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DEVELOPING SELF-CURING CEMENT SAND MORTAR USING SODIUM POLYACRYLATE

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Abstract: As the sustainable construction intends to optimize the use of natural resources and because of the important of water resources, the self -curing could be assigned as sustainable strategy.This study introduces self-curing cement sand mortar with specific properties concern compressive strength, consistency by using sodium polyacrylate as additive. The sodium polyacrylate has wide ranges of uses for many purpose, for its ability to absorbe water and its good mechanical, physical and chemical properties. This study assesses the possibility of using it with traditional raw materials for developing self-curing high workability cement sand mortar which could be useful in many construction applications such as ferrocement slabs and building partitions. The study assigned the possibility of using sodium polyacrylate in gel fashion within cement sand mix as efficient additives for self-curing, as well as its positive effect upon compressive strength and consistency of cement sand mortar comparing with specimens cured with traditional technique of immersing them within water for week. Specimens of sodium polyacrylate to cement ratio (S/C) between 1 to 5 % as gel (with constant water cement ratio, W/C=50%) developed significant strength improvement in absent of any curing techniques, compressive strength upgrading ratio assigned between 1.12 to 1.25 with respect to specimens cured by water for seven days while excellent ratio (1.37) associated with positive effect of specific W/C ratio beside sodium polycraylate effect.

Keywords: *Cement Sand Mortar, Lightweight, Compressive Strength, Consistency, Self-Curing.*

تطوير مونة اسمنت رمل ذاتية المعالجة باستخدام الصوديوم بوليكريلايت

الخلاصة: كون الهندسة المستدامة تهتم بالاستغلال الأمثل للموارد الطبيعية و كون مصادر المياه من أهمها، يمكن تقديم المعالجة الذاتية كستراتيجية للاستدامة. الدراسة الحالية تقدم مونة اسمنت رمل ذاتية المعالجة بخواص نوعية متمثلة بمقاومة الانضغاط و القوام و ذلك باستخدام مادة الصوديوم بوليكريلايت كمضاف. ان استخدام مادة الصوديوم بوليكريلات تمثل بطيف من التطبيقات و ذلك بسبب تميزه بقدرة امتصاص الماء و الاحتفاظ به بالإضافة لخواصه الميكانيكية و الفيزيائية و الكيميائية الجيدة. تم تقييم إمكانية استخدامه مع المواد الانشائية التقليدية لتطوير مونة اسمنت رمل ذاتية المعالجة مع قابلية تشغيل عالية يمكن الاستفادة منها في العديد من التطبيقات الانشائية مثل بلاطات الفيروسمنت و كذلك إمكانية استخدامها في انتاج القواطع الانشائية. بينت الدراسة ان استخدامها في الخلط بنسبة من الاسمنت بصورة جل كمادة للمعالجة الذاتية كان فعالا جدا أدى لزيادة ملحوظة بالمقاومة و تحسين بقابلية التشغيل بالمقارنة بنماذج تم معالجتها بالطريقة التقليدية متمثلة بالغمر بالماء لفترة أسبوع. نماذج مصنعة باستخدام نسبة تتراوح بين (1%- 5%) من مادة الصوديوم بوليكريلات كجل الى الاسمنت بنسبة ماء خلط ثابتة (50%) اظهرت نسب تحسين لمقاومة الانضغاط تتراوح بين (1.12-1.25) بالمقارنة بنماذج

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معالجة بطريقة تقليدية بالغمر بالماء لمدة سبعة ايام بينما افضل نسبة تحسين كانت 1.37 والتي تضمنت تاثير مادة الصوديوم بوليكريلات بالاضافة الى تاثيرتحديد نسبة ماء الخلط.

1. Introduction

Investigation of the best alternatives of using materials in construction industry is behind the expansion in the researches of construction materials. Many studies carried out to improve cement mortar properties.

As the sustainable construction intends to optimize the use of natural resources [1] and when water resources have special important, self -curing strategy could be assigned as significant technique in region where water is not sufficiently available.

Curing should be undertaken in accordance with good practice. The curing regime should be applied as soon as finishing is complete. To avoiding costed techniques required for curing, introducing self-curing construction material presented a challenge.

The Guide to concrete curing, ACI-308 [2] defined self-curing as the process of providing internal water out of mixing water to be used for hydration of cement. Using of curing additive for self curing techniques is very important topic as the resources of water are getting valuable every day.

Some studies achieved relate to self-curing of concrete. In 2016 Basil [3] investigated the use of water-soluble polymeric glycol as self-curing agents. Influence of using polymeric glycol on mechanical properties and workability of concrete had been evaluated and prove that the strength is higher when compared with concrete cured traditionally. The best dosage was found to be 1%.

