Evaluation of Compression Strength of Microbial Cement Mortar

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ABSTRACT

In this research, the effect of added the microorganisms in cement mortar on compressive strength was studied. In addition, evaluate durability of the cement mortar with and without microorganisms by study the increment of compressive strength after sulfuric acid, H_2SO_4 (Concentration 6%), attack.

The experimental work consisted of four mixes (case 1,case 2,case3, case4) which differ according to the way of addingmicroorganisms, (castingwater, curing water or both) and control mix.

Each mix consisted of three specimens of cube except case 4 and control, which consisted of six cubes. We found that when we added microorganisms; the compressive strength increased, which means that allmixes give a higher percentage of compressive strength, compared with control mix.

The results revealed that for the microbial cement mortar (case 4), Percentage of decline of compressive strength, was smaller, after the sulfuric acid H_2SO4 (Concentration 6%) attacked the samples, than the control mix.

Key words: *Microorganisms, Biomineralization, Microbial Cement Mortar, Compressive strength, and urability.*

1. INTRODUCTION

Available literature shows that microorganisms' materials have an essential part to improve mechanical properties of cement mortar. They precipitate and fill the pores of the mix, which increase the strength and durability [1, 2, 3, 4, 5]. In addition, in specific cases, microorganisms' materials managed to make a transformation for the periodic table elements [5].

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These findings lead to a new term that called "biomineralization process". The applications of this process expected to be used widely in construction and in other new materials [6, 7, 8].

Moreover, many studies have shown that bacterial calcium carbonate precipitation can used to improve the compressive strength of mortar[6, 7, 9, 10, 11, and 12]. They encouraged using themicrobial materials that produce the calcite precipitation as a green material, these actives arenatural and pollution-free.

Durability is the ability of material to last a long time without deterioration. In general, durability of cement mortar depends on permeability of mix [13]. The permeability depends on the porosity and on the pores structure. The addition open the pore of materials high penetrability was a reason of degradation of materials. The open pore allows to high possibility of penetrating by aggressive substances [14]. Therefore, mechanical properties, such as the test of compressive strength may be required toevaluate concrete durability [15]. There is a need to further research focuses on understanding relation between adding organic material and the compression strength and durability of material.

2. EXPERIMENTAL WORK

2.1. Materials

2.1.1. Cement

Ordinary Portland local cement (Type–I)was used in all mixes throughout this research.

2.1.2. Fine Aggregate

Fine aggregate (sand) characteristics were; 4.75mm maximum size, specific gravity was 2.6, smooth texture and rounded particle shape. Fine aggregate collected locally from Al- Ukhaidhir area.

2.1.3. Mixing water

Normal water for drinking used for mixing and curing to all samples in this study

2.1.4. Limestone Powder (LSP)

It is a white grinding material from limestone collected locally in Iraq. Fine powder of this material that grinded by blowing technique, used.

2.1.5. Silica Fume (S.F.)

Silica fume is highly reactive pozzolanic substance and is a byproduct from the production of silicon or ferro-silicon metal. It is a very fine powder and composed from the flue gases from electric arc furnaces. This research used a silica fumeimported from Egypt.

2.1.6. Eggshell

Eggshell powder is used in the cement mortar mixes

2.1.7. Microorganisms

In this study Bacteria *Bacillus Subtilis* ATCC 6633 is used.Table (1) show the microscopic and phenotypic features of *Bacillus subtilis*

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Table (1) Microscopic and Phenotypic Features of *Bacillus Subtilis*

Microscopic Features	Gram-Postive bacilli
Phenotypic Features	Results
Raffinose	-
Rhamnose	-
Salicin	+
Sorbitol	+
Sucrose	+
ONPG	+
Nitrate	+
Arginine Dihydrolase	-
Citrate Utilisation	-
Other Features	Results
H_2O_2	+
Note: "+" :- Present "-" :- Absent	

2.1.7.1. Culture of *Bacillus Subtilis*

The pure culture was isolated from the soil sample of HKM.It had been cultivated in a laboratory using a nutrient agar slants. After 24 hours,It forms colonies in nutrient agar slants which were maintained in test tube.Then the test tube kept at refrigerator temperatures (4°C), till further use.

