SULFATES EFFECT IN FINE AGGREGATE ON SELF COMPACTING CONCRETE PROPERTIES BY USING RISE HUSK ASH

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ABSTRACT

One of the important problems in fine aggregate is the contaminated with interior sulfates in manufacturing concrete in Iraq. Within standard specifications a difficult to obtain of well-graded fine aggregate with sulfates content is existed. The present research is devoted to enhancement of some properties of self-compacting concrete with fine aggregate contains internal sulfates by partial replacement of gypsum to fine aggregate by weight. This study is bifurcate of self-compacting concrete they are: first category is incorporating powder of limestone (LSP) in self-compacting concrete and the second one is incorporating 10% rise husk ash (RHA) plus powder of limestone (LSP). The investigated scales of fine aggregate with sulfates contents were (0.37%, 0.5%, 1.0%, and 1.5%) which is corresponding replacement by weight of cement equal of (3.74%, 3.99%, 4.96% and 5.93%) for mixes contained limestone powder and of (3.76%, 4.01%,4.98% and 5.96%) for mixes contains rise husk ash plus powder of limestone. Experimental program of this study is bifurcate; first one is using superplasticizers and fillers to produce self-compacting concrete then determine the workability. Second one is to evaluate the mechanical properties such as splitting tensile strength and compressive strength. It was noticed that, the exemplary content of gypsum was by weight of cement for all mixes was 0.5%. While increase in compressive strength in a range between 5.9% and 10.1%, and in tensile strength in a range between 1.2% and 8.5% for mixes of self-compacting concrete with limestone powder plus rise husk ash instead of limestone powder.

تأثير الأملاح الكبريتية في الركام الناعم على خواص الخرسانة ذاتية الرص باستخدام رماد قشور الرز

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الخلاصة

واحدة من المشاكل الهامة في الركام الناعم هو تلوثه بالكبريتات الداخلية في تصنيع الخرسانة في العراق. ضمن المواصفات القياسية من الصعب الحصول على تصنيف جيد الركام الناعم مع وجود محتوى الكبريتات. ويخصص هذا البحث إلى تعزيز بعض خواص الخرسانة ذاتية الرص مع الركام الناعم الحاوي على الكبريتات الداخلية عن طريق استبدال جزء من الركام الناعم بالجبس استبدالا وزنيا. هذه الدراسة من الخرسانة ذاتية الرص تنقسم الى صنفين هم: الفئة الأولى هي دمج مسحوق الحجر الجيري (LSP) في الخرسانة ذاتية الرص وثانية والاخرى هو دمج 10٪ من رماد قشور الرز (RHA)، بالإضافة إلى مسحوق الحجر الجيري (LSP). كانت نتائج الاستكشاف للركام الناعم الحاوي على الكبريتات (0.37٪، 0.5٪، 1.0٪، و1.5٪) والتي يقابلها استبدال من وزن الاسمنت يساوي الى (3.74٪، 3.99٪، 4.96٪ و 5.93٪) للخلطات الحاوية على مسحوق الحجر الجيري و(3.76٪، 4.01٪، 4.98٪ و 5.96٪) للخلطات الحاوية على رماد قشور الرز بالاضافة الى مسحوق الحجر الجيري. الجانب العملي من هذه الدراسة ينقسم الى قسمين؛ أول قسم هو استخدام الملدنات والمادة المالئة لإنتاج الخرسانة ذاتية الرص ثم تحديد قابلية التشغيل. والقسم الاخر هو لتقييم الخواص الميكانيكية مثل مقاومة الشد الانشطاري وقوة الانضغاط. وقد ملاحظة ما يلي، كانت القيمة المثلى من الجبس وزنا من الاسمنت لجميع الخلطات كان 0.5٪. بينما الزيادة في قوة الانضغاط تقع ما بين 5.9٪ و 10.1٪، بينما قوة الشد تقع ما بين 1.2٪ و 8.5٪ للخلطات الخرسانية-ذاتية الرص مع مسحوق الحجر الجيري بالإضافة إلى رماد قشور الرز بدلا من مسحوق الحجر الجيري.

المفاتيح الدلالية: خرسانة ذاتية الرص، رماد قشور الرز، الاملاح الكبريتية، الديمومة، الركام الناعم، مقاومة الانضغاط، مقاومة الشد

1. INTRODUCTION

During the last decade, self–compacting concrete (SCC) is outstay in advances concrete technology. The SCC is developed in Japan since the last of 1980s, which is meanwhile spread all over the world with a continuously increasing of applications.(Holschemacher and Klug, 2002).

Self-compacting concrete (SCC) was developed to respond to the need for concrete which can improve durability while eliminating the need for compaction and vibration work. SCC can compact itself into complicated formwork and congested structural elements under its own weight without the need for mechanical vibration. It needs to be both highly deformable and resistant to segregation and bleeding (Okamura and Ouchi, 1999).

