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# Influence of Types Anti-Fungal Admixtures on the Concrete Mix

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## Abstract:

In recent years, the antifungal concrete is developed by using several materials as admixtures. In this present study, the antifungal activity of concrete was evaluated against specie of fungi; Aspergillus niger which can be easily discovered in the interiors and exteriors of buildings by using two types of organic antifungal agents which are known commercially as Bleach and Savlon. Besides, the investigations also extends to evaluated the effect of these agents on the some basic properties of concrete produced such as: slump, compressive strength and absorption tests. Generally the results show that the all concrete mixes produced with different concentrations (0.5-2 % by weight of cement) for agents exhibited inhibitor effect for growth that fungi with varying degrees. Furthermore, most properties of activated concretes with antifungal agents demonstrate noticed decrease compared with properties of reference concrete.

**Keywords: anti-fungal admixture, bleach, savlon,slump,compressive strength, absorption,fungi growth resistance.**

## Introduction

ACI 116R-00 defines the term admixture as “a material other than water, aggregates, hydraulic cement, and fiber reinforcement, used as an ingredient of a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during its mixing.” In ACI 212.3R it is stated that “chemical admixtures are used to enhance the properties of concrete and mortar in the plastic and hardened state. These properties may be modified to increase compressive and flexural strength at all ages, decrease permeability and improve durability, inhibit corrosion, reduce shrinkage, accelerate or retard initial set, increase slump and workability, improve pumpability and finish ability, increase cement efficiency, and improve the economy of the mixture. An admixture or combination of admixtures may be the only feasible means of achieving the desired results. In certain instances, the desired objectives may be best achieved by mixture changes in addition to proper admixture usage.” The admixtures interact with the hydrating cementitious system by physical and chemical actions, modifying one or more of the properties of concrete in the fresh and/or hardened states. (David, 2003). The admixtures may be broadly classified as belonging to the general category and the specially category. One from these specially category admixtures known as fungicidal, germicidal and insecticidal admixtures (Gambhir, 2004).

The effectiveness of any admixture will vary depending on its concentration in the concrete and the effect of the various constituents of the concrete mixture, particularly the cement. Each class of admixture is defined by its primary function. It may have one or more secondary functions, however, and its use may affect, positively or negatively, concrete properties other than those desired. Therefore, adequate testing should be performed to determine the effects of an admixture on the plastic and hardened properties of concrete. The final decision as to the use of any admixture and the brand, class, or type, depends on its ability to meet or enhance specific concrete performance needs. Many of the improvements can be achieved by proper selection and application of specific admixtures. The selection process should focus on the functional qualities required by structural demands, architectural requirements, and contractor needs (David, 2003).

The past decade has witnessed a significant increase in the prevalence of fungi growth resistance. Hence, substantial attention has been focused on developing a more detailed understanding of the mechanisms of antimicrobial resistance, improved methods to detect resistance when it occurs (Mahmoud, 1999).

The antifungal agents could effectively reduce fungi in food processing plants, hospitals, institutional kitchens, athletic locker rooms and other areas susceptible to biological attack, but where extraordinary cleanliness is required. These agents could also reduce mold and mildew which may cause discoloration and odor in slabs on grade, stucco and roofing materials in damp or wet climates (Mahmoud, 1999).

## BACKGROUND AND LITERATURE SURVEY

Nowadays, a plurality of microbicide agents that can be used alone or combined to avoid microbe adhesion and spreading at homes and several industries surfaces has been developed. These microbicide agents can be mixed for example with cleaning products, compositions and disinfectants, or being applied as wall coverings on fabrics, paper, adhesive strips, plastic materials sheets (Levowitz, 1952).

Hence various investigations and studies on the durability, physical and chemical properties have been carried out, and results of these investigations and studies have aided the development, performance, and serviceability of high durability concrete, high fluidity concrete, and high performance concrete such as ultra high strength concrete (UHSC) to advanced states (Ramachandran,1995). Nevertheless, only the academic and scientific studies investigating into the influence of organisms (such as bacteria, fungus, microbial and insects) on concrete have been reported (Jung, 1995).

