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Behevior of Bond Strength between Steel Reinforcement and Recycled Concrete Exposed to Sulphate and Chloride Attack

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ملخص البحث :

سلوك المنشآت الخرسانية المسلحة يتأثر مباشرة بمقاومة التماسك بين الخرسانة وأسياخ صلب التسليح. وعند تعرض بعض المنشآت للهجوم من املاح الكبريتات او املاح الكلوريدات يجب تقييم تلك المنشئات لمعرفة تأثير مقاومة التماسك بين الخرسانة وأسياخ صلب التسليح في هذه الحالة. يهدف هذا البحث الى دراسة مقاومة التماسك بين أسياخ صلب التسليح قطر 16 مم والخرسانة المحيطة باستخدام 9 خلطات مختلفة. وقد تم اختبار عدد 81 عينة مكعبات خرسانية (15*15*15 سم) وعدد 81 إسطوانة (15 *30 سم) لدراسة تأثير المتغيرات المختلفة على كل من مقاومة الضغط والتماسك بين الخرسانة وأسياخ صلب التسليح. وقد اشتملت المتغيرات على استخدام ركام كبير من كسر الخرسانة كإحلال للركام الطبيعى بنسبة 50 % وكذلك إضافة غبار الاسمنت بنسبة 10 , 30 % من محتوى الاسمنت وأيضا إضافة السيليكا فيوم بنسبة 5 , 10 % من محتوى الاسمنت مع تعرض العينات لمحلول الكلوريدات ومحلول املاح الكبريتات ومحلول خليط منهم بنسبة تركيز 5 , 10 % لمدة ستة اشهر. وقد أظهرت نتائج ان استخدام الإضافات المعدنية مثل السيلكا فيوم والرماد المتطاير تحسن كل من مقاومة الضغط ومقاومة التماسك كما أظهرت العينات التي تحتوي على اسمنت خليط أداء افضل من العينات التي تحتوي على اسمنت بورتلاندى عادى بالإضافة الى ان العينات باستخدام الخرسانة المعاد تدويرها كركام كبير وخليط من السيليكا فيوم والرماد المتطاير والاسمنت الخليط اعلي قيمة من حيث مقاومة الضغط ومقاومة التماسك وافضل مقاومة لهجوم الكلوريدات والكبريتات.

ABSTRACT:

The performance of reinforced concrete structures depends directly on the bond between steel reinforcing bars and concrete and plays a vital role in reinforced concrete elements resistance to sulphate and chloride attacks which need an assessment of their residual capacities to evaluate the durability aspects. This study investigates the bond behaviour between concrete and 16-mm reinforcing steel rebars after exposure to both sulphate and chloride attack with 5 % concentration and chloride attack only with 10% concentration for six months, Eighty-one cubes (150mm side length) and 81 pull-out cylinders (150*300 mm) were prepared using 35 MPa compressive strength concrete with different cement type, cement content, recycled aggregates and different percentages of fly ash and silica fume. The results showed reductions in residual compressive and steel–concrete bond after exposure to both sulphate and chloride attacks. Using of mineral admixtures such as fly ash and silica fume enhances both the compressive strength and bond strength. Also, Specimens contain CEMIII showed better behaviour than Specimens with CEMI in sulphate and chloride attack resistance, finally the specimens contain both silica fume and fly ash with recycled aggregates and the mix with high content of CEMIII achieved almost the highest compressive and bond strengths and also sustainable resistance for sulphate and chloride attack.

KEYWORDS

concrete, sulphate attack, chloride attack, Recycle aggragte, pullout, bond strength.

INTRODUCTION

Durability of Concrete element continues to be a subject of challenges for design professionals. The occurrence of degradation of properties of concrete in structures elements lead to changes or modifications in Codes limits in each countries. This study investigate the effect of using different types of concrte additvies such as fly ash and silica fume with differnt percentage and recycle aggragtes replacement as coarse aggreagtes on the bond strength between the steel reinforced bars and concrete after exposure for six months to sulphate and chloride attack with different solution percentage.

Based on the state of the art in structural concrete design the bond between the reinforcing steel and concrete is very important. according on the current ACI code and Egyptian code provisions the description of rebar-concrete bond is essentially for bond and development length of reinforcement, which are empirical relationships and depend on adjustable parameters most probably which generally lack physical meaning and which should be adjusted for each type of concrete with different material contents, concentration of solution and durations of exposure the reinforced concrete elements to elevated temperatures, [1,2]