Because of highly flow-able nature of self-compacting concrete, care is required to ensure adequate stability, passing ability and excellent filling ability (Sonebi and Walraven , 2007) To achieve this ability, ensuring suitable rheological fresh concrete properties of like adequate plastic viscosity with a low yield stress.

To attain high flow-ability for fresh concrete water to binder attribution could be to increase in a simple manner. Increasing the water to binder ratio alone; however, might concrete to be less durability and lead to segregation. Thus, mineral and chemical admixtures, e.g., pozzolans, limestone powder, super-plasticizer, and viscosity-modifying admixture (VMA), need to be added to the mix for successfully develop SCC and to prevent segregation and enhance the workability of SCC (Suksawang , Nassif, and Najm, 2006).

Sulfates cause concrete or mortar deterioration when it exists in excessive amount. This phenomenon is called sulfate attack. The sulfate reacting with $Ca(OH)_2$ with hydrate of calcium aluminates (H-C-A). The volume of gypsum and calcium sulphoaluminate products reactions is a considerably great in a comparison with the compounds they replace; therefore, expansion and disruption of the concrete will occur in the reaction with the sulfates. Sulfate in fine aggregate is a major problem encountered in the Middle and Southern part of Iraq. Most of the sulfate salts in fine aggregate are composed of calcium, magnesium, potassium and sodium sulfates. Calcium sulfate is the most predominant salt present in Iraqi fine aggregate. It is usually finding in fine aggregate as gypsum. About 95% of sulfates in fine aggregate are in the form of calcium sulfates because of the low solubility of this type of sulfate (Al-Samerai 1977).

Sulfates may come either from raw materials and or from gypsum added to cement at grinding stage**. (**Al-Qaisi,1989) Stated that the activity of gypsum is dependent on its fineness. (Al-Rawi, Ali, Shallal and Al-Salihi, 1997) studied the effective sulfate content in concrete ingredients, they pointed out that the effect of SO_3 existing in cement on compressive strength of concrete is about two times more that in fine aggregate and effect of the latter is about two times more that in coarse aggregate. They attributed this to the fine particle size distribution of cement compared with fine aggregate and coarse aggregate. In a later study by (Al-Rawi, 2000), to develop the concept of effective sulfate content, he found that the effectiveness of sulfates increased with increased fineness of fine aggregate. He suggested a formula to account for the effectiveness of sulfates in fine aggregate depending on its fineness modulus. He showed also that the same formula is applicable. The sulfate content in fine aggregate contains sulfate higher than the acceptable limits in most of the fine aggregate in Middle East countries (Al-Kadhimi and Hamid, 1983).

(Al-Ameeri and Issa,2013**)** results show that the fresh properties such as decreased workability of self-compacting concrete is passively influenced from sulfate, also the hardened properties. Furthermore, they found that the optimum SO_3 content to give little tendency to expanding and maximum strength is up to 5% (by weight of cement) which is acceptable limits more than Iraqi specifications. In addition, they noticed a considerable reduction of self-compacting concrete mechanical properties, and increment in expansion of concrete after increase the optimum value of sulfates content in concrete.(Al- Rawi,1997) investigated the effect of the gypsum content of cement on several engineering properties of concrete cured by accelerated and normal methods. He stated that increased gypsum content results in a significant decrease in the slump of concrete and that there is an optimum gypsum content, considerably higher for accelerated cured concrete than for normally cured concrete, at which maximum strength is obtained. The optimum gypsum content under accelerate curing conditions may be used without risk of reduction in the durability of concrete caused by excessive, delayed expansion.

(Al- Rawi, and Latif, 1998), suggested a new test called "Compatibility test" to investigate the possibility of using sands with relatively high (SO_3) contents with suitable cement without deleterious effect on concrete. The work was carried out on seven cements, three ordinary Portland cement, three sulfate-resisting cements and white cement. The sand used had SO_3 contents between 0.18% and 1.5% and the mix was designed to give 30 MPa compressive strength at 28 days. The results show that the SO_3 content in sand gives the maximum concrete strength which differs from one cement to the other ranging from (0.18% to 1.5%) depending on the chemical composition and fineness of cement.

(Alwash, 2005) found the percentage in compressive strength of the mix with OPC and sand of zone 2 which contains sulfate of 1.5% by weight of it, compared with the reduction in strength of the mix with OPC and sand of zone 4 which contains sulfate of 1.5% by weight of it. At ages 7, 28 and 56 days the reduction was (30.86%-37.7%), (10.47%-17.9%) and (2.29%-8.16%) for air curing and (23.6%-28.4%), (7.7%-13.4%) and (5.8%-5.5%) for moist curing. The influence of sulfates on elastic modulus and indirect tensile strength was found to be somewhat likely to that influence on compressive strength.

