Experimental Research on the Behavior of Concrete using Mica as Partial Replacement of Fine Aggregates

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Abstract - *The main focus of this research is to study the effects of "Mica" as partial replacement of fine aggregates in mortar and concrete. The fine aggregate replacement percentages of mica such that 1%, 2%, 3%, 4% and 5% by weight are used in this research. There are three portions in this research. In the first portion, chemical composition and physical properties of materials are analyzed. All tests are performed according to ASTM standard procedure. In the second portion, the tensile and compressive strengths of mortar and fire resistance of mortar by using mica as partial replacement of fine aggregates are investigated. In the last portion, the effect of "Mica" as partial replacement of fine aggregate in concrete is studied. The target strength of concrete is 27.6MPa. Mix design of concrete is calculated according to ACI method. Slump, air-content and compressive strength of concrete are conducted. Finally, all the results obtained by using Mica as partial replacement of fine aggregate are compared with those by using pure sand.*

***Key Words*: partial replacement, chemical composition, physical properties, tensile strength, compressive strength, fine aggregate replacement, slump, air content**

1. INTRODUCTION

River sand is one of the constituents used in the production of mortar and concrete. In many countries, sources of natural sand for use as an aggregate in construction are becoming scarce. River sand has been the most popular used fine aggregate in the production of concrete, but due to the overuse of the material, our environment is the worst hit. This is driving the need to find materials which are affordable and available to a replacement of river sand in the production of concrete.

If fine aggregate is replaced by mica in specific percentage, it will decrease fine aggregate content and thereby providing another advantage such as fire resistance. The research will also investigate how replacing sand with mica in mortar and concrete affects its strength and heat resistance. This work is focused on the use of mica as partial replacement of river sand in the production of mortar and concrete.

2. MICA

Mica is a natural occurring material that is based on a collection of silicate minerals and composed potassium, iron, aluminum, magnesium and water. It is constant and entirely static to the action of water, acids, alkalis, conventional solvents, bases, and oil. Mica is stable when exposed to electricity, light, moisture and extreme temperatures.

Mica is a metamorphic mineral. Mica formations are associated with volcanoes and hydrothermal vents. Mica is found in many rocks around the world. Mica is highly tough, elastic and along with being flexible. It is invariably used for fillers, extenders along with providing smoother uniformity, improving workability and prevents cracking. Mica can be used as an insulator in home attics, concrete blocks and also poured into walls (usually in retrofitting uninsulated open top walls). Mica has a recommended exposure limit of 3mg/m^3 respiratory exposure over an 8-hour workday. Mica used in this research is obtained from Ma Au village , Yesagyo Township, Magway Region in Myanmar. Chemical analysis of mica is carried out at Research Centre of Yangon University and is shown in Table I and physical properties of mica are tested in laboratory of Civil Engineering Department and are presented in Table 2.

Table -1: Chemical Composition of Mica

Chemical Constituents	Composition In Percentage (%)
Silica (SiO_2)	8.110
Ferric Oxide (Fe_2O_3)	8.742
Calcium Oxide (CaO)	69.069
Manganese Oxide (MnO)	0.438
Sulphur Trioxide (SO_3)	8.856
Dipotassium Oxide (K_2O)	4.240
Titanium Dioxide (TiO_2)	0.442
Strontium Oxide (SrO)	0.112
Others	0.001
Total	100

Table -2: Physical Properties of Mica

Sr No.	Properties	Result Value	ASTM Standard range
1	Specific gravity	2.22	2.5 to 2.9
2	Finess Modulus	3	2 to 3.1
3	Water Absorption	0.2	<3%

3. TESTING OF MATERIALS USED IN THIS RESEARCH

In this study, chemical composition and physical properties of cement are tested. Then, the physical properties of fine aggregates and coarse aggregates are also determined.

3.1 Cement

Cement is a binding material that sets and hardens independently, and can bind other materials together. It hardens and attains strength from chemical reaction with the water known as hydration. Local product (Crown cement) is used in this research and it is ordinary Portland cement (Type I). The chemical composition of Crown cement is shown in Table 3.The physical properties of crown cement are expressed in Table 4.