The sulphates attack, such the more common type and typically arises where water containing dissolved sulphate penetrates the concrete. Behind the reaction front, the composition and microstructure of the concrete will have reformed. These changes may vary in type or severity according to different variables such as cement type, cement content, mineral admixtures, etc. but commonly include; Extensive cracking, Expansion, Loss of bond between the cement paste and aggregate and therefore the reinforcement. When sulphates penetrate the concrete elements combines with the C-S-H, or concrete paste, and begins destroying the paste that consolidates the concrete together. As sulphate dries, new compounds are formed, often called ettringite. These new crystals occupy empty space, and as they continue to form, they cause the paste to crack and the physical degradation of the concrete, further damaging the concrete elements. The physicochemical process of “Sulphate attack” are interdependent as is the resulting damage, physical sulphate attack, often evidenced by bloom (the presence of sodium sulphates Na_2SO_4 and/or $Na_2SO4.10H_2O$) at exposed concrete surfaces. It is not only a cosmetic problem, but it is the visible displaying of possible chemical and microstructural problems within the concrete matrix.[3]

the most important dimention for attention when Chloride attack concrete is affect on the durability. Corrosion of the reinforcing steel occur base on the chloride attack mains to and a subsequent reduction in the tensile strength of steel bars, serviceability, and aesthetics of the structure elements. The effect of the exposure time for chlorides to reach the reinforcing bars and, therefore, the corrosion initiation time. Chloride ions enter into concrete through two sources such as internal chloride (at the time of preparation of concrete, through chloride contaminated aggregates, chloride-containing admixtures, or mixing water) and external chloride (entering from the external environment into the hardened concrete through dicing salts, sea water, soil and ground water),[4]

The concrete structure, in fact the low permeability and dense microstructure proved to extend the time needed for corrosion to occur. Statistics have indicated that over 40 per cent of failure of structures was due to reinforcement corrosion. Due to high alkalinity of concrete a protective oxide film is occure on the surface of steel reinforcement. carbonation can negatively affect the protective passivity layer. This protective layer also can be lost due to the presence of chloride in the presence of water and oxygen. In reality the action of chloride in inducing corrosion of reinforcement is more serious than any other reasons. One may understand that Sulphates attack the concrete whereas the chloride attacks steel reinforcements. The amount of chloride required for initiating corrosion is partly dependent on the pH value of the pore water in concrete. At a pH value less than 11.5 corrosion may occur without the presence of chloride. At pH value greater than 11.5 a good amount of chloride is required. The effect is that chloride penetration is a complex function of position, environment and concrete properties, [3]

if the concrete cover is not deteriorated then diffusion of chloride ion into concrete is very slowly. However, when the concrete cover is damaged by sulphate solution attack, which is commonly encountered in field constructions, chloride ion will rapidly access to the surface of steel rebar embedded in concrete. The attack of sulphates on concrete is due to two principal reactions: the reaction of Na_2SO_4 and Ca $(OH)_2$ to form gypsum and the reaction of the formed gypsum with calcium aluminate hydrates to form ettringite. In addition, it is noticed that MgSO4 reacts with all cement compounds, including C–S–H, thus decomposing cement, and subsequently forming gypsum and ettringite which damage the concrete itself and cause reduction in mechanical properties of the concrete,[5]

Potential-dynamic polarization test, XRD analysis and FTIR spectroscopy were also performed for State of rebar corrosion in concrete powder aqueous solution contaminated with chloride and sulphate ions from the results, different zones of corrosion in terms of potential ranges have been identified. The presence of Na2SO4 has decreased the effect of chloride ions whereas the presence of $MgSO_4$ has stimulated the effect of chloride ions on reducing the passivity of steel reinforcement in a chloride environment. Ordinary Portland cement performed better against Mg-oriented sulphate attack whereas Portland pozzolana cement performed better against Na-oriented sulphate attack in the presence of chloride ions,[6].

Katarzyna Konieczna et al [7] investigate three low-clinker HPC mixtures incorporating slag cement (CEM III/B as per EN 197-1) and Supplementary Cementitious Materials (SCMs)- Ground Granulated Blast Furnace Slag (GGBFS), Siliceous Fly Ash (SFA) and Silica Fume (SF). The maximum amount of Portland cement clinker from CEM III/B change from 64 to 116 kg in 1 m3 of concrete mix. The compressive strength was measured of HPC at different age ststing from 2 days till 2 years, also test the specimens for modulus of elasticity. The research proved that it is possible to achive low-clinker High-Performance Concretes that reach compressive strength of 76–92 MPa after 28 days of curing, show high values of modulus of elasticity (49–52 GPa) as well as increased resistance to enviroment conditions.

Lämmlein et al. [8] indicate that it was avialble to obtain low-clinker self-compacting HPCs with OPC content of 134–204 kg in 1 m3 of concrete mix by incorporating fly ash, limestone, silica fume, and metakaolin. The designed HPCs reached compressive strength ranging from 77 to 88 MPa after 28 days of curing. Research into the synergistic effect of GGBFS, FA and SF addition on the microstructure, as well as mechanical and durability properties, has already been conducted for normal strength concretes by Dave et al. [9].

Jin Zuquan et al [10] test two sets of concretes under attack of erosion solution of sulphate and chloride salt . The one set is the plain concrete without fly ash addition. The other set is the concrete with 20% and 30% of fly ash addition, respectively. The corrosion solution includes three types: 3.5%NaCl, 5% Na_2SO_4, and a composite solution of 3.5%NaCl and 5% Na_2SO_4. In addition, two corrosion regimes were employed: naturally immersion (stored in corrosion solution for long duration), drying-immersion cycles. The experimental results shows that a presence of sulphate in the composite solution increased the resistance to chloride ingress into concretes at early exposure period, but the opposition was observed at latter exposure period. For the damage of concretes, a presence of chloride in the composite solution reduces the damage of concrete caused by sulphate. Addition of fly ash may significantly improve the resistance to chloride ingress into concretes and the resistance to sulphate erosion when a suitable amount of fly ash addition.