(Hussain, 2008) investigated some mechanical properties of self-compacting concrete and effect of internal sulfates in fine aggregate on it with several filler types of such as powder of limestone, pigment and hydrated lime. The mechanical properties were flexural strength, modulus of elasticity, compressive strength, the ultrasonic pulse velocity, indirect tensile strength and schmidt rebound hammer tests. He found the optimum gypsum content at which the strength is maximum . Further increase in SO_3 content beyond the optimum causes a decrease in strength and nondestructive tests.

(Kawkab &elt, 2008) used 8% partial replacement by weight of cement rise husk ash, the results showed considerable increase in mechanical properties at all ages of curing simulated with the original concrete.

(Alwash, 2013) noticed in his experimental results that elastic modulus and strength of SCC at age after 60 days improved by adding rice husk ash. The optimum strength was at 15% replacement. Also, a reduction in water absorption and increase the ultrasonic pulse velocity was noticed using rice husk ash.

2. EXPERIMENTAL PROGRAM

The research is devoted to enhancement of some properties of self-compacting concrete with fine aggregate contains internal sulfates by partial replacement of gypsum to fine aggregate by weight. The study is bifurcate of self-compacting concrete they are: first category is incorporating powder of limestone (LSP) in self-compacting concrete and second one is incorporating 10% rise husk ash (RHA) plus powder of limestone (LSP). Four scales of SO3 contents in fine aggregate were investigated; these scales were 0.37%, 0.5%, 1.0% and 1.5% by weight of sand. In order to view the differences in behavior during the fresh state as well as the hardened state some of tests were performed. The slump flow, V-funnels, sieve segregation and L-box tests were performed on concrete in the fresh state. The tests for splitting tensile strength and compressive strength were carried out on concrete specimens at ages (28, 56 and 90 days). The details of each concrete mix were listed in **Table 1**.

2.1 MATERIALS

2.1.1 Cement

The ordinary Portland cement (named Tasluja Bazian) is used. The cement was tested and compared according to **(**IQS No.5 /1984). The chemical and physical tests were conducted in Construction Materials Laboratory of Babylon University.

2.1.2 Fine Aggregate (Sand)

Al-Akhaider natural fine aggregate with fineness modulus (2.64) was used throughout this work. Results indicate that the fine aggregate grading, physical properties and the sulfate contents are within the requirements of the Iraqi specification limits (IQS No.45 /1984).

2.1.3 Coarse Aggregate (Gravel)

Rounded coarse aggregate of passing sieve size 10 mm from AL- Nibaee quarry is used. The coarse aggregate was washed and then stored in air to dry. The grading of this aggregate which conforms to Iraqi Specifications limits (IQS No.45/1984). The specific gravity and sulfate content of coarse aggregate are within the requirements of the Iraqi specifications limits (IQS No.45 /1984).

2.1.4 Water

For both mixing and curing all specimens ordinary tap water is used.

2.1.5 Superplasticizer

A chemical admixture based on modified polycarboxylic ether, which was known commercially (Glenium 51) was used in producing SCC as a superplasticizer admixture. It was complied with (ASTM C494-05 Type F).

2.1.6 Limestone Powder (LSP)

Limestone powder is a white ground material from limestone that found in different regions in Iraq, and usually used in the construction processes. Limestone powder that has been brought from local market is used to increase the amount of powder (cement + filler), the fraction less than 0.125mm will be of most benefit. This filler conforms the (BS 7979) . The chemical analysis of LSP was listed in **Table 2**.

2.1.7 Gypsum

The gypsum was added to the fine aggregate to obtain the required SO_3 content. The added gypsum is natural gypsum rock (brought from Kufa cement factory). It was crushed and grounded to obtain nearly the same gradation set of fine aggregate used in the mix. This gypsum was using as a partial replacement by weight of fine aggregate with limited percentages. The quantity of natural gypsum was calculated and added to the fine aggregate according to the following equation(Al-Kadhimi and Hamid, 1983).

$$W=(R - M)\, S / N \qquad (2\text{-}1)$$

where:

W= the weight of natural gypsum needed to be added to fine aggregate.

R= the percentage of SO_3 % desired in fine aggregate.

S = the weight of fine aggregate in mix.

M = the actual SO_3 in fine aggregate (0.37 %).

N= the percentage of SO_3 % in the used natural gypsum.