A particular example of the efforts made on the art is disclosed by the United States application entitled "Sheet or film material having antibacterial and anti-fungal activity", issued on February 15, 1977 to Mayumi et al, which discloses a sheet or film material having antibacterial and antifungal activity utilized to cover walls, ceiling and floors. Material is obtained by mixing a benzimidazole and phtalimide. Such sheet or film material disclosed by application is a thermoplastic material based product, and even that can provide a protection against microbial growth, it has the disadvantages of being an additional component which is submitted to wearing due to use and can be coated or replaced at the short run with the additional expenses entailed (Yoshiyuki, 1992).

Japanese application entitled "Anti-bacterial and Anti-fungal Basic Material for Construction" to Nawata Nozomi et al., published on November 19, 1992 is referred to the addition of 0.01 to 30 parts by weight of an antibacterial and anti-fungal compound, such as 2,2,3-thioyodineallyl alcohol added to the base material (cement or plaster).The anti-bacterial and anti-fungal compound can be mixed with a base material, where the base material is in powder, not molded or not cured yet; this antibacterial and antifungal compound is applied to the base material surface through the recoating or spraying method (Murata,, 1999).

In 2000, Freed and Wayne, W., investigated the reinforced concrete containing antimicrobial-enhanced fibers. A fiber-reinforced concrete-like material product includes a plurality of fibers containing an effective amount of at least one antimicrobial agent to inhibit organisms and protect the concrete from biological attack. Preferably, the antimicrobial agents are added to the fibers prior to the fibers being dispersed in the concrete. Such a concrete product containing antimicrobial-enhanced fibers simultaneously inhibits organisms from biological attack, reduces plastic shrinkage cracking of the concrete and improves post-peak flexural strength of the concrete.

In 2008, Willem, D., Muynck, Nele, D., Belieand, and Willy, V., detected the effectiveness of admixtures, surface treatments and antimicrobial compounds against biogenic sulfuric acid corrosion of concrete. In situ failure of laboratory tested coatings against biogenic sulfuric acid (BSA) corrosion of concrete in sewers has lead to new approaches that affect microbial activity. This paper reports on the performance of concrete surfaces containing antimicrobial polymer fibers or metal-zeolites in preventing BSA corrosion. Additionally, the effectiveness of commercial surface treatments and admixtures was measured by means of accelerated chemical exposure and microbiological simulation tests. The biocidal effect of antimicrobial additives was quantified by means of incubation tests on mortar specimens. The presence of antimicrobial compounds resulted in a 3–12-fold decrease of the bacterial activity, as observed from ATP measurements. The largest deterioration from the accelerated tests was noticed for a cementitious coating. The anti-microbial and silicates admixtures did not result in a protective effect towards degradation under the given test conditions. The best protection was obtained with a polyurea lining and an epoxy coating. No loss of coating integrity could be observed after 8 and 10 cycles of microbiological and chemical testing, respectively.

In 2009, Park, S.K., Kim, J.H, Nam, J., Phan, H. and Kim, J.K., studied development of anti-fungal mortar and concrete using Zeolite and Zeocarbon microcapsules. Anti-fungal mortar and concrete are developed using micro-encapsulated fungus-resisting material. d -Limonene is selected for the core anti-fungal material and Zeolite and Zeocarbon are used for reinforcing the capsule membranes. Damage and survival possibilities of microcapsules in the casting stage of mortar and concrete are examined by scanning electron microscopy (SEM) and high pressure liquid chromatography (HPLC). Several tests are conducted to evaluate the effects of microcapsule additions on the properties of fresh and hardened mortar and concrete. Anti-fungal effectiveness of the developed mortar is verified by mock-up panel tests, in which resistance to fungus growth on the panel surface is studied.

## Experimental program

### Materials

The cement used was ordinary Portland cement conforming to type1 cement specified in IQS No.5/1984. The fine aggregate was natural sand, while the coarse aggregate was crushed gravel with nominal maximum size 10 mm. Both aggregates complied with the requirements of IQS No.45/1984. The physical properties of the cement, fine aggregate and coarse aggregate used were listed in Table 1,2 and 3 respectively, while the sieve analysis for both aggregates were illustrated in Table 4 and 5.

Two types of organic antifungal agents were employed in this study (as described in Table 6) which presently use for disinfection.