Table -3: Chemical Composition of Crown cement

Oxide	Content (%)	Approximate Composition Limits of Portland Cement (%)
Calcium Oxide (CaO)	62.38	60-67
Silica (SiO_2)	20.40	17-25
Alumina (Al_2O_3)	5.12	3-8
Ferric Oxide (Fe_2O_3)	3.11	0.5-6.0
Manganese Oxide (MgO)	3.54	0.1-4.0
Sulphur Trioxide (SO_3)	2.34	1-3
Others	1.59	1
Loss	1.52	2
Total	100	

3.2 Fine Aggregates

Fine aggregates are sand and crushed stone or gravel screenings. Sand is a granular form of Silica (SiO_2). The grains vary in size and shape and these may be rounded or angular. Good sand is that whose mineralogical composition approaches to pure quartz. In this research, fine aggregates are obtained from Ayeyarwaddy river. Physical properties of fine aggregates are summarized in Table 5.

Table -4: Physical Properties of Crown cement

Sr No.	Properties		Result Value	ASTM Standard range
1	Specific gravity		3.14	3.1 to 3.25
2	Finess Modulus		6.5%	<10%
3	Normal Consistency		27.5%	26% to33%
4	Setting time (min)	initial	50min	>45 min
		final	110min	<375 min
5	Soundness		0.7 mm	<10 mm

Table -5: Physical Properties of Fine Aggregrates

Sr No.	Properties	Result Value	ASTM Standard range
1	Specific gravity	2.62	2.5 to 2.9
2	Finess Modulus	3	2 to 3.1
3	Water Absorption	0.79	<3%

3.3 Course Aggregates

Coarse aggregates are particles greater than 4.75 mm, but generally range between 9.5mm to 37.5mm in diameter. In this research, coarse aggregates which are well graded and have the maximum size of 20 mm are used for concrete. Table 6 shows the physical properties of course aggregates.

Table -6: Physical Properties of Course Aggregates

Sr No.	Properties	Result Value	ASTM Standard range
1	Specific gravity	2.74	2.5 to 2.9
2	Finess Modulus	7.17	6 to 8
3	Water Absorption	0.73	<3%

4. TESTING OF MORTAR

Mortar is a mixture of cement, sand and water. It is generally used in masonry construction to fill the gaps between the bricks. Mortar's adhesive characteristics vary, depending on the amount of water added to the mixture .The sand used for mortar shall be natural silica sand conforming to the requirement for sieve No.20-30 standard sand. The following tests are performed according to ASTM standard procedure.

1. Compressive Strength Test
2. Tensile Strength Test

Both tests are carried out for 7 days, 28 days, 56 days and 91 days strength of mortar with pure sand and with mica as partial replacement of fine aggregates in order to know the variation of strengths with different percentage of mica.

4.1Compressive Strength Test

For the compressive strength test, water to cement ratio can be determined by using the flow table test. Water content for cement is that sufficient to obtain a flow of 110 ± 5 % in 25 drops of the flow table. Table 7 shows the required amount of materials for various percentage of mica.

Table -7: Required Amount of Materials for Various Percentage of Mica

Wt. of cement (g)	Wt. of standard sand, SSD (g)	Replacement of mica (%)	Wt. of mica (g)	W/C	Flow (%)
1000	2750	0	0	0.62	107.50
1000	2722.5	1	27.5	0.60	107.30
1000	2695	2	55	0.60	106.80
1000	2667.5	3	82.5	0.60	106.25

1000	2640	4	110	0.60	105.00
1000	2612.5	5	137.5	0.60	105.00

According to Table 7, the water-cement (w/c) decrease when specific amount of mica is used. For the compressive strength test, cement and standard sand are taken in ratio of 1:2.75. The compressive mortar specimens are cured one day in the moulds and stripped and immersed in water until they are tested. The specimens are then tested for 7, 28, 56 and 91 days. At each period interval, three specimens are tested and average of compressive strength of these specimens is taken as the compressive strength. Standard compressive strengths of mortar are 14.724 MPa for 7 days and 24.034 MPa for 28 days respectively. The test results are summarized in Table 8 and compared in Chart 1.From the results, compressive strength of mortar with mica amount up to 2% is reached to standard strength.