2.1.8 Rise Husk Ash (RHA)

Prepared of rice husk ash was by burning the husk in a controlled temperature furnace in order to get a pozzolanic material rich in amorphous silica and minimum amount of unburned carbon. Generally, the optimum burning condition was 500 ^oC for 2 hours (AL-Khalaf and Yousif, 1984). A grinding mill effected the grinding of ash for a period of 15 hours for each 0.5 kg of the ash. The fineness was determining by Blaine air permeability method in accordance with (ASTM C204-84). The fineness modulus and specific gravity were 1.45 and 1.85, respectively. The Chemical properties of rise husk ash (RHA) were listed in **Table 3**.

2.2 MIXING PROCEDURE

In order to obtain the desired level of SO_3 in the sample, first adding suitable amount of gypsum to the fine aggregate then fine aggregate and gypsum were mixed until a homogeneous mix is obtained. Rise husk ash (RHA) powder was mixed with the quantity of cement with the aid of trowels, until the RHA particles were thoroughly dispersed between cement particles. Mixing procedure is important to obtain the required workability and homogeneity of the concrete mix. Concrete was mixed in drum laboratory mixer, with a capacity of $0.05m^3$. Before starting to mix, it is necessary to keep the mixer clean, moist and free from previous mixes.

The procedure used for mixing the batches was as follows (Emborg ,2000):

1. Adding the fine aggregate to the mixer with 1/3water, and mixing for 1minute.
2. Adding the powder (cement+filler) with another 1/3 mixing water, and mixing for 1 minute.
3. After that, the coarse aggregate was added with the last 1/3mixing water and one third of superplasticizer, and mixing for 1.5 minute then the mixture is left for 1.5 minute for rest.
4. Then, the remaining of superplasticize (two third) is added and mixed for 1.5 minute. The SCC mix Proportions were summarized in **Table 4**.

2.3 TEST METHODS FOR FRESH (SCC)

The fresh properties of plain SCC were tested by the procedures of (European Guidelines for self-compacting concrete) (Efnarc, 2005). SCC was defined by its behavior when it is in the fresh state, and it is determined whether concrete meets certain requirements, while flowability is an essential property in qualifying concrete as SCC or not. The slump flow, L-box, V-funnel, sieve segregation test and V-Funnel at T5 minutes were all used for all mixes of this study.

2.3.1 Slump Flow and T50cm Tests

The most widely used method for evaluating concrete consistency and filling ability in the laboratory and at construction sites is the slump flow test and can indicate segregation resistance of SCC to an experienced user. Slump flow with Abrams cone was used to investigate flowing ability of fresh concrete. The slump spread values and T500 for the produced mixes listed in **Table 5**.

2.3.2 L-Box Test

The passing ability of self-compacting concrete is measures by the L-box test. Originally developed in Japan for underwater concrete. Table 5 shows the value of L- Box (H1/H2) which represents the blocking ratio and the value of T400 represents the time of concrete to reach 400 mm flow.

2.3.3 V-Funnel Test And V-Funnel at T5 Minutes Tests

To evaluate the material segregation resistance and to measure the filling ability (flowability) of SCC the V-funnel can be used. Table (5) shows test results of V-funnel. No blocking or segregation behavior observed in all mixes, and these results are within the limits pointed out in the literatures.

2.3.4 Sieve Segregation Resistance Test

To assess the resistance of (SCC) to segregation sieve segregation test is used. **Table (5)** shows the value of segregation resistance results test of (SCC) mixes.

2.4 TESTING OF HARDENING (SCC)

2.4.1 Compressive Strength

According to Iraqi specification (IQS No.348-1992), compressive strength test was carried out on 150 mm cubes by using a hydraulic compression machine with a capacity of 2000 kN. For each test average of three cubes was adopted.

2.4.2 Splitting Tensile Strength

According to the procedure outlined in Iraqi specification (IQS No.283-1995), indirect tensile strength was carried out**.** Cylindrical concrete specimens (100x200 mm) were used. In each test average of three specimens is taken.

3. RESULTS AND DISCUSSIONS

3.1 Compressive Strength

The compressive strength test results of the concrete specimens were tested at ages (28, 56 and 90 days), three cubes are tested at each age to compressive strength of self-compacting concrete with various percentages of gypsum content in fine aggregate are shown in **Table (6)** and **Figs. (1)** and **(2)** .It can be seen that for all mixes, there is an optimum SO_3 content at which the compressive strength is maximum, beyond which content the compressive strength has decreased. The present data indicates that the optimum SO_3 content for these mixes is about (0.5) % (by weight of sand) and it is equal to 3.99 % (by weight of cement) for mixes that contain limestone powder filler and it is equal to 4.01% (by weight of cement) for mixes which contain limestone powder filler and rise husk ash (RHA).