2.1.7.2. Maintenance of Stock Cultures

Whenever required to use microorganisms with a single colony of the culture, take swab from test tube which has (nutrient agar slants+ *Bacillus Subtilis*) by using a sterile loop and but in the glass bottles which had medium broth of 13 gram/Liter(This research take the initiative to test the behavior of bacteria on the reaction without adding reagent material such as, urea).These glass bottles were kept at warm temperature 37 °C for 48 hours in laboratory incubation. When growth becomes noticeable, it will be compared with the MacFarland tube 0.5. This tube prepared to determine the concentration of bacteria per ml. When the cell concentrations become 1×10^7cells/ml, the glass bottles preserved at refrigerator temperatures (under 4°C) until usage in the present work. Fig. (1) shows a glass bottles that contains the *Bacillus Subtilis*

Fig. (1) Glass Bottles that Contains the Bacillus Subtilis

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2.2. Cement Mortar Mixes

Proportions of mixing cement mortar, (cement sand: limestone powder), was (1:1.9:0.1) by weight, respectively. The water-cement ratio was 0.5. Silica fume and eggshell powder added to the mixes with proportion (3%:1%) by weight of cement, respectively.

2.2.1. Ways of Adding Microorganisms to Mixes

In this experimental study, Microorganisms were added to the four cases of the cement mortar, by three ways:-

1- By mixing water which have cell concentration 1×10^{7}cells/ml and Nutrient broth (13gram/liter) [case1, case2]

2- After casting, Microorganisms were added by curingwater which had Nutrient broth (13gram/liter) + microorganisms [case 3]

3- Using the point 1 and point 2 together, that explained above [case 4] shown table (2)

2.2.2. Mixing Procedure

In the beginning, dry materials such as, cement, sand, limestone powder, silica fume and eggshell were mixing in a pan for several minutes. After thatNeeded amount of water added to the mix with, Microorganisms according to the method that have explained previously with four cases of cement mortar. Mixing continued until a homogeneous fresh cement mortar obtained.

2.2.3. Casting and Curing

When the mixing process was finished, the fresh cement mortar was then poured into the cubes mold (shown in Figure (2)) and compacted in a vibration machine (over electric generator). Twenty–four hours later, samples stripped out from the molds. Then, samples cured using three type of water for four cases (and control) of the cement mortar in the present work

1- Water of curing without any additive [control and case 1]

2- Water of curing which have Nutrient broth (13gram/liter) [case2]

3-water of curing which had (13gram/liter) Nutrient broth + microorganisms [case 3 and case 4].shown table (2)

The curing was at laboratory conditions, temperature of water was between 25ºC and 30ºC.Samples kept in curing water for a month. Then,they taken out from the curing water and were ready to testas seen in the following paragraphs.

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Table (2) Description the Cases of Mixes

No. of case	Cell concentration/ml of mixing water	Type of curing water
Control	Nil (control)	Normal water with no additive
Case 1	1×10^7	Normal water with no additive
Case 2	1×10^7	Water + Nutrient broth
Case 3	Nil	Water + Nutrient broth + microorganisms*
Case 4	1×10^7	Water + Nutrient broth + microorganisms*

***unknown cell concentration

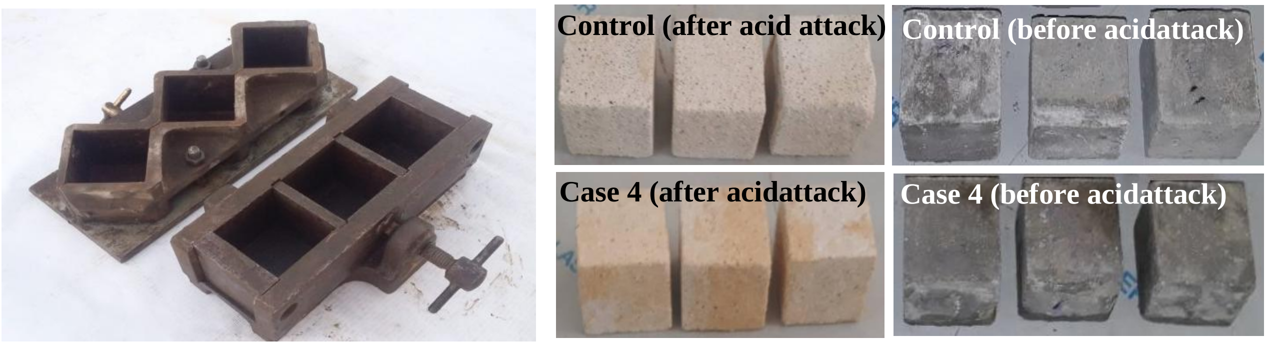

Fig. (2) Specimen's Molds and Specimens Cement Mortar with and without Microorganisms, Before and After Acid Attack