Table -8: Compressive Strength of Mortar with Various Percentage of Mica as Partial Replacement of Fine Aggregates

Replacement of mica (%)	Compressive Strength, MPa			
	7 days	28 days	56 days	91 days
0	24.79	30.50	36.11	36.94
1	20.25	27.76	33.30	33.80
2	18.81	24.90	29.48	30.02
3	16.12	22.76	26.94	27.29
4	15.68	19.57	23.32	23.74
5	13.77	18.94	20.77	21.08

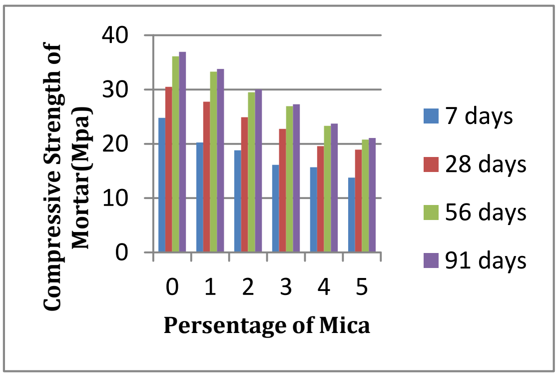

Chart -1: Comparison of Compressive Strengths of Mortar with Mica as Partial Replacement of Fine Aggregates

4.2 Tensile Strength Test

To determine the tensile strength of mortar, the ratio of cement and fine aggregates (1:3) is used. The percentage of water is determined by the following formula:

$Y = 2/3[P/(n+1)] + K$

Where,

Y = water required for the sand mortar, %

P = water required for neat cement paste of normal consistency, %

n = number of parts of sand to one of cement by weight

K = a constant (which for the standard sand has the value of 6.5)

Table 9 shows the required amount of materials for various percentage of mica.

Table -9: Required Amount of Materials for Various Percentage of Mica

Wt. of cement (g)	Wt. of standard sand, SSD (g)	Replacement of mica (%)	Wt. of mica (g)	Wt. of water (g)	W/C
480	1440	0	0	212.794	0.443
480	1425.6	1	14.4	212.794	0.443
480	1411.2	2	28.8	212.794	0.443
480	1396.8	3	43.2	212.794	0.443
480	1382.4	4	57.6	212.794	0.443
480	1368	5	72	212.794	0.443

Standard tensile strengths of mortar are 1.959 MPa for 7 days and 2.455 MPa for 28 days respectively. Tensile strength test results of mortar with partial replacement of mica as fine aggregates is shown in Table 10 and Chat 2. It can be seen that the tensile strengths of mortars with mica up to 3% meet the standard value.

Table -10: Tensile Strength of Mortar with Various Percentage of Mica as Partial Replacement of Fine Aggregates

Replacement of mica (%)	Tensile Strength, MPa			
	7 days	28 days	56 days	91 days
0	2.47	3.41	3.51	3.56
1	2.12	3.29	3.39	3.45
2	1.90	2.63	2.71	2.75
3	1.89	2.46	2.62	2.67
4	1.48	2.01	2.07	2.10
5	1.16	1.44	1.61	1.64

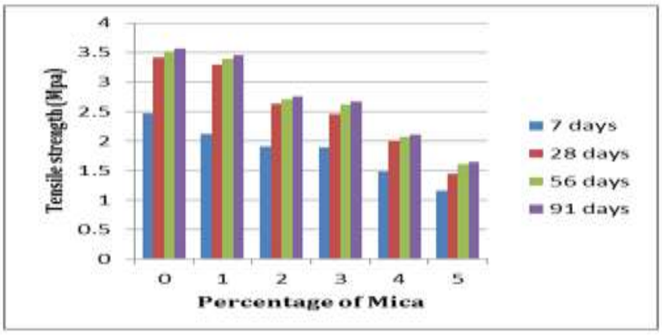

Chart -2: Comparison of Tensile Strengths of Mortar with Mica as Partial Replacement of Fine Aggregates

5. TESTING OF CONCRETE

Concrete is a composite material, which is made from a mixture of cement, fine and coarse aggregates, water and sometimes admixtures (natural or chemical) in required proportions. When all the ingredients such as cement, aggregates and water are mixed in the required proportions, the cement and water start a reaction with each other to bind themselves into a hardens mass. This hardens rock-like mass is known as concrete. The following tests are performed to check on the quality of concrete.