From the results of compressive strength shown in Table 6, and Fig. 1 and 2 it can be noticed that:

1. When SO_3 content in fine aggregate increases from (0.37 to 0.5%), this leads to an enhancement in compressive strength of concrete cubes in the range (5.9, 7, and 8.7%) for DL1 at ages (28, 56 and 90) days respectively.
2. When SO_3 content in fine aggregate increases from (0.37 to 1%), this leads to a diminution in compressive strength of concrete cubes in the range (5.4, 6.8 and 7.7) % for DL2 at ages (28, 56 and 90) days respectively.
3. When SO_3 content in fine aggregate increases from (0.37 to 1.5%), this produce to a diminution in compressive strength of concrete cubes in the range (8.2, 8.8 and 9.9 %) for DL3 at ages (28, 56 and 90) days respectively.

This was expected since several researchers as mention before, had referred to the presence of optimum gypsum content. The enhancement in compressive strength of the concrete can attribute to the ettringite formation, which was produced by a chemical reaction between SO_3, C_3A and water. It fills some of the voids inside the cement past and increases the strength. But more ettringite formation motives internal stresses and decreases the compressive strength (Neville, 1995) and (Al-Ameeri and Issa,2013**).**

Also, results showed that the use of 10% rise husk ash (RHA) in self-compacting concrete was the best compared with other mixes that contain limestone powder (LSP) by improving compressive strength for all sulfates contents and for all ages as shown in Fig's below .

Figs. (3) and (4) show the effect of rise husk ash (RHA) on compressive strength at ages 28 and 90 days with increment percentage as (24.6, 26.7, 29.9 and 27.1)% at 28 days and (28.5, 30.5, 30.9 and 30.9) at 90 days for levels of sulfates contents in fine aggregate (0.37, 0.5, 1.0, and 1.5)%.

The results indicated that the (SCC) with (RHA+LSP) yielded the lowest compressive strength loss when compared (SCC) with (LSP), this can be attributed to the fact of the incorporation of (RHA) in SCC mix leads to minimizes the compressive strength loss compared to mixes without (RHA). This behavior because of pozzolanic effect of (RHA) which reacts with the calcium liberated (during the hydration of cement) and contributes to densification of the concrete matrix resulting in a considerable increase in strength and reduction in permeability. Also, the grain size and pore-size refinement process associated with pozzolanic reaction can effectively reduce the microcracking and strengthen the transition zone (Neville, 1995).

3.2 SPLITTING TENSILE STRENGTH

Splitting tensile strength (indirect tensile strength) of self-compacting concrete results of the (28, 56 and 90 days) with various percentages of SO_3 content in sand are presented in **Table (7) and Figs.(5) and Fig.(6)** for different mixes. It is clear that the effect of sulfates on the indirect tensile strength is somewhat similar to that on compressive strength. For all mixes, there is an optimum SO_3% content at which the splitting tensile strength is maximum, beyond this content indirect tensile strength has decreased.

From the results of splitting tensile strength shown in **Figs. 5 and 6** it can be it can be noticed that:

1**.** When SO_3 content in fine aggregate increases from (0.37% to 0.5%), this leads to enhance in indirect tensile strength of the concrete cylinders in value of (1.2., 4.5 and 6.4 %) for DL1 at ages (28, 56 and 90) days respectively.

2. When SO_3 content bin fine aggregate increases from (0.37 to 1%), this leads to a decrease in indirect tensile strength of the concrete cylinders in the range (3.3, 3 and 2.7%) for DL2 at ages (28, 56 and 90) days respectively.

3. When SO_3 content in fine aggregate increases from (0.37% to 1.5%), this leads to a decrease in indirect tensile strength of the concrete cylinders in value of (5.6, 5 and 4.8%) for DL3 at ages (28, 56 and 90) days respectively.

These results agree with that obtained by (Alwash, 2005) and (Hussain, 2008)**.** In addition Also, results showed that the use of 10% rise husk ash (RHA) in self-compacting concrete was the best compared with other mixes that contain limestone powder (LSP) by improving splitting tensile strength loss for all sulfates contents and for all ages as shown below :-

1. When SO_3 in fine aggregate increases from (0.37% to 0.5%) this leads to an increase indirect tensile strength of the concrete cylinders in value of (4.7, 6.2, and 8.5%) for DLR1 at ages (28, 56 and 90) days respectively.
2. When SO_3 in fine aggregate increases from (0.37 to 1%), this leads to a decrease indirect tensile strength of the concrete cylinders in value of (2.4, 2.6 and 2.1%) for DLR2 at ages (28, 56 and 90) days respectively.
3. When SO_3 in fine aggregate increases from (0.37 to 1.5%) this leads to a increase indirect tensile strength of the concrete cylinders in value of (4.5, 4.0 and 3.8%) for DLR3 at ages (28, 56 and 90) days respectively.