2.3. Compressive Strength Test

The compressive strength test was achieved according to ASTM C109 / C109M - 08 [16].This test was carried out on cubic specimens (50mm ×50mm × 50mm).The test was conducted using electrical testing machine with capacity of (2000 kN). Samples were at ages of about one month for all type of mixes.(asshown in Figure (2))

3. RESULTS AND DISCUSSION

3.1. Effect of Additive Microorganisms on Compression Strength of Cement Mortar with Variable Cases

In this work, we studied three type of added Bacteria *Bacillus Subtilis* in cement mortar and three type of water cuing,[case 1, case 2, case 3, case 4and control]as explained in table (2)

Table (3) and fig (3) show the effect of additive Bacteria *Bacillus Subtilis* on compression strength of cubes of cement mortar.

The results illustrate that the case 4 gives a higher percentage of increase.

This improvement in compressive strength of cement–sand matrix depends on structure of the pores, whether $CaCO_3$ fills and precipitates these pores. As a results of the bacterial growth, the calcium precipitation process occurs continuously, clogging the internal pores with calcium precipitate [17]

Table (3) Effect of Additive Microorganisms on Compression Strength of Cement Mortar with Variable Cases

No. of case	Compressive strength MPa	Percentage of increase %
Control	31.62	----
Case 1	33.384	5.58
Case 2	34.046	7.67
Case 3	33.508	5.97
Case 4	35.076	10.93

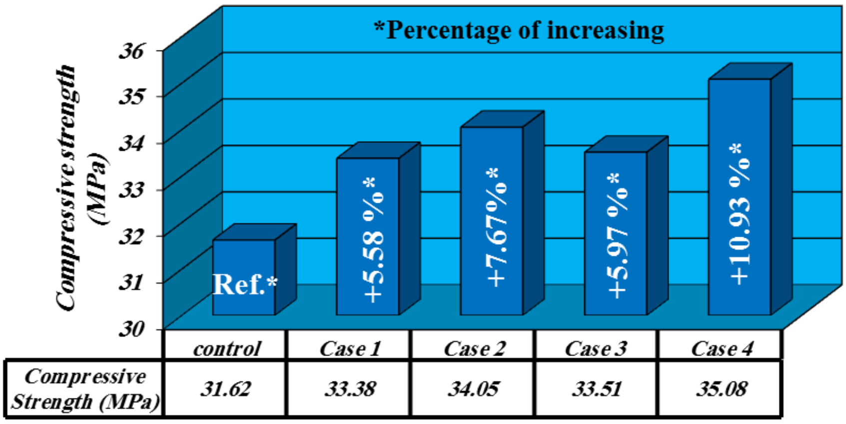

Fig. (3) Effect of Additive Microorganisms on Compression Strength of Cement Mortar with Variable Cases

3.2. Durability

The Experimental work was conducted oneffectiveof Sulfuric acid attack oncompression strengthof cement mortar specimens with and without Bacteria [control and case 4]. Specimens wereimmersed in 6% solutions of H_2SO_4. Thespecimens are arranged in the plastic tubs about one week.Before testing, each specimenwas removed from the baths, and rinsed in tap water.

3.2.1. Effect of Sulfuric Acid on Compression Strength of Cement Mortar with and without Microorganisms

Table (4) and fig (4) show the effect of attacksulfuric acid (H_2SO_4) (6%) on declinecompression strength of cement mortar with and without Microorganisms (case 4 and control). The results illustrate, that the effect of attack sulfuric acid (H_2SO_4) ondecline compression strength of cement mortar, decreased with presence of microorganisms. This behaviormay occur due to deposition of CaCO3 bymicroorganisms in the voids or pores within cement mortar specimens, which increased durability by increased resistance to attack sulfuric acid (H_2SO_4)

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Table (4) Effect of Sulfuric Acid on Compression Strength of Cement Mortar with and without Microorganisms

Test Condition	No. of case	Compressive strength MPa	Percentage of decrease %
before acid attack	Control	31.62	----
after acid attack	Control	19.56	38.14
before acid attack	Case 4	35.08	----
after acid attack	Case 4	23.1	34.15