1. Slump Test
2. Air content Test
3. Compressive Strength Test

Mix design of concrete with target specified strength 27.6 MPa is calculated by using International System of ACI Method. Firstly, Compressive strength of concrete with pure sand is tested. And then, some amount of fine aggregates in mix design is replaced by mica and compressive strength of concrete with mica is determined to investigate the variation of the strength of concrete. Table 11 shows the required amount of materials per m^3 for concrete mix design with different percentages of mica as partial replacement of fine aggregates.

Table -11: Required Amount of Materials per M^3 for Concrete with Various Percentage of Mica

Replace-ment of Mica (%)	Wt. of cement (kg)	Wt. of fine agg; SSD (kg)	Wt. of Mica (SSD) (kg)	Wt. of coarse agg; SSD (kg)	Wt. of water (kg)
0	453.76	521.327	0	1224.612	209.184
1	453.76	516.114	5.213	1224.612	209.184
2	453.76	510.9	10.427	1224.612	209.184
3	453.76	505.688	15.639	1224.612	209.184
4	453.76	500.474	20.853	1224.612	209.184
5	453.76	495.261	26.066	1224.612	209.184

The slump and air contents of concrete with mica as partial replacement of fine aggregates are shown in Table 12and slump of concrete with mica is slightly decrease. But air content of concrete with mica is slightly increased. Compressive strength of concrete with mica as partial replacement of fine aggregates are shown in Table 13 and the variation can be seen in Chat 3.

Table -12: Slump and Air Content for Concrete with Various Percentage of Mica

Replacement % of mica	0%	1%	2%	3%	4%	5%
Slump(mm)	82	82	82	82	81	81
Air Content (%)	1.8	1.8	1.8	1.9	1.9	2.0

Table -13: Compressive strength for Concrete with Various Percentage of Mica

Replacement % of Mica	Compressive Strength, MPa			
	7days	28days	56days	91days
0	22.91	34.00	35.53	36.78
1	21.70	31.59	33.01	34.12
2	20.50	30.78	32.86	33.09
3	19.90	29.92	31.06	32.07
4	19.29	29.11	30.23	31.12
5	18.69	28.64	29.64	30.44

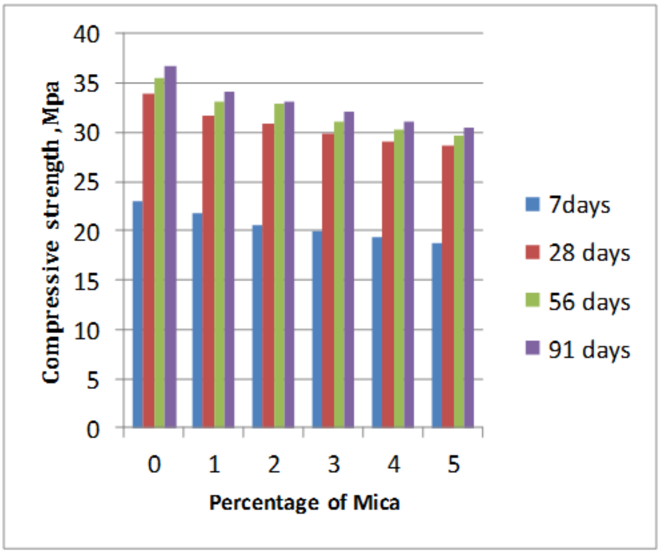

Chart -3: Comparison of Compressive Strengths of Concrete with Mica as Partial Replacement of Fine Aggregates

Although the compressive strengths of concrete with mica as partial replacement of fine aggregates are gradually decreased, all strength of concretes with mica meet the target strength.

6. TESTING ON HEAT RESISTANCE

Mica is highly fireproof, incombustible, non-flammable, infusible, and also can resist temperature of up to 1000 degrees Celsius but this depends on the type and variety of mica used. It has excellent thermal stability, lower heat conductivity, and can be easily exposed to high temperatures without visible effect. Therefore heat resistance of mortar and concrete with and without mica is tested.