Figs. 7 and 8 show the effect of rise husk ash (RHA) on indirect tensile strength at ages 28 and 90 days with increment percentage as (25.3, 29.7, 26.5, and 26.8%) at 28 days and (25.0, 27.5, 25.7 and 26.3) at 90 days for levels of sulfates contents in fine aggregate (0.37, 0.5, 1.0, and 1.5%).

4. CONCLUSIONS

The following conclusions can be noticed from the experimental work,-

1. With a constant superplasticizer dosage and water content, (SCC) mixes with (LSP) had a better a passing ability filling ability, and segregation resistance than (SCC) mixes with (RHA+LSP) in the fresh state.
2. There is an optimum gypsum content in which both indirect tensile strength and compressive strength are maximum, beyond this content the splitting tensile strength and compressive strength decrease. The optimum gypsum content for these mixes is about (0.5% by weight of fine aggregate) and it is equal to (3.99%) by weight of cement for mixes containing (LSP), while it is equal to (4.01% by weight of cement) for mixes containing (RHA+LSP).
3. The (SCC) which contain 10% (RHA) as a partial permutation by weight of cement in mixes contain (RHA+LSP) was found to be effective in reducing compressive strength and splitting tensile strength due to interior sulfates contents in fine aggregate beyond optimum gypsum contact as compared with mixes contain (LSP).

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Table (1): Concrete mix designations

Mixes designation	Types of filler	Curing Time (days)	SO_3 content in sand (by weight of sand) %	Total SO_3 content (by weight of cement) %
DL* 0 DL 1 DL 2 DL 3	**Limestone Powder (LSP)**	**28, 56, 90**	**0.37 0.5 1.0 1.5**	**3.74 3.99 4.96 5.93**
DLR *0 DLR 1 DLR 2 DLR 3	**Limestone Powder plus rise husk ash (LSP+ RHA)**	**28, 56, 90**	**0.37 0.5 1.0 1.5**	**3.76 4.01 4.98 5.96**

Table(2): limestone powder chemical analysis

Oxide	Content %	Oxide	Content %
SiO_2	1.34	MgO	0.13
Fe_2O_3	0.12	SO_3	1.90
Al_2O_3	0.69	CaO	55.13

Table(3) Rice husk ash chemical and physical properties[21].

Oxides of RHA	Percentage	Oxides of RHA	Percentage
SiO_2	93	AL_2O_3	0.1
CaO	1.31	P_2O_3	0.56
MgO	1.7	CL	0.36

SO_3	0.1	Fe_2O_3	0.31
K_2O	3.77	MnO	0.2
Na_2O	1.5	L.O.I	2.51

Table (4): Mix proportions

Materials	**Content**	**Limitation (Kg/m3)**
Cement (kg/m^3)	400	350-450
Fine aggregate (kg/m^3)	775	710-900
Coarse aggregate (kg/m^3)	820	750-920
Filler (kg/m^3)	100	50-150
(Water / powder) ratio	0.42	0.33-0.62
SP (Liter/100kg cement)	3	-

Table (5) Results of Fresh Properties of SSC of all Mixes

Test	**Unit**	**Mix Notation**		**Typical range of Values**
		DL	**DLR**	
Slump-flow	mm	740	680	600-800
T 50cm	sec	3	3.5	2-5
V-funnel	sec	6	7	6-12
V-funnel at $T_{5\ min.}$	sec.	7	9	+3 sec, max.
L-Box	(H2/H1)	1	0.9	0.8-1.0
SR	%	3	2	≤ 15%

Table(6): Effect of sulfate content in fine aggregate on compressive strength of SCC

Mix Notation	**SO_3 content % by weight of fine aggregate**	**Total SO_3 content % by weight of cement**	**Compressive strength (MPa) for Ages**		
			28 (days)	**56 (days)**	**90 (days)**
DL0	0.37	3.74	35.3	39.7	42.4
DL1	0.5	3.99	37.4	42.5	46.1
DL2	1.0	4.96	33.4	37	39.1
DL3	1.5	5.93	32.4	36.2	38.2
DLR0	0.37	3.76	44.0	50.1	54.5
DLR1	0.5	4.01	47.4	54.3	60.0
DLR2	1.0	4.98	43.4	47.5	51.2
DLR3	1.5	5.96	41.2	46.4	50.0

Table(7) Effect of sulfate content in fine aggregate on splitting tensile strength of SCC

Mix Notation	SO_3 content % by weight of fine aggregate	Total SO_3 content % by weight of cement	Splitting tensile strength (MPa) for Ages		
			28 (days)	56 (days)	90 (days)
DL0	0.37	3.74	3.36	3.58	3.76
DL1	0.5	3.99	3.40	3.74	4.0
DL2	1.0	4.96	3.25	3.47	3.66
DL3	1.5	5.93	3.17	3.4	3.58
DLR0	0.37	3.76	4.21	4.52	4.70
DLR1	0.5	4.01	4.41	4.80	5.1
DLR2	1.0	4.98	4.11	4.4	4.6
DLR3	1.5	5.96	4.02	4.34	4.52