Sajjad Ali Mangi el al [11] study the effect of ground coal bottom (CBA) ash on the strength performances of concrete exposed to sulphate and chloride environment by replaced the ordinary portland cement with 10% of coal bottom ash by weight of cement and same water to binder ratio of 0.5 was used in all concrete mixes. After demoulding samples were immersed in a water for the curing period of 28 days. Afterward, specimens were shifted in 5% sodium sulphate (Na_2SO_4) and 5% sodium chloride (NaCl) solutions for additional difeerent curing periods of. It was observed that the addition of CBA in concrete, gives the significant development in compressive strength, around 11.32% and 13.92% higher strength than that of the control mix in water and 5% Na_2SO_4 solution respectively at the exposure period of 90 days. However, the development of compressive strength in 5% NaCl solution was slower, about 6.87% decrease was recorded in concrete containing CBA at the exposure period of 90 days as compared to the control mix.The outcome of this study indicated that application of ground CBA as supplementary cementitious material in concrete increases the resistance against aggressive environment.

Pull-out test is frequently used to determine the bond between steel reinforcing bars and the surrounding concrete [12, 13]

R.K. Majhi, A.N. Nayak [14] investigate the impact of high volume ground granulated blast furnace slag (GGBFS) as the replacement of ordinary Portland cement (OPC) on the compesive and bond, strength of recycled aggregate concrete (RAC). Seven concrete mixes are prepared; one mix is the control mix. while six concrete mixes contain 0%, 40% and 60% GGBFS with each of 50% and 100% recycled coarse aggregate (RCA). Also durability characteristics of these mixes are evaluated by exposing the concrete to various chemical attacks such as magnesium sulphate attack, sulphuric acid attack and sodium chloride attack. it is found that the strength values decrease with the increase in GGBFS content, the high volume GGBFS can be utilized in the production of sustainable concrete, and the resistance to sulphate, acid and chloride attacks improve with increase in the content of GGBFS.

AIM OF THE RESEARCH

This study investigates the effect of using different types of mineral admixutres such as fly ash and silica fume with differnt percentage in recycled aggragtes concrete on the bond strength between the steel reinforced bars and concrete after exposure to composite solution of sulphate and chloride attack with different solution percentages for six months.

MATERIALS CHARACTERESTICS

The bond strength between concrete and reinforced steel is affected by many variables including the charactistics of materials used in experimental program, which still the same during preparing all tested specimens. Different types of mineral admixtures were used in this research ; fly ash and silica fume. Local sand from natural sources,crushed dolomite and recycled aggragte produced from concrete waste size (10 and 20) mm complying with Egyptian standard specification ESS No. 1109- 2001 [15], were used with CEMI 42.5N and CEMIII A42.5N, cement complying with ESS 4756- 2013 [16] and tap water to produce the concrete mixes. The consistency of concrete was measured by slump tests, as a comparison test, and resulted from 85 to 125 mm. The content of cement, water, aggregate, recylce aggregate and fly ash and silica fume are given in Table (1).

EXPERIMENTAL PROGRAM

The experimental program was designed to attained the research objectives of the research. Bond behaviour
between concrete and reinforcing bars was studied after exposure to sulphate and chloride attack with different solution percentage for six months.

Nine different concrete mixes with different variables were used as mentioned in table (1). Eighty-one pull-out cylinder specimens (Ø150 mm, 300 mm) were cast, then reinforced steel bar of 16mm was embeded in the middle of each cylinder for 200mm, Horizontal steel bar above the cylinders to control reinforced steel bar's embedded length, as shown in figure (1-a). After removing the tested specimens from the moulds, they were stored in water for seven days then kept at laboratory conditions until testing as shown in figure (1-b), then exposure for to composite solution of sulphate and chloride attack and chloride attack only in soluation tank as shown in figure (1-c).

The specimens exposed for six months to composite solution sulphate and chloride attack with different solution percentage in as shown in figure (2-a), then removed from soluation tank and prepreaed for bond test as shown in figure (2-b) Finally six cubes were tested at room temperature, see figure (2-c) . tested cubes were cast for each mix to obtain the compressive strength, cured in the same condition as the pullout cylinders specimens, then tested to determine the compressive strength for each mix in each exposure condition.