In 2014 Rajendran [4] studied self curing concrete using polyethylene glycol. The cubes compressive strength were higher than of concrete cured by full and sprinkler curing methods, for M40 grade of concrete, the percentage increase in compressive strength at 28 days curing is 8.7 and 17.2 respectively. The cylinders split tensile strength also were higher than that of the conventionally cured specimens.

The previous studies highlight promising of additional work. Mortar with specific properties concern strengths, lightweight, consistency and self-curing ability by using sodium polyacrylate as additive had been investigated. The study showed the possibility of using sodium polyacrylate gel as efficient self-curing additives, as well as its positive effect upon compressive strength and consistency of cement sand mortar. The study also showed that sodium polyacrylate powder could be used in scope of light weight mortar developing.

1.1 Study Scope

The aim of this investigation is to evaluate the use of sodium polyacrylate as a multi effect agent equivalent to internal curing and superplasticizer additive efficiency which intends to improve self-curing and workability characteristics. Compressive strength and consistency of cement mortar at different percentages of sodium polyacrylate evaluated and compared with conventional mortar.

2. Experimental Investigation

The test program concerns obtaining and analyzing data regarding the compressive strength and consistency for cement sand mortar which include the effectiveness of sodium polyacrylate as additive. The main variable which expected to influence the performance of mortar as self-curing agent is sodium polyacrylate ratio as gel verse sodium polyacrylate ratio as powder. Water cement ratio was investigated to assign acceptable water cement ratio working with adopted additive which is highly water locking. Fifteen cement sand mortar mixes type have been carried out, the specimens of cubes 50x50x50 mm were tested according to ASTM C109-07 [5] to investigate their performance. As the effect of curing so much limited for seven day, the study focused on specimens tested in seven days. Tests were achieved by using a compression machine of (20 ton), Plate 1.

The flow table test of cement mortar intends calculating the amount of water amount for gauging for conducting strength test of cement sand mortar. They conformed to ASTM C1437-07 [6] which gave clear idea on the workability and consistency of cement sand mortar, Plate 2.

The main variables are mortar compressive strength, mortar consistency and density reduction. The variables are studied in scope of using sodium polyacrylate in two different fashions, gel and powder.

Plate 1. Compression test machine

Plate 2. Flow table

3. Materials Properties

Locally available materials, which were used in producing, cement sand mortar included:

3.1Cement

In this study ordinary Portland cement was used. Chemical analysis and main compounds of the used cement beside physical properties were conformed to the Iraqi specification number (5/1984) [7], Tables 1 and 2 . Cement setting time test was accomplished according to ASTM C191[8]. The whole required quantity was brought to the laboratory and stored in a dry place.

Table 1. Cement physical properties

Compressive strength, N/mm²	
3 – day	16.2
7 – day	25.12
Setting time, h:minutes	
Initial setting	47.01
Final setting	511
Soundness autoclave expansion %	0.31
Fineness, Specific surface area (by Blaine method), cm²/gm	2610

Table 2. Cement chemical compositions

Compositions	%
Silicon Dioxide, SIO2	30.02
Aluminum Trioxide, AL2O3	2.85
Ferric Oxide, Fe2O3	5.21
Calcium Oxide, CaO	32.01
Magnesium oxide, MgO	3.06
Sulphate, SO3	1.07
potassum oxide, K2O	0.66
Sodium Oxide, Na2O	0.18
Insoluble Residue	1.14
Loss on Ignition	2.98
Freelime	0.74
Tricalcium Silicate	3.77
Dicalcium Silicatr	26.22
Tricalcium Aluminates	2.67

3.2 Fine Aggregate

Natural normal weight sand of Al-zubaer quarry was used as the fine aggregate throughout this work. Its grading and fineness modulus were satisfied the requirements of the Iraqi specification number (45/1984) [9].

3.3 Mixing Water

Ordinary pure tap water was used for mixing and curing of control specimens which cured by immersing them into water for seven days.

3.4 Sodium Polyacrylate

Sodium polyacrylate is a sodium salt of polyacrylic acid . This polymer has the ability to absorb as much as 200 to 300 times its mass in water and consider as superabsorbent polymer.

The superabsorbent polymer chemistry history backs to the 1960s when America United States Department of Agriculture was introduced the first superabsorbent polymer [10]. Sodium polyacrylate and its polyacrylic acid have a wide field of commercial and industrial applications. These include cable coating water proofing, artificial snow [11], disposable diapers [12] and others. Sodium polyacrylate in different fashion are shown in Plate 3. Generally, in scope of materials source, it is consider as advanced polymer production characteristics by specific properties, as listed in Table 3.

Table 3. Sodium polyacrylate typical properties

Item	Description
Chemical formula	(C3H3NaO2)n
Color	white powder
Purity	Free alkali Sulfate, Not more than 0.48% as SO4
Molar mass	Low molecular weight polymers Not more than 5.0%
Density	1.22 g/cm3

A-Expanded balls b- Powder c- Gel

Plate 3. Sodium polyacrylate in different fashions.