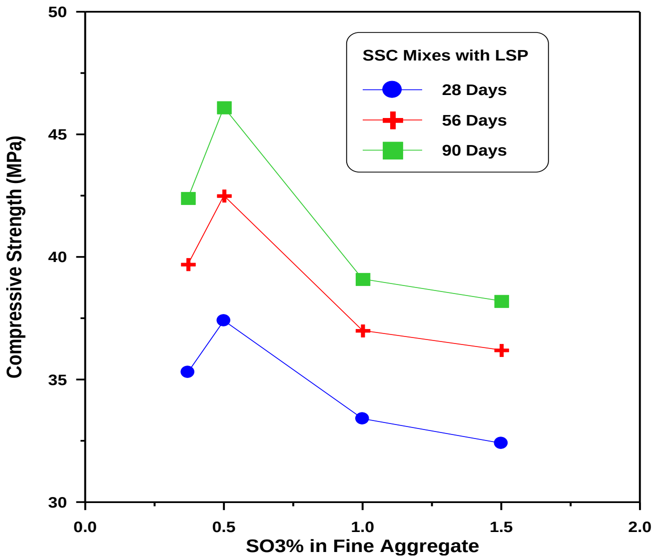

Fig. 1: Relationship between Compressive Strength and SO_3 content in fine aggregate at different age with limestone powder filler.

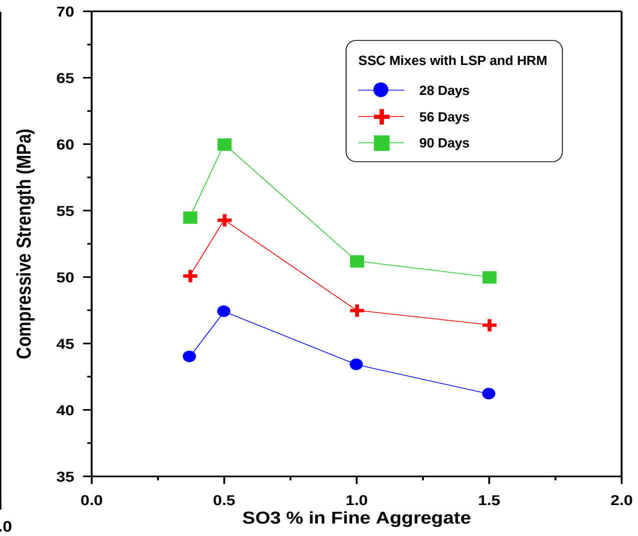

Fig. 2: Relationship between Compressive Strength and SO_3 content in fine aggregate at different age with limestone powder filler and rise husk ash (RHA).

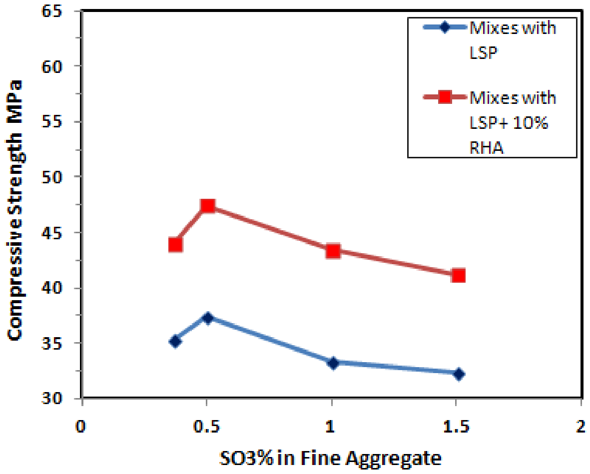

Fig.3 Comparison of Compressive Strength Results of Mixes with and without RHA at age 28 days

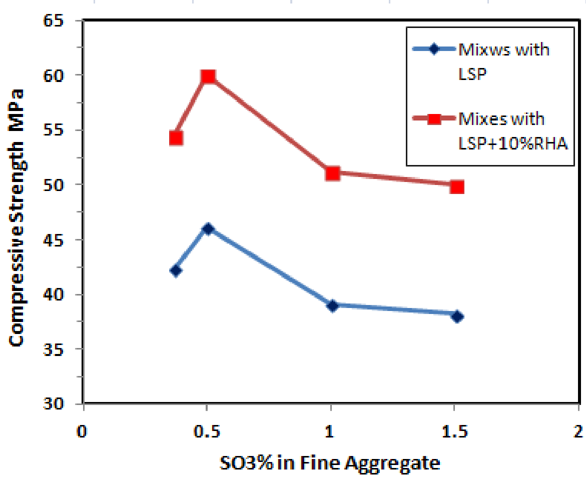

Fig.4 Comparison of Compressive Strength Results of Mixes with and without RHA at age 90 days