In order to test the heat resistance, the specimens with various mix proportions of mica as fine aggregate replacement after curing for 28 days were heated in box type electric furnace under the following conditions shown in Table 14. For each temperature and duration, the specimens were heated. As soon as the furnace is switched on, the temperature did not reach the desired temperature. After switching on the furnace about 30 minutes, the temperature of furnace gradually increased to 400°C. Also, temperature of

800°C increased gradually for 45minutes. After heating the specimens, they have been waited for one day because of very high temperature. Then, the heated specimens were tested.

Table -14: Heating conditions for specimens

Heating Conditions	Temperature(°C)	Duration (hour)
Case 1	400	0.5
Case 2	800	1.0
Case 3	800	1.5
Case 4	800	2.0

6.1 HEAT RESISTANCE OF MORTAR

Table 15 shows the compressive strength of mortar before and after heating at various conditions and comparison of the strengths are compared in Chart-4.And then; the decrease percentage from strength at room temperature is expressed in Table 16.

Table -15: Compressive Strength of Mortar Specimens After heating

Replac-ement % of Mica	Compressive Strength (MPa) Before heating	Compressive Strength After Heating (MPa)			
		Case 1	Case 2	Case 3	Case 4
0	30.49	20.24	16.19	14.09	12.54
1	27.76	22.21	18.21	15.85	14.10
2	24.90	22.16	19.28	16.78	15.09
3	22.76	20.48	18.23	15.86	14.27
4	19.57	17.90	15.93	13.86	12.48
5	18.94	17.59	15.84	13.78	12.40

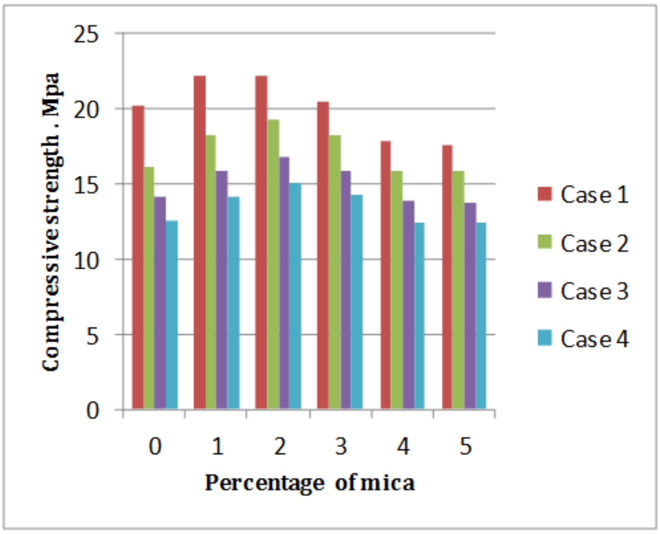

Chart -4: Comparison of Compressive Strengths of Mortar at Room Temperature and after heated conditions

Table -16: Decreased Percentage from Compressive Strength of Mortar before Heating

Replac-ement (%) of mica	compres-sive strength Before Heating (MPa)	Decreased percentage from strength at room temperature (%)			
		Case 1	Case 2	Case 3	Case 4
0	30.49	33.62	46.89	53.80	58.89
1	27.76	19.99	34.39	42.92	49.20
2	24.90	10.99	22.57	32.64	39.37
3	22.76	10.0	19.90	30.32	37.29
4	19.57	7.24	18.57	29.15	36.24
5	18.94	7.01	16.36	27.24	34.51

From the results, it is observed that the compressive strength of mortar with 2% mica is highest in case 2,3 and 4. In case 1, fire resistance of mortar with 1% replacement of mica is the highest. When more percentage of mica as partial replacement of sand is added, the fire resistance of mortar with up to 3% mica replacement is greater than pure sand. Finally, it can be found that 2% replacement of mica as fine aggregate has better heat resistance than other replacement percentages.

And then, Table 17 shows the tensile strength of mortar before and after heating at various conditions and comparison of the strengths are compared in Chart-5.