Table (1) : Concrete compositions per one m^3

Mix	Cement (kg)	Fine Aggregate (kg)	Crushed dolomite S1 (kg)	Recycle agg. S1 (%)	Crushed dolomite S2 (kg)	Recycle agg. S2 (%)	Water (kg)	Add. (Lit)	Minerals	
								*Sp	fly ash (%)	SF (%)
M1	350 CEMI	700	595	0	595	0	167	7	0	0
M2	350 CEMI	700	298	298	298	298	167	7	0	0
M3	350 CEM III	700	298	298	298	298	167	7	0	0
M4	450 CEM III	700	298	298	298	298	202	9	0	0
M5	350 CEMI	700	298	298	298	298	167	7	10	0
M6	350 CEMI	700	298	298	298	298	167	7	30	0
M7	350 CEMI	700	298	298	298	298	167	7	0	5
M8	350 CEMI	700	298	298	298	298	167	7	0	10
M9	450 CEMIII	700	298	298	298	298	202	9	10	5

*Sp: Superplasticizer

Exposure and Testing

All specimens are exposed to a chemical attack with different sulphate and chloride solutions percentages for six months. the outer part of the tested rebar was not covered in order to simulate what may happen in real life applications. The specimens were exposed to composite of four types of sulphate and chloride compounds with percetage of 5% and also exposed to mix of two chloride soluations with 10% concentration for six months. After exposure to the mentioned solutions the specimens removed from the tank and then tested at room temperature. For each exposure condition, three samples were prepared for each concrete mix and exposed to external sulfate and cloride attack. The following types of tests were performed:

1-The exposed specimens by sulfate and chloride in liquid form at tank-1. The samples were immersed in the sodium and Magnesium sulfate composite soluation with 5 % concentration(5%Na_2SO_4+ $MgSO_4$) and sodium chloride and Magnesium chloride soluation with 5 % concentration. (5% NaCl+ $MgCl_2$) which is considered as a severe condition of external sulfate and chloride attack for concrete.

2-The attack by chloride in liquid form. The samples were immersed in the sodium chloride and Magnesium chloride soluation with 10 % concentration (10% NaCl+10% $MgCl_2$). حوض رقم (2)

		
Casting Specimens (a)	Specimens during curing (b)	The Soluation tank (C)

Figure (1): Preparing, casting and curing the specimens

		
Figure (1-a) : Specimens during sulphate and chloride attack	Figure (1-b) : Specimens before bond testing	Figure (1-c) : Specimens after bond test

Figure (2): The specimens during sulphate and chloride attack and before and after bond testing

TEST RESULTS AND DISCUSSION

Compressive Strength

After exposure to sulphate and chloride attack for 6 months, an average values of the concrete compressive strength is determined at 28 days as shown in Table (2) and figure (3).

Table (2) : Compresive load and compresive strength for experimental programe

MIX	Control (Ton) At 28 days	Control (Kg/cm^2) At 28 days	Composite Sulfate & Chloride Attack 6 month (Ton)	Composite Sulfate and Chloride Attack 6 month (Kg/cm^2)	Chloride Attack 6 month (Ton)	Chloride Attack 6 month (Kg/cm^2)
M1	104	462.22	99	440.00	90	400.00
M2	91	404.44	81	360.00	80	355.56
M3	98	435.56	96	426.67	95	422.22
M4	131	582.22	116	515.56	102	453.33
M5	127	564.44	120	533.33	102	453.33
M6	142	631.11	129	573.33	139	617.78
M7	111	493.33	101	448.89	110	488.89
M8	129	573.33	123	546.67	119	528.89
M9	147	653.33	142	631.11	127	564.44