### Methods

A reference concrete mix was used, designed to achieve a characteristic compressive strength of 30 MPa at 28 days with a slump of between 75-100 mm. The mix was designed using the code of practice of design of normal concrete mixes by ACI 211.1-95. In order to analyze and comprehend with the changes as a result to addition of antifungal agents on the some basic properties of concrete, four mixes were used for each type of admixture with four levels to antifungal agent (0.5, 1.0, 1.5 and 2.0)% by weight of cement.

Antifungal agents were directly added into the mixing water. Then, the solution was thoroughly stirred before it's used. For all mixes, the mix proportion was (1:1.65:2.54) by weight and water to cement (W/C) ratio was equal to 0.41.

### Preparation and Curing of Concrete Specimens

The cubical molds of size 100 mm lightly oiled were filled with fresh concrete and compacted by using vibrating table. The molds after casting were covered with polyethylene sheet and kept in the laboratory environment for a period of 24hr. After that, the specimens were demoulded and stored in the water tanks up to the wanted age for test. Besides, the specimens for testing of anti-fungal activity were wrapped and sealed in polyethylene sheets until the antifungal activity in the specimens were measured; this was done because the moisture of specimens placed in water tended to disturb precise measurement of antifungal activity.

**Concrete Tests**

**Slump**

This test was used to measure the consistency of fresh concrete mixes according to ASTM C143-89.

**Compressive Strength**

Compressive strength test was carried out on 100 mm cubes according to B.S.I 1881: part 116: 1989. The specimens were tested at age of 28-day. For each concrete mix, the average of three specimens was adopted.

**Water Absorption**

The water absorption test was performed according to ASTM C 642-06 and carried out on 100 mm cube specimens at age 28-day. Three samples were tested and the average of the three test results was reported.

**Fungi Growth Resistance**

In this test, small samples were taken from each concrete specimen. Where, it was mailed and sent directly to Micro Test Laboratories in sealed plastic bags. Then, the samples were incubated in a Petri dish over a salts agar that provides nutrients suitable for fungi growth (NCMA, 2004). After that, samples were placed in a chamber and incubated according to ASTM G21-96. Following the incubation period, samples were visually examined for traces of fungi growth and rated based on the amount of growth observed. If no growth or mere traces of growth were observed, samples were then further examined under a microscope and determine the rating of observed fungi growth as shown in Tables 8 and 9.

**Results and discussion**

1. Table 7 summarizes the results of the basic physical properties for all tested mixes. The results of slump test for activated concrete mixes by antifungal agents (Bleach and Savlon) revealed that the slump was the lowest compared with slump of reference mix. On the other hand, the consistency of activated mixes by antifungal agent decreased with increase the dosage of antifungal agents as denoted in Fig.1. This is may be returned to the reaction of a little surfactant present in the antifungal agents.
2. From Fig.1, it can be seen that the consistency of activated mixes with savlon was the lowest compared with their corresponding activated mixes with bleach. This is may be attributed to the low activity for savlon with attending the impure water and the organic materials compared with bleach agent (Al-Shwaili, 2004).
3. The results of compressive strength and water absorption for activated concrete specimens by antifungal agents when compared it with non-activated concrete specimens, it is appeared reduction in values of compressive strength versus increasing in values of water absorption with increasing the dosage of admixture as illustrated in Fig.2, and 3. This behavior is substantially ascribed to the natural of antifungal agents used ( an organic compounds) which caused no uniform distribution for products of hydration within the paste as a result to that lower rate to cement hydration. The ratios of reduction in compressive strength were 11.23% for MB1 and 11.35 .0% for MS1 versus 4.35% for MB1 and 5.60 % for MS1 increasing in water absorption compared to reference concrete specimens.
4. For the same mix proportion and antifungal agent ratio, the results clear indicated that with presence of savlon, the activated concrete specimens exhibited slight reduction in compressive strength and

noticeable increasing in water absorption compared to their corresponding of activated concrete specimens by bleach. This can be attributed to the savlon used may causes an increase in the pore sizes and also no uniform the pore size distribution of the concrete or may be reason some disruptions in concrete matrix integrity when it used. The ratios of reduction in compressive strength versus the increasing in water absorption were 0.14% and 1.20 % respectively for MS1 compared to MB1.