Table -17: Tensile Strength of Mortar Specimens After heating

Replace-ment % of Mica	Tensile Strength (MPa) before Heating	Tensile Strength After Heating (MPa)			
		Case 1	Case 2	Case 3	Case 4
0	3.41	1.67	0.80	0.56	0.40
1	3.29	1.81	0.96	0.67	0.48
2	2.63	1.79	0.98	0.69	0.50
3	2.46	1.70	0.94	0.67	0.48
4	2.01	1.41	0.78	0.56	0.40
5	1.44	1.01	0.55	0.39	0.28

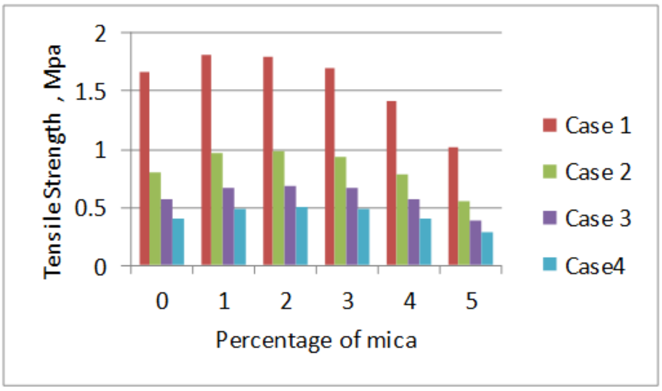

Chart -5: Comparison of Tensile Strengths of Mortar before Heating and after heated conditions

The decrease percentage from tensile strength before heating is expressed in Table 18. According to the test results, it is noted that 2% replacement of mica as sand replacement in mortar have better heat resistance property than other replacement. In case 1, fire resistance of mortar with 1% of mica is the highest strength. The fire resistance of tensile mortar with up to 3% of mica replacement as sand is greater than tensile mortars with pure sand.

Table -18: Decreased Percentage from Tensile Strength of Mortar before Heating

Replacement (%) of mica	tensile strength Before heating (MPa)	Decreased percentage from strength at room temperature (%)			
		Case 1	Case 2	Case 3	Case 3
0	3.41	51.01	76.47	83.54	88.14
1	3.29	45.00	70.86	79.61	85.32
2	2.63	31.99	62.61	73.46	80.88
3	2.46	31.01	62.05	72.69	80.36
4	2.01	30.01	61.50	72.28	80.03
5	1.44	29.99	61.52	72.30	80.10

6.1 HEAT RESISTANCE OF CONCRETE

Similarly, the concrete specimens are tested according to the above procedure and the results are shown in Table 19 and compared in Chart 6. The decrease percentage from strength at room temperature is expressed in Table 20.

Table -19: Compressive Strength of Concrete Specimens After heating

Replace-ment % of Mica	Compressi-ve Strength (MPa)Before heating	Compressive Strength After Heating (MPa)			
		Case 1	Case 2	Case 3	Case 4
0	34.00	20.49	13.84	6.63	4.43
1	31.59	22.91	15.44	9.85	6.67
2	30.78	24.53	16.65	10.99	7.63
3	29.92	25.54	18.09	12.72	8.84
4	29.11	26.75	21.89	14.13	10.65
5	28.64	24.73	18.07	11.91	7.94

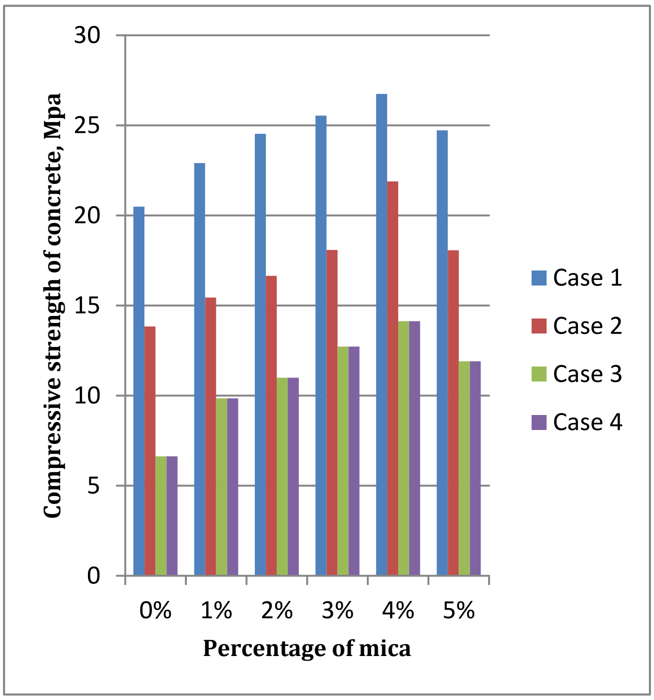

Chart -6: Comparison of Compressive Strengths of Concrete before Heating and after heated conditions