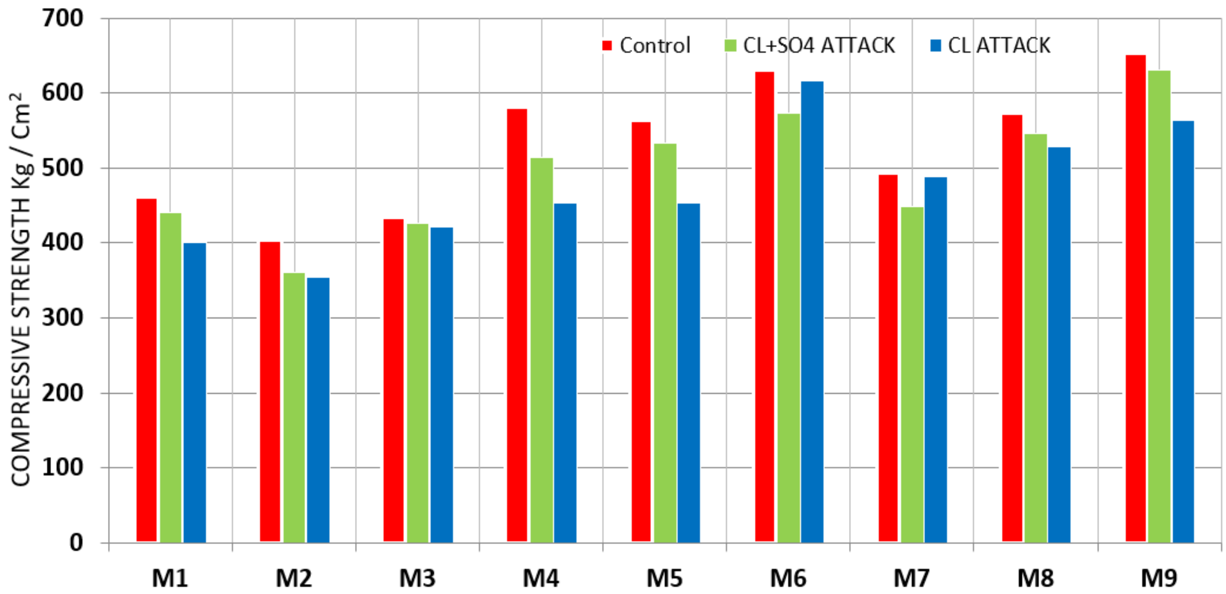


Figure (3) The compressive load and strength values of experimental concrete mix

Bond Strength

After exposure to sulphate and chloride attack for 6 months an average values of the concrete load and compressive strength are determined at 28 days and listed in Table (3) and figure (4).

Table (3) : Bond strength for experimental concrete mix

MIX	Control (Kg/cm^2)	Composite Sulfate and Chloride Attack (Kg/cm^2)	Chloride Attack (Kg/cm^2)
M1	90	63	80
M2	76	44	64
M3	56	52	52
M4	98	86	89
M5	108	107	106
M6	111	103	98
M7	115	112	110
M8	102	78	82
M9	112	100	106

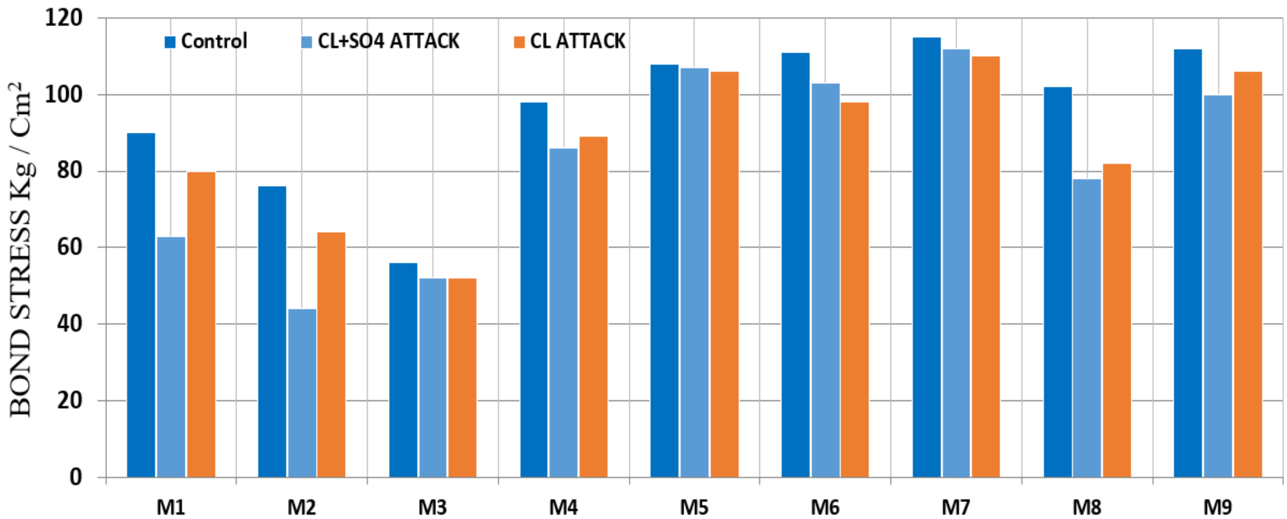


Figure (4) The bond strength values of experimental concrete mix

To examine the effect of using recycled aggregate, figure (5) indicates the difference between the M1 control mix and M2 mix with 50% replacement of recycled coarse aggregate produced from old conctrete cubes in the Housing and Building National Research Center material lab. The results reflect a decrese in the compressive strength with about 12.5 , 18 and 10 % respectively due to the replacement of coarse aggregate with recycle aggregate on the other hand, the compresive strength affected with expose to sulphate and chloride attack with about 10 % from its value for control specimens in M2 while about 5 % for M1 this slightly decrease due to when sulphates penetrate the concrete elements and react with the C_3A, or concrete paste to form ettringite and tricalcium aluminate chloride, and begins These new crystals occupy empty space, and as they continue to form, they cause the paste to crack and the physical degradation of the concrete. The trend of affected by composite sulphate and chloride attack is the same at normal concrete also with decrese in bond strength about 42 % at composite sulphate and chloride attack while 14% at chloride attack only for concrete with recycle aggregate.