5. The results of fungi growth resistance test, as denoted in Table 8, showed increased in the antifungal activity for activated concrete specimens by bleach and savlon with raise the percent of agent added into the mix compared to control mix. Besides, specimens by antifungal agents were the highest at addition 2% antifungal agent for both two types (Bleach and Savlon) as represented in MB4 and MS4 comparison with MB1 and MS1 respectively.
6. From Table 8, it can be noticed that the Bleach used as antifungal agent enhanced the antifungal activity more than Savlon at the dosages higher than 1%, as illustrated in MB2, MB3 and MB4 compared with MS2, MS3 and MS4 respectively. While the antifungal activity for the activated concrete specimens with both two types of antifungal agents at 0.5% antifungal agent was equal as denoted in MB1 and MS1. The main reason strongly linked with unsuitable concentration used (0.5% for antifungal agents) may be caused changes in the cellular wall of fungi cell or in the composition of protein channels (porins) subsequently, prevention the agents from the entering to cell inner and its arriving to target site (Al-Shwaili, 2004).
7. Visual observations were confirmed by microscopically at 40 X magnification. The results also revealed that no changes in the physical appearance of the samples tested except observation some discoloration on the samples which may be attributed merely to moisture content change of specimens as a result of their prolonged exposure to moisture.

## Conclusion

Based on results obtained from the basic investigation on physical properties and antifungal activity for activated concretes manufactured by changing types of antifungal agents and the ratio of antifungal agent addition, the following conclusions were reached in this study;

1. The consistency of activated concrete mixes by antifungal agents was the lowest than the consistency of reference mix. Subsequently, the consistency of activated concrete mixes was decreased with increase the dosage of antifungal agent. On the hand, it can be seen that activated concrete mixes by bleach exhibited more slump than activated concrete mixes by savlon.
2. From the experimental results for the slump of mixes, it is possible that excessive usage of antifungal agents for activation of concrete mixes may cause loss in consistency of concrete mixes and can act adversely from the standpoint of consistency in concrete mixes.
3. With presence antifungal agents, the mixes were demonstrated reduction in compressive strength versus decreasing in water absorption compared with reference mix.
4. There is an adverse effect for both two types of antifungal agents (Bleach and Savlon) used in this study on the consistency, compressive strength and water absorption of activated concrete mixes. Where, the ratios of reduction in compressive strength were 11.23% for MB1 and 11.35 % for MS1 versus 4.35% for MB1 and 5.60 % for MS1 increasing in water absorption compared to reference concrete specimens.
5. For the same content of antifungal agent, activated concrete specimens by savlon showed slight reduction in compressive strength and noticeable increasing in water absorption than that activated concrete specimens by bleach. The ratios of reduction in compressive strength versus the

increasing in water absorption were 0.14% and 1.20 % respectively for MS1 compared to MB1.

6. The activated concrete specimens by antifungal agents appeared high antifungal activity with raise the dosage of agent than non-activated concrete specimens. Furthermore, the activated concrete specimens by bleach exhibited higher antifungal activity than savlon at the contents of antifungal agent higher than 1%. While, the activated concrete specimens for both two types antifungal agents (bleach and savlon) demonstrated equal antifungal activity at 0.5% addition.
7. From the results of fungi growth resistance test, it can be observed that the types of antifungal agents used in this paper exhibited excellent antifungal activity on that specie of fungi; Aspergillus niger.
8. The effectiveness of any antifungal agent in any concrete mix is depends on many factors such as; content of agent, pH-value, period of exposed and type of fungi.

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**Table (1) Oxides, Compound composition and Physical properties of ordinary Portland cement**

| Oxides | Content, % | IQS No.5/1984 | Property | | Result | IQS No.5/1984 |
|---|---|---|---|---|---|---|
| $SiO_2$ | 20.54 | – | Fineness, $m^2/Kg$ | | 341 | ≥230 |
| $Al_2O_3$ | 5.88 | – | Setting time, hrs:min | Initial set. | 2:35 | ≥00:45 |
| $Fe_2O_3$ | 3.28 | – | | | | |
| CaO | 60.78 | – | | | | |
| MgO | 1.93 | ≤ 5.0 | | Final set. | 4:45 | ≤ 10:00 |
| $SO_3$ | 1.87 | ≤2.8 | | | | |
| $Na_2O$ | 0.34 | – | | | | |
| $K_2O$ | 0.26 | – | | | | |
| L.O.I | 3.31 | ≤4.0 | Compressive strength, MPa | 3-day | 18.8 | ≥15.00 |
| I.R. | 0.15 | ≤1.5 | | | | |
| L.S.F. | 0.89 | 0.66-1.02 | | | | |
| $C_3S$ | 41.74 | – | | 7-day | 23.3 | ≥23.00 |
| $C_2S$ | 27.48 | – | | | | |
| $C_3A$ | 10.04 | – | | | | |
| $C_4AF$ | 9.97 | – | Autoclave expansion,% | | 0.03 | ≤ 0.80 |