Table -20: Decreased Percentage from Compressive Strength of Concrete before Heating

Replace-ment (%)of Mica	Compressive Strength (MPa Before heating	Decreased percentage from strength Before heating (%)			
		Case 1	Case 2	Case 3	Case 4
0	34.00	39.72	59.30	80.50	86.98
1	31.59	27.48	51.12	68.81	78.90
2	30.78	20.33	45.93	64.29	75.21
3	29.92	14.63	39.55	57.49	70.46
4	29.11	8.11	24.78	51.46	63.43
5	28.64	13.64	36.90	58.41	72.28

According to the test results, after heating the concrete specimens, the strength of concrete with 4% of mica is highest in all cases. The fire resistance of concrete with replacement percentages of mica (1%, 2%, 3% and 4%) is greater than that of pure sand. Compressive strength with 1% to 4% of mica gradually increased but 5% of mica decreased. In case 1, 4% replacement of mica has reached to the nearest value of target strength (26.75 MPa). It is also found that compressive strength of concrete with pure sand is the lowest strength. After heating the concrete specimens, spalling of concrete is occurred in cylindrical specimen surface. There are full of spalling in pure sand of cylindrical concrete specimen. Concrete made with mica also has better heat resistance than pure concrete.

7. DISCUSIONS

In this research, the basic ingredients used in this experimental research are ordinary Portland cement (Crown Cement), fine aggregate, mica and coarse aggregate. The properties of materials are within the range of ASTM standards. In this study, the fineness modulus of fine aggregates and mica are 2.08 and 2.12 respectively. The specific gravity of fine and mica are 2.62 and 2.22 respectively. Based on test result of specific gravity and fineness modulus, mica can be used as partial replacement of sand in mortar and concrete. The replacement percentages of mica as fine aggregate are 1%,2%,3%,4% and 5%.

Compressive mortar without mica has water-cement ratio of 0.6 and 1%, 2%, 3%, 4% and 5% mica has water-cement ratio of 0.6 because mica has very low water absorption value. For tensile strength of mortar, the water-cement ratio of 0.443 is obtained. The compressive and tensile strengths of mortar without and with various replacement percentages of mica as fine aggregate were tested for 7 days, 28 days, 56 days and 91 days. The compressive and tensile strength of mortar gradually decreased with increasing replacement percentages of mica. But, the compressive strength of mortar with 0%, 1% and 2% sand replacements by mica are greater than the standard 28days limit (24.034MPa).

The mix proportions for compressive strength of concrete were calculated by making trial mix according to ACI methods. Using 1%, 2%, 3%, 4% and 5% sand replacements by mica in concrete, the compressive strengths of concrete were tested. When mica was replaced as sand in concrete, 7days and 28days compressive strength of concrete gradually decreased from 1% to 5%. With up to 5% of mica as sand replacement, 28days compressive strength of concrete reached above the target 28days compressive strength 4000psi (27.6MPa).

The main advantage of using mica as partial replacement of fine aggregate is that it has heat resistance property. In order to test the heat resistance, the specimens with various mix proportions of mica as fine aggregate replacement after curing for 28 days were heated under four conditions.

8. CONCLUSIONS

The compressive strength of mortar with 1% and 2% sand replacements by mica are greater than the standard 28days limit (24.034MPa). Replacement percentages up to 3% of mica as sand for tensile strength of mortar are greater than the standard 28days strength (2.255MPa). Therefore, 2% of mica as replacement of fine aggregate by weight may be used in producing motar.

With up to 5% of mica as fine aggregate replacement, 28days compressive strength of concrete reached above the target 28days compressive strength 4000psi (27.6MPa).So, mica may be used as as fine aggregate replacement in concrete.

From the strength point of view, mica can be used up to 2% as sand replacement for compressive strength and up to 3% as sand replacement for tensile strength of mortar. For concrete, up to 5% of mica replacement reached the target 28day strength of concrete. For insulation of mortar, 2% replacement of mica is the highest for compressive and tensile strength. Concrete with 4% of mica replacement as sand is the highest for insulation.

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