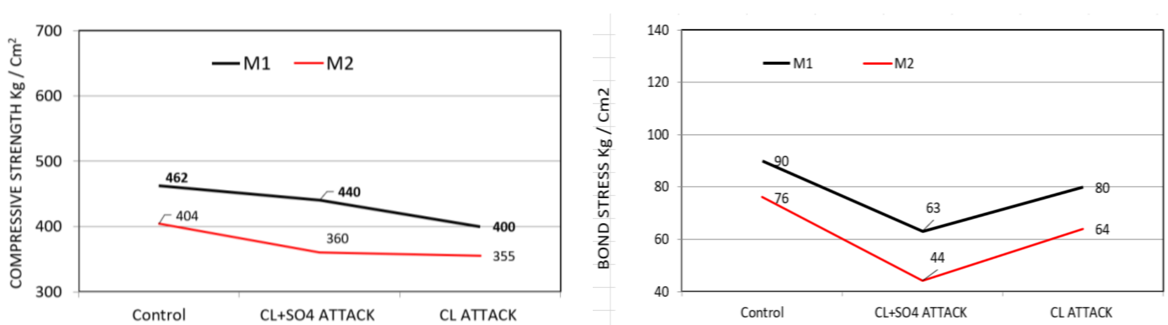
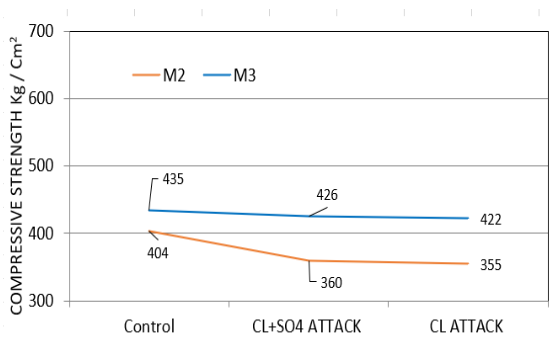


Figure (5) The compresive and bond strength values of M1 and M2 mix

To examinate the effect of using cement CEMIII figure (6) indicate the difference between the M2 control mix and M3 mix with replacement of cement type CEMI to CEMIII. The results reflect increase the compressive strength with about 7.5 , 18.5 and 18 % for control, sulphate and chloride attack and chloride attack only respectively. on the other hand the bond strength affected with expose to sulphate and chloride attack with about 42 % from its value for control specimens in M2 while about 8 % for M3 this slightly decrese due to the presence of Cement (CEM III) is a specially formulated blend of traditional cement and a minimum of 50% Ground Granulated Blastfurnace Slag, its unrivaled strength, durability and low heat properties make CEM III ideally suited to marine, agricultural and chemically aggressive environments as well as better in hydration in cement. GGBFS C-S-H hydrates add density to the cement paste, as they are more gel-like than the OPC hydration products. The incorporation of GGBFS in normal, high-strength and ultra-high-strength concretes results in the improvement in the pore structure and durability properties of the composite, such as increased electrical resistivity and reduced chloride penetration



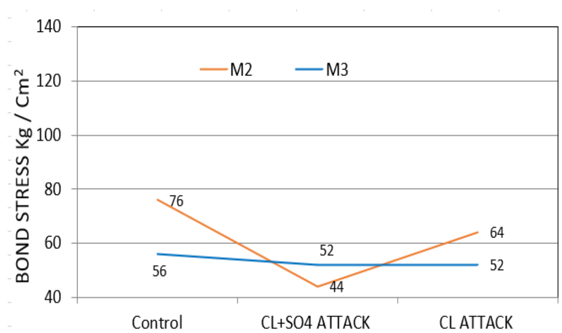


Figure (6) effect of Cement type on the compresive and bond strength values

The effect of increase the cement content from 350 kg/m3 to 450 kg/m3 is evaluated by testing M3 and M4 figure (7) indicates the different between the M3 and M4 mix. The results reflect increase the compressive strength with about 33 , 20 and 7 % for control, sulphate and chloride attack and chloride attack only respectively due to increase of cement content. also the bond strength decrease with expose to sulphate and chloride attack with about 8 % from its value for control specimens in M3 while about 12 % for M4 this slightly decrease due to effect of sulphate and chloride attack, but we can see although thid decrease the final bond strength of M4 is higher than M3 with about 65 % at sulphate and chloride attack due to increse in cement contemt and increase the hyadration of cement with CEMIII.