**Table(2) Physical properties of fine aggregate**

| Physical properties | Specific gravity | Sulfate content, $SO_3$ | Organic materials | Absorption |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **Test results** | 2.65 | 0.12% | - | 0.78% |
| **IQS No.45/1984** | - | $\leq$0.50% | - | - |

**Table (3) Physical properties of coarse aggregate**

| Physical properties | Specific gravity | Sulfate content, $SO_3$ | Organic materials | Absorption |
|---|---|---|---|---|
| **Test results** | 2.66 | 0.09% | - | 0.66% |
| **IQS No.45/1984** | - | $\leq$0.1% | - | - |

**Table (4) Sieve analysis of fine aggregate**

| Sieve size (mm) | 10 | 4.75 | 2.36 | 1.18 | 0.60 | 0.30 | 0.15 |
|---|---|---|---|---|---|---|---|
| **Cumulative % passing** | 100 | 99.78 | 89.07 | 81.31 | 75.45 | 32.96 | 7.82 |
| **IQS No. 45/1984, Zone 3** | 100 | 90-100 | 85-100 | 75-100 | 60-79 | 12-40 | 0-10 |

**Table (5) Sieve analysis of coarse aggregate**

| Sieve size (mm) | 14 | 10 | 5 | 2.36 |
|---|---|---|---|---|
| **Cumulative % passing** | 100 | 90.50 | 10.20 | 1.03 |
| **IQS No. 45/1984** | 100 | 85-100 | 0-25 | 0-5 |

**Table (6) Technical description for Antifungal Agents**

| Type of agent / Property | Bleach | Savlon |
|---|---|---|
| **Composition** | Sodium hypochlorite | Chlorhexidine/Cetrimide |
| **Appearance** | Conqueror yellow aqueous solution | Colorless aqueous solution |
| **Density** | 1.11 | 1.1 |
| **pH-value** | 11.38 | 7.55 |

**Table (7) Details of the mixes used in the test program**

| Type of agent | Mix symbol | Antifungal agent,% wt. of cement | Slump, mm | Compressive strength, MPa | Absorption,% |
|---|---|---|---|---|---|
| | | | | 28-day | 28-day |
| | M0 | 0 | 83 | 32.69 | 1.61 |
| Bleach | MB1 | 0.5 | 80 | 29.02 | 1.68 |
| | MB2 | 1.0 | 77 | 26.15 | 1.77 |
| | MB3 | 1.5 | 73 | 24.45 | 1.85 |
| | MB4 | 2.0 | 69 | 21.31 | 1.96 |
| Savlon | MS1 | 0.5 | 77 | 28.98 | 1.70 |
| | MS2 | 1.0 | 71 | 25.73 | 1.79 |
| | MS3 | 1.5 | 66 | 22.84 | 1.88 |
| | MS4 | 2.0 | 62 | 19.49 | 2.03 |

**Table (8) Results of fungi growth resistance test for specimens**

| Type of agent | | Bleach | | | | Savlon | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ages / Samples | M0 | M1 | M2 | M3 | M4 | M1 | M2 | M3 | M4 |
| 0-day | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-day | 4 | 4 | 4 | 3 | 2 | 4 | 4 | 4 | 3 |
| 14-day | 4 | 4 | 4 | 3 | 2 | 4 | 4 | 4 | 2 |
| 21-day | 4 | 4 | 3 | 2 | 1 | 4 | 4 | 3 | 2 |
| 28-day | 4 | 3 | 3 | 2 | 1 | 3 | 3 | 3 | 1 |