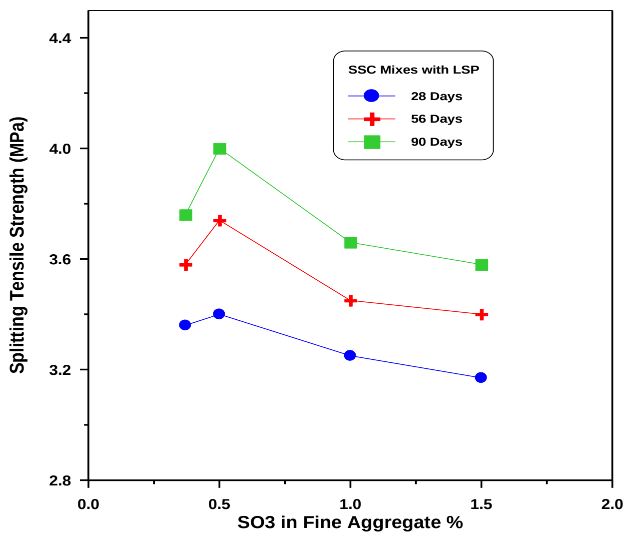

Fig. 5: Relationship between splitting tensile strength and SO_3 content in fine aggregate at different age with limestone powder filler.

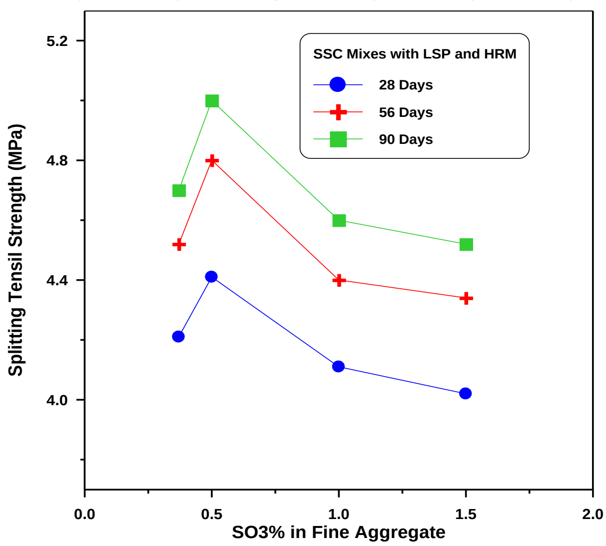

Fig. 6: Relationship between splitting tensile strength and SO_3 content in fine aggregate at different age with limestone powder filler and rise husk ash (RHA).

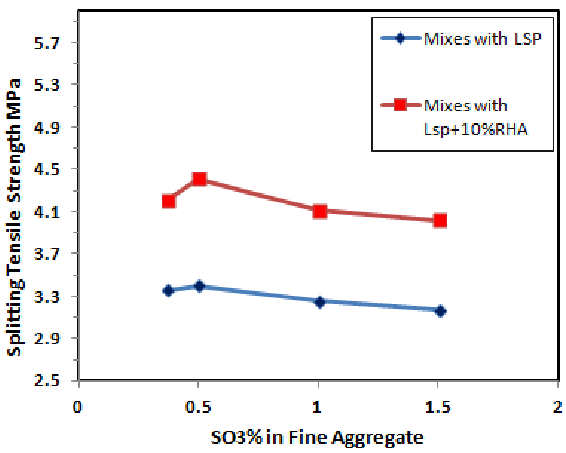

Fig.7 Comparison of Splitting Tensile Strength Results of Mixes with and without RHA at age 28 days

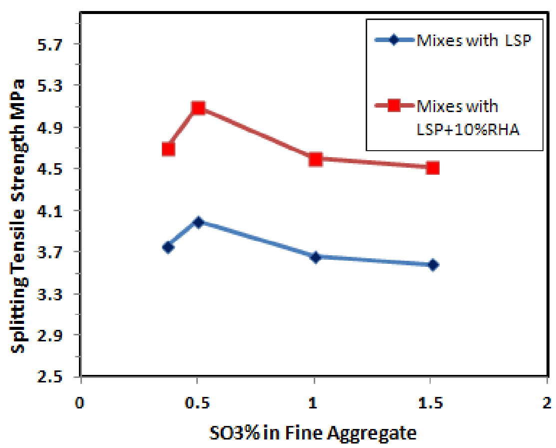

Fig.8 Comparison of Splitting Tensile Strength Results of Mixes with and without RHA at age 90 days