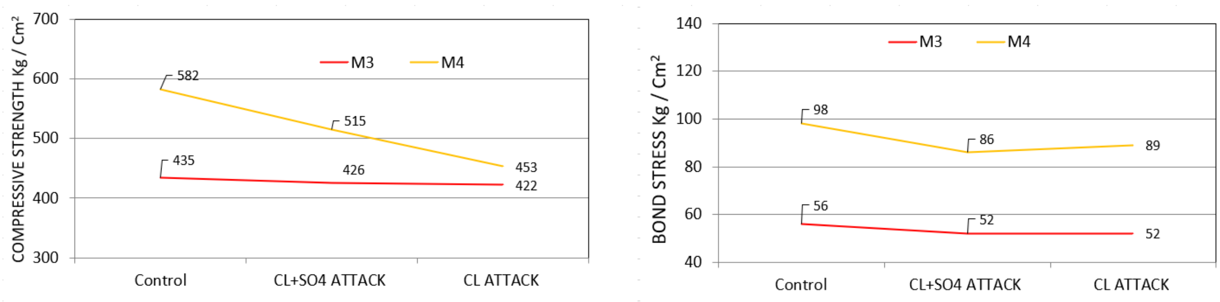


Figure (7) effect of Cement content on the compresive and bond strength

Figure (8) shows the impact of adding fly ash as additive to the cement content with 0, 10 and 30% by weight of cement by examing mix M2, M5 and M6 respectively. The results indicate an increase in the compressive strength with about 40 in M5 with 10 % fly ash and 56 % in M6 with 30 % fly ash due to the chemeical compoenet of fly ash with present of active SiO_2 which increase the hydration of cement in the mix due to its reaction with free lime liberated from C-S-H. After exposure to both sulphate and chloride attacks and chloride attack only, the compresive strength decreases with about 6 and 23 % for M5 compared to control specimens and 10 and 2 % for M6 from the control specimens. The bond strength decrease with expose to sulphate and chloride attack vary from 2 to 12 % from its value for control specimens in M5 and M6 due to effect of sulphate and chloride attack, but it can be seen the bond strength of M5 and M6 is higher than M2 with about 50 and 250 % for 10 and 30 % fly ash additives respectively at sulphate and chloride attack. It can be seen that the behviour of concrete contain fly ash is better than that of normal concrete due to increase in cementioues material in the mix in both compresive and bond strength

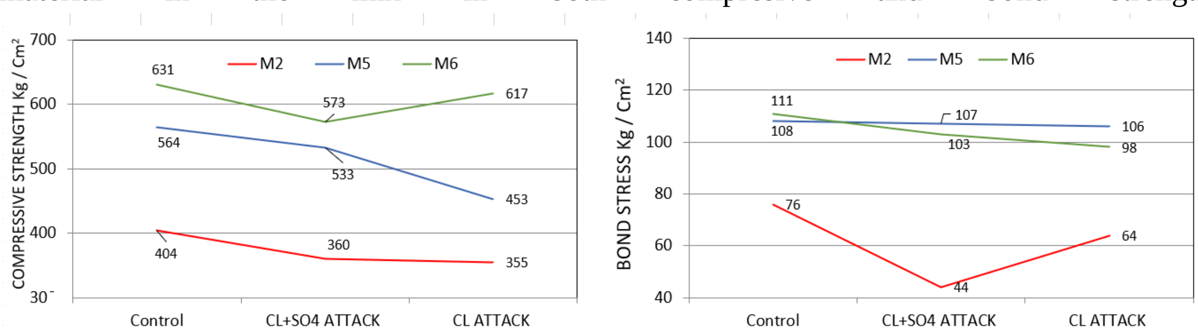


Figure (8) Impact of fly ash percentage on the compresive and bond strength

The impact of adding silica fume as additive to the cement content with 0, 5 and 10% by weight of cement is presented in Figure (9) by examing mix M2, M7 and M8 respectively. The results indicate an increase in the compressive strength with about 22 in M7 with 5 % silica fume and 41 % in M8 with 10 % silica fume due to the chemeical compoenet of silica fume with high percentage of active SiO_2 and high specific surface area which increase the hydration rate of cement in the mix due to its pozzolanic reaction with free lime forming C-S-H. After exposure to both sulphate and chloride attacks and chloride attack only, the compresive strength decreases with about 10 and 2 % for M7 compared to control specimens and 5 and 8 % for M8 compared to control specimens. The bond strength decrease with expose to sulphate and chloride attack vary from 4 to 24 % from its value for control specimens in M7 and M8 due to effect of sulphate and chloride attack, but we can see the bond strength of M7 and M8 is higher than M2 with about 77 and 255 % for 5 and 10 % silica fume additives respectively at sulphate and chloride attack. It can be seen that the behviour of concrete contain silica fume is better than that of normal concrete due to increase in cementioues material and high percentage of SiO2 and high specific surface area which increase the hydration rate of cement in the mix in the mix in both compresive and bond strength