**Table (9) Rating of fungi growth on specimens according to ASTM C21-96**

| ASTM Rating | Observed Bacteria Growth on Specimens |
|---|---|
| 0 | None |
| 1 | Traces of growth ( less than 10% ) |
| 2 | Light growth ( 10% – 30% ) |
| 3 | Medium growth ( 30% – 60% ) |
| 4 | Heavy growth ( 60% – to complete coverage ) |

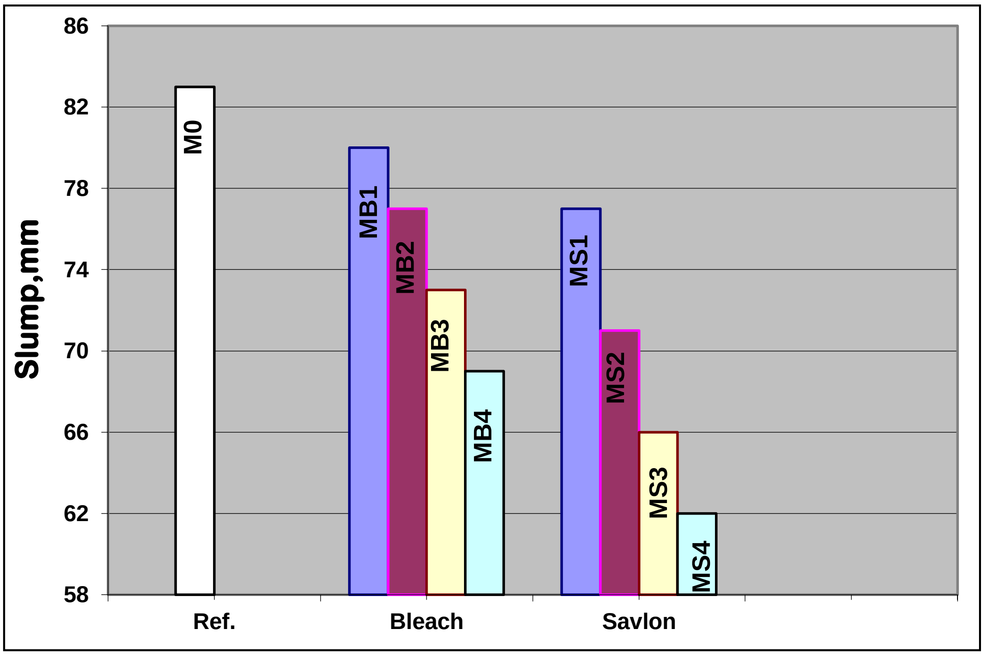


**Fig.1 Slump of activated and non-activated concrete Specimens according to type and content of antifungal agent**

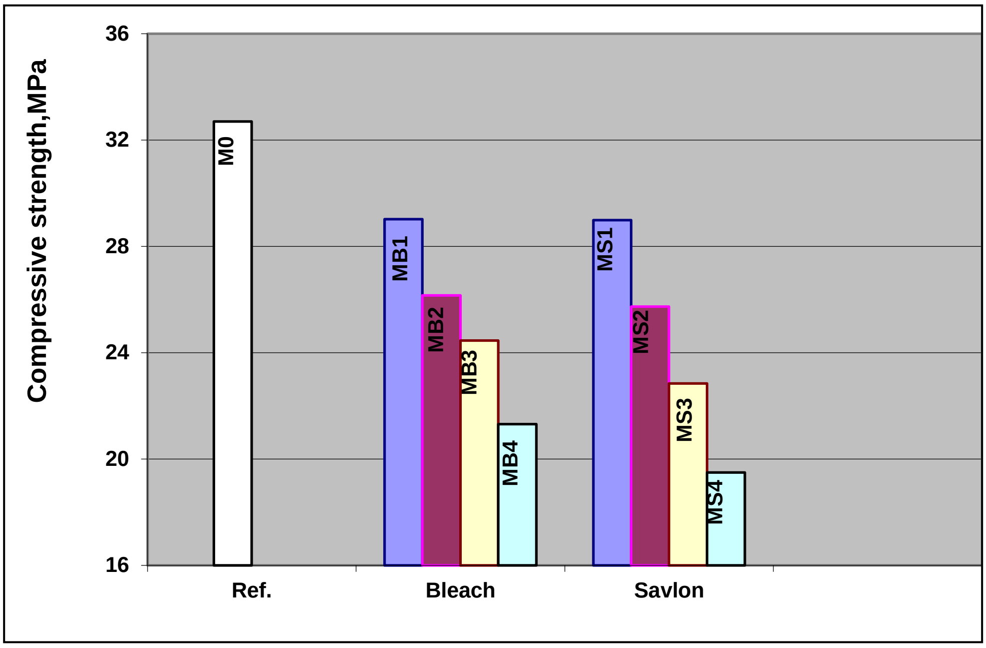


**Fig.2 Compressive strength of activated and non-activated concrete Specimens according to type and content of antifungal agent**

