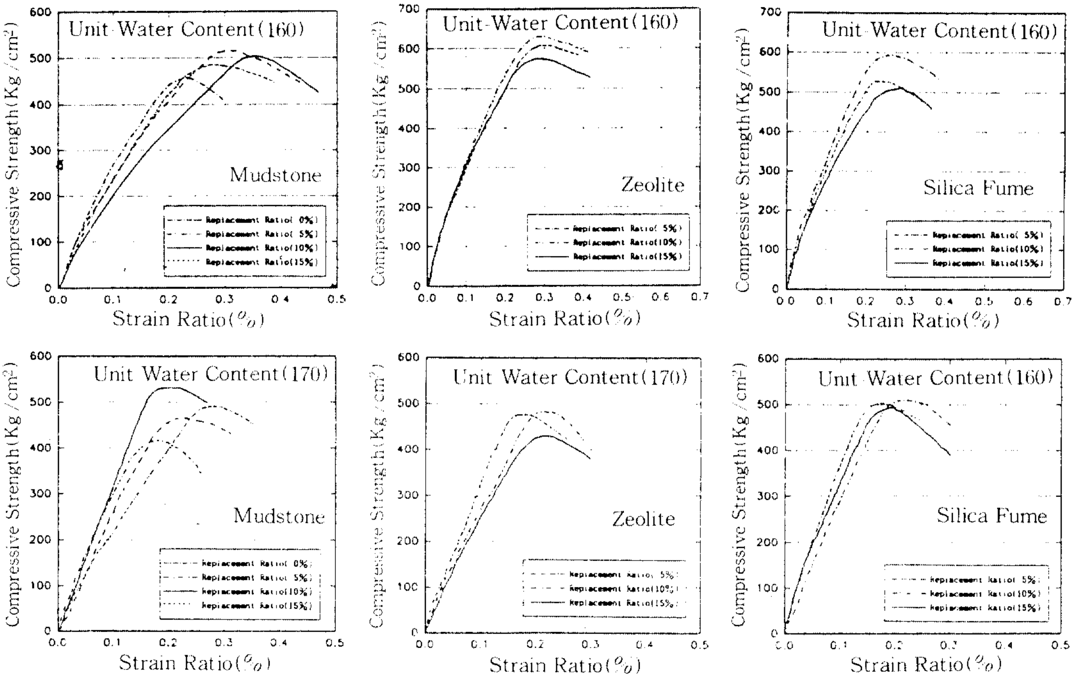


Fig. 13 Stress-strain curve

KS F 2438. The calculated results showed that all values of the elastic modulus for the concrete except for the concrete replaced by Mudstone is higher than plain concrete.

In the case of Zeolite, on the whole, the valuewas appeared to be 5~20% higher than that of the plain concrete. The results of elastic modulus calculations are shown in Table 10.

Table 10 Elastic modulus of replaced concrete as admixture

Elastic Modulus(kg/cm²×10⁵)				
Unit Water Amount	Replacement Ratio(%)	Mud Stone	Zeolite	Silica Fume
160	0%	2.94	-	-
	5%	2.38	3.15	3.52
	10%	2.16	3.03	3.13
	15%	2.51	3.63	3.35
170	0%	2.88	-	-
	5%	2.24	3.12	2.89
	10%	2.88	3.14	3.46
	15%	2.21	2.97	3.48

5. Summary

In this study, the possiblity of the strength increase effectiveness and economical efficiency of the concrete replaced with natural mineral of Silica component(Zeolite and Mudstone) as an admixture are investigated. Zeolite and Mudstone are mainly consisted of silica component and a-bundant in Korea.

In the point of view of a new material development and resources-savings against the problem of exhaustion in natural resources, it is desirable to investigate how to improve the strength of concrete economically.

The results are summarized as follows :

1) Experiment for mortar

① The flow values of the mortar replaced by admixtures were decreased,compared with the plain mortar, and these ratios are remarkable as the replacement ratio of powder increases.

② The test results of for the compressive strength of concrete replaced by admixtures, it can be said that the optimum replacement ratio to increase the strength of the mortar replaced by admixtures is 10% for Zeolite and 15% for Mudstone.

③ The effect of grain size in Zeolite and Mudstone on a strength increase appeared to be in different way.

Accordingly, it is considered that Zeolite and Mudstone have to be used in powder-type for the maximum effect after sieving with No. 200 sieve.

2) Experiment for concrete

① The results of the slump test for the concrete replaced by admixtures, the slump of concrete replaced by all kinds of admixture decreased significantly, as the replacement ratio increases and the decrease ratios of Zeolite and Mudstone are a little larger than that of Silica Hume.

② The compressive strength of the concrete replaced by Zeolite is the highest among all batches of the concrete replaced by admixtures, and these were increased by 30~40% in the range of the replacement ratio of 5~10%, compared with plain concrete.

③ In general, the increase ratio of the splitting tensile strength for the concrete replaced by adimixtures is the highest at the replacement ratio of 5~10%.

Also, the increase in the splitting tensile strength of the concrete replaced by Zeolite is more remarkable than that of the other replaced concrete.

④ From the stress-strain curves for the concrete replaced by admixtures, it can be recognized that the strains at the ultimate load for the concrete replaced by admixtures are larger than those of the plain concrete.

And the secant modulus of the stress-strain curves for the concrete replaced by Mudstone is smaller than that of the plain concrete, but those of the concrete replaced by Zeolite and Silica Fume are larger than that of plain concrete.

From these results, it is considered that the natural Zeolite and Mudstone are able to be utilized economically as an admixture substituting for existing Silica Fume, etc.

Afterward,it is recommended to investigate fireresistance and durability for the replaced concrete.

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