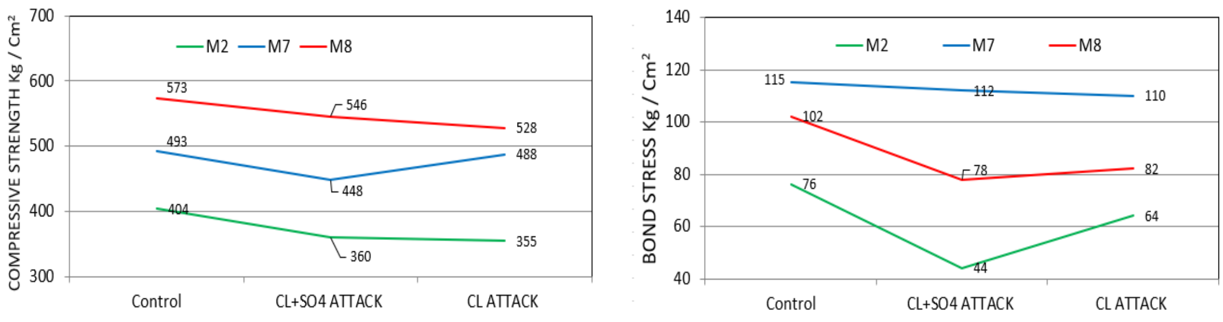


Figure (9) Effect of silica fume percentage on the compresive and bond strength

Finally the effect of combined adding cementitious materials such as fly ash and silica fume is explained in figure (10) by co comparing the test results for M5, M8 and M9. M9 is concrete mix with 10% fly ash and 5 % silica fume. The results showes an increase in the compressive strength of M9 with about 15 and 32 % comparing with M5 and M7 respectively due to the chemeical compoenet of silica fume and the fly ash with high percentage of active SiO_2 and high specific surface area which increase the hydration rate of cement in the mix due to its reaction with free lime liberated forming C-S-H. After exposure to sulphate and chloride attack, the compresive strength of M9 still highr than M5 and M7 with 18 and 40 % respectively while at chloride attack only the compresive strength decrease with about 20, 10 and 14% for M5, M7 and M9 respectively compared to control specimens. The bond strength slightly decreases after exposure to sulphate and chloride attack vary from 2 to 12 % compared to control specimens in M5,M7 and M9 due to effect of sulphate and chloride attack, but we can see the bond strength of M7 and M8 is higher than M2 with about 77 and 255 % for 5 and 10 % silica fume additives respectively at sulphate and chloride attack. It can be seen that the behviour of concrete mixes contain silica fume and fly ash is better than that of concrete mixes contain only one type of cementioues materials due to the increase in cementioues material and compatablity of chemeial components and reaction of fly ash and silica fume which increase the hydration rate of cement in the mix

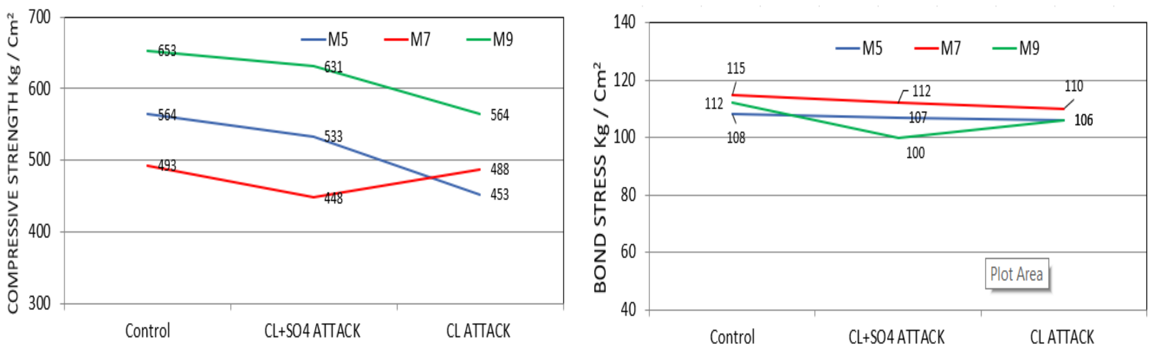


Figure (10) Effect of silica fume percentages on the compresive and bond strength

Failure Mode

Failure modes due to the pullout force is almost the same for most of the concrete mixes as shown in figure (11), the tested cylinders didn't split into two halves and cracks propagated up to failure, bond failure partly occurs on the surface of the bar and partly in the concrete by peeling the cortical layer of the bar.

			
Figure (11a): failure of M1 control mix	Figure (11b): failure of M2 mixes	Figure (11c): failure of M4 mixes	Figure (11d): failure of M8 mixes

Figure (11): Failure Modes of pullout test specimens of mixes

CONCLUSIONS

Accordind to the experimental programe and results analysis the folwwing conclusions can be founded :

1. Using recycled aggreate as a replacement of coarse aggregate with 50 % can achieve an accebtable concrete properties during sulphate and chloride attacks with less mechanical properties with only about10 %.
2. The trend of the dual effect of sulphate and chloride attacks and chloride attack only is almost the same on recycled concrete compared to normal concrete.
3. The increase of cement content from 350kg/m^3 to 450 kg/m^3 enhances the compressive strength with about 33 , 20 and 7 % for control, both sulphate and chloride attacks and chloride attack only respectively and bond strength with about 65 % at sulphate and chloride attack .
4. It can be seen that the behviour of compresive strength of concrete contains silica fume is better than that of normal concrete due to increase in cementioues material and high percentage of active SiO^2 and high specific surface area which increase the hydration rate of cement in the mix reaction with free lime liberated from C-S-H in the mix in both compresive and bond .
5. The behviour of concrete mixes containing fly ash is better than that of normal concrete in both compresive and bond strengths due to the effect of pozzalanic reaction of fly.
6. The bond strength slightly decreases with exposure to both sulphate and chloride attacks for the specimens contain fly ash or silics fume or both of them.
7. It can be seen that the resistance behviour for sulphate and chloride of concrete mixes contain CEMIII , silica fume and fly ash is achive higher results than that of concrete contain only one type of cementioues materials.
8. For all concrete mixes, bond failure partly occurs on the surface of the bar and partly in the concrete by peeling the cortical layer of the bar.

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