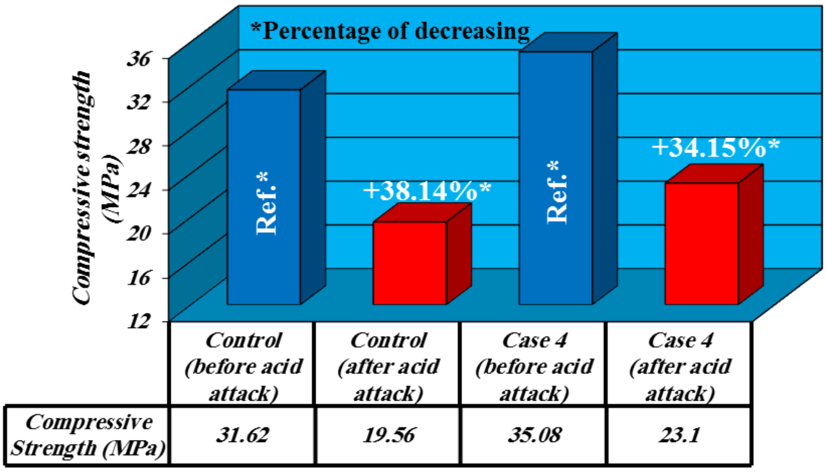

Fig.(4) Effect of Sulfuric Acid on Compressive Strength of Cement Mortar with and without Microorganisms

3.2.2. Effect of Additive Microorganisms on Compression Strength of Cement Mortar with and without SulfuricAcid

Table (5) and fig (4) show the effect of using bacterial additive on increased compression strength of cement mortar with and without attack sulfuric acid (H_2SO_4) (6%) (case 4 and control). The results illustrate, that the effect of presence of microorganisms on increased compression strength of cement mortar, increased with sulfuric acid (H_2SO_4) (6%) attack. This behavior may be cased to deposition of $CaCO_3$ bymicroorganisms in the voids or pores within cement mortar specimens, which increased durability by increased resistance to attack sulfuric acid (H_2SO_4).

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Table (5) Effect of Additive Microorganisms on Compression Strength of Cement Mortar with and without Sulfuric Acid

Test Condition	No. of case	Compressive strength MPa	Percentage of increase %
before acid attack	Control	31.62	----
	Case 4	35.08	10.94
after acid attack	Control	19.56	----
	Case 4	23.1	18.1

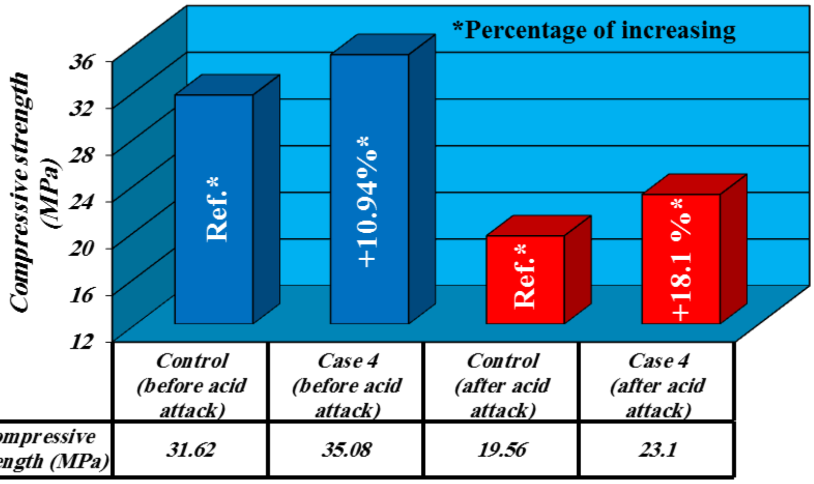

Fig. (5) Effect of Additive Microorganisms on Compressive Strength of Cement Mortar with and without Sulfuric Acid

4. CONCLUSION

1- When added microorganisms to the cement mortar indifferent ways, through four cases (casting water or curing water or both), the compression strength was improved. Case (4) gives the higher parentage of increasing

2- Durability was studied by Immersing cement mortar in sulfuric acid (H_2SO_4) by 6%, for a week to evaluate the degradation of compression strength, we founded:

a- The Effect of Sulfuric acid on degradation of compression strength of cement mortar, was decreased in microbial cement mortar(case4) compared with conventional cement mortar

b- The effect of using bacterial additiveson increasing compression strength of cement mortar (case4 and control), was increased with sulfuric acid (H_2SO_4) by 6% attacked.