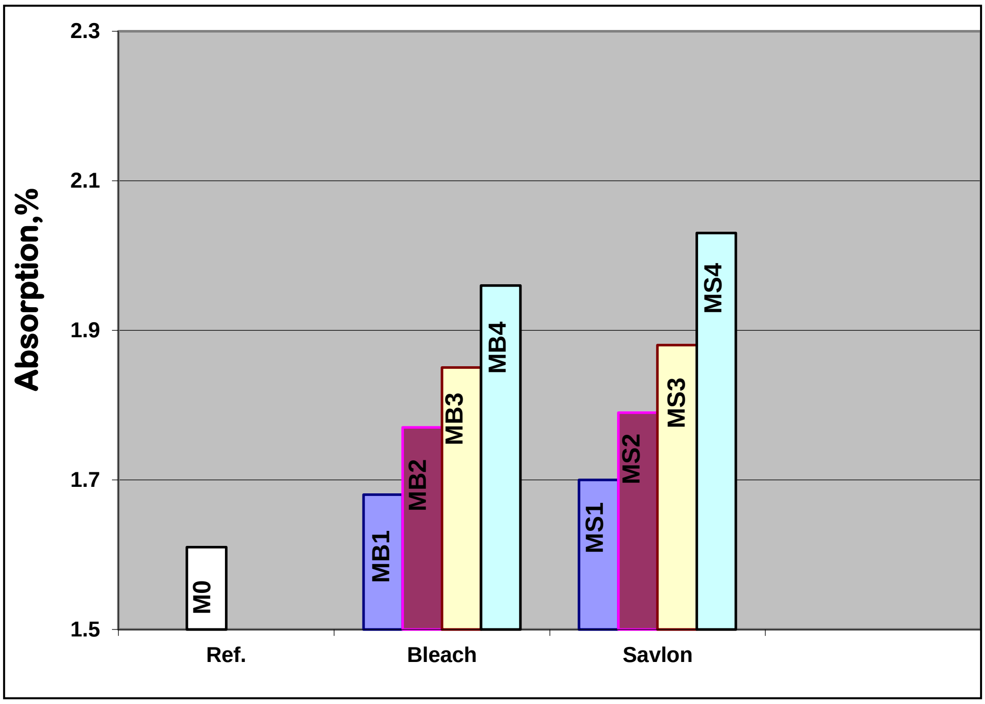


**Fig.3 Absorption of activated and non-activated concrete specimens according to type and content of antifungal agent**

# تأثير انواع المضادات للفطريات على خلط السمنت

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**الخلاصة :**

في السنوات الاخيرة, تم تطوير الخرسانة المضادة للفطريات بأستخدام العديد من المواد كمضافات. وفي هذة الدراسة الحالية تم تخمين النشاط المضاد للفطريات في الخرسان ةضد صنف معين من الفطريات بالامكان اكتشافه بسهولة داخل وخارج الابنية باستخدام نوعين من المضافات العضوية المضادة للفطريات والتي تعرف محليا بالقاصر والسافلون. بجانب ذلك, امتدت الفحوصات ايضا لتشمل تخمين تأثير تلك المضافات على بعض الخصائص الاساسية للخرسانة المنتجة مثل الهطول, مقاومة الانضغاط والامتصاص.وعموما اظهرت النتائج بأن كل الخرسانة المنتجة وبغض النظر عن التراكيز المختلفة للمضافات (5و0-2% من وزن السمنت) أبدت تأثير مانع لنمو تلك الفطريات وبدرجات متفاوتة. فضلا عن ذلك, فأن معظم خصائص الخرسانة المفعّلة بالمضافات المضاد للفطريات اظهرت نقصان ملحوظ مقارنة بخصائص الخرسانة المرجعية.