5. REFERENCES

[1] Bang, S.S., Galinat, J.K. & Ramakrishnan, V. (2001). "Calcite precipitation induced by polyurethane-immobilzed Bacilluspasteurii".Enzyme and Microbial Technology, 28, 404-409. Cited by Reference 5

[2] Biswas, M., Majundar, S., Chowdury, T., Chattopadhyay, B., Mandal, S., Halder, U. & Yamasaki, S. (2010). "Bioremediaseaunique protein from a novel bacterium BKH1, ushering a new hope in concrete technology". Enzyme and Microbial Technology, 46,581-587 Cited by Reference 5

[3] Dick, J., Windt, W., Graef, B., Saveyn, H., Meeren, P., De Belie, N. &Verstraete, W. (2006) "Biodeposition of a CalciumCarbonate Layer on Degraded Limestone by Bacillus species". Biodegradation, 17 (4), 357-367 Cited by Reference 5

[4] Fischer, S.S., Galinat, J.K. & Bang, S.S. (1999). "Microbiological precipitation of CaCO3".Soil Biology and Biochemistry, 31,1563-1571. Cited by Reference 5

[5] Afifudin, H. ,Nadzarah, W., Hamidah M.S and Noor Hana H." Microbial Participation in the Formation of Calcium Silicate Hydrated (CSH) from Bacillus subtilis "The 2nd International Building Control Conference 2011

[6] Ghosh, P., S. Mandal, B. D. Chattopadhyay, and S. Pal. 2005."Use of microorganism to improve the strength of cementmortar".Cem.Concr. Res. 35: 1980-1983. Cited by Reference 11

[7] Ghosh, S., M. Biswas, B. D. Chattopadhya, and S. Mandal.2009. "Microbial activity on the microstructure of bacteriamodified mortar". Cem.Concr.Compos. 31: 93-98. Cited by Reference 11

[8] Schultze-Lam, S., D. Fortin, B. S. Davis, and T. J. Beveridge.1996. Mineralization of bacterial surfaces. Chem. Geol. 132:171-181. Cited by Reference 11

[9] Achal, V., A. Mukherjee, P. C. Basu, and M. S. Reddy. 2009."Strain improvement of Sporosarcinapasteurii for enhancedurease and calcite production". J. Ind. Microbiol. Biotechnol. 36:981-988. Cited by Reference 11

[10] Bang, S. S., J. K. Galinat, and V. Ramakrishnan. 2001. "Calciteprecipitation induced by polyurethane-immobilized Bacilluspasteurii". Enzyme Microb. Technol. 28: 404-409. Cited by Reference 11

[11] Ramachandran, S. K., V. Ramakrishnan, and S. S. Bang. 2001."Remediation of concrete using micro-organisms". ACI Mater. J.98: 3-9. Cited by Reference 11

[12] Park, Sung-Jin, Yu-Mi Park1, Woo-Young Chun, Wha-Jung Kim, and Sa-YoulGhim" Calcite-Forming Bacteria for Compressive Strength Improvement inMortar" J. Microbiol.Biotechnol. (2010), 20(4), 782–788

[13] Khan, M. I. (2003)."Isoresponses for strength, permeability and porosity of high performance Mortar".Building and Environment, 38, 1051-1056. Cited by Reference 15

[14] Claisse, P. A., Elsayad, H. A., and Shaaban I. G. (1997)."Absoprtion and sorptivity of cover concrete". Journal of Materials in Civil Engineering, 9, 105-110. Cited by Reference 15

ISBN : 978-93-87793-43-9

[15] VarenyamAchal, Abhijit Mukherjee, and M. Sudhakara Reddy "Microbial Concrete: A Way to Enhance Durability of Building Structures" Second International Conference on Sustainable Construction Materials and TechnologiesĐune 28 - June 30, 2010, UniversitàPolitecnicadelle Marche, Ancona, Italy.

[16] ASTM C-109-08, Standard Test Method for Compressive Strength of Hydraulic Cement Mortar

[17] M. V. Seshagiri Rao, V. Srinivasa Reddy, Ch. Sasikala." Performance of Microbial Concrete Developed Using Bacillus Subtilus JC3" J. Inst. Eng. India Ser. A, 2017