A gel of solidified style is formed when water is poured onto sodium polyacrylate powder [13]. The significant mechanism of Sodium polyacrylate associated with self curing concept represented by locking as much as 200 to 300 times its mass of water and free to feedback mortar structure by water required throughout curing process. Chemical composite of Sodium polyacrylate gel denoted in Fig. 1.

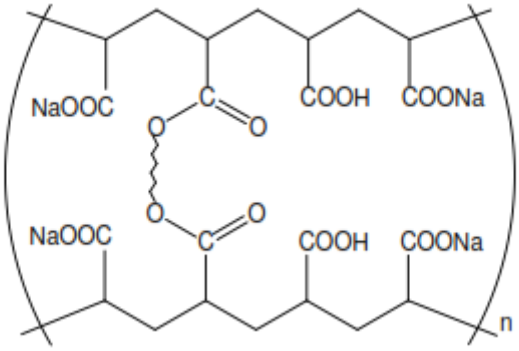

Figure 1. Chemical composite of Sodium polyacrylate gel [14].

4. Mortar Mixture Proportions

Mixing proportions are listed in Table 4. All mixes have the same cement sand ratio (1:3) The W/C ratio in this study ranges between 0.35 and 0.8 in order to investigate mortar consistency as well as strength. Two series of specimens prepared, the first one included sodium polyacrylate powder adding to mixes initially within cement powder and determined as weight ratio of cement weight while in the second specimens series, the sodium polyacrylate added as gel after treating its powder by water before mixing, The gel weight is determined as weight ratio of cement weight.

Control specimens which were produced without any additive of sodium polyacrylate, they were cured by immersing them by water for seven day as traditional curing limited for seven days and in order to investigate considered additive as self curing agent as smart replacement of curing process, tests concerned with specimens of 7 days

Two approaches have been considered for adopting W/C ratio, the first one depend on using constant ratio in order to investigate S/C ratio effect on compressive strength, while the second approach depend on using various W/C ratios in order to assign applicable consistency of different S/C ratios beside them effect on compressive strength.

The various fashion of used additive (Gel and Powder) in addition to different S/C ratio considered in this study as shown in Table 4 intended to assign positive effect of utilizing it with specific ratio as self curing agent otherwise hardened cement sand mortar is transformed into sponge week structure.

Table 4. Details of Mortar Mixes

No.	Mix Designation*	S, Sodium polyacrylate fashion	W/C (Water cement ratio %)	Cement sand ratio	S/C (Sodium polyacrylate cement ratio %)
1	MN	None	50	1:3	0.00
2	MG1	Gel	50	1:3	1.00
3	MG2	Gel	47	1:3	3.00
4	MG3	Gel	45	1:3	5.00
5	MG4	Gel	35	1:3	10.00
6	MG5	Gel	50	1:3	3.00

7	MG6	Gel	50	1:3	5.00
8	MG7	Gel	50	1:3	10.00
9	MP1	Powder	50	1:3	0.50
10	MP2	Powder	60	1:3	0.70
11	MP3	Powder	60	1:3	1.00
12	MP4	Powder	60	1:3	1.30
13	MP5	Powder	60	1:3	1.50
14	MP6	Powder	60	1:3	3.00
15	MP7	Powder	80	1:3	3.00

*Designation
MN Mortar without soudium polyacrylate
MGi Mortar with soudium polyacrylate as Gel
MPi Mortar with soudium polyacrylate as Powder

5. Result and Discussion

The experimental study in the current research program focused on compressive strength of cement sand mortar and observed consistency.
A typical failure mode dedicated in plate 4, the shown mode customary for all tested specimens which have different considered variables.

Plate 4 failure mode

Test results from the experimental program presented and compared in order to investigate the significance of the considered test variables.
The experimental results were listed in Table 5, specimens of S/C ratio between 1 to 5 % as gel (with constant water cement ratio, w/c=50%) assigned significant strength improvement in absent of any curing techniques, strength ratio assigned between 1.12 to 1.25 with respect to specimens cured by water for seven days (MN), these ratios clearly denoted enhancing of cement sand hardened structure due to self curing process.

Slightly effect indicated on density of tested specimens, average density ratio was 0.99 for spectrum ratios of sodium polycryalate gel while the effect more efficient for using sodium polycryalate powder. Density reduction ratio changed from 0.96 to 0.8 when S/C ratio changed between 0.7% and 3% which them corresponding to strength reduction ratio range between 0.91 to 0.61 for MP2 and MP6 samples.

Table 5. Results Details

No.	Mix Designation	Sodium polyacrylate fashion	S/C (%)	Mortar Consisntecy	Compressive strength (MPa)	Density (kN/m3)	Strength ratio MG/MN or MP/MN	Density ratio MG/MN or MP/MN
1	MN	None	0.00	Applicable	22.2	21.08	1.00	1.00
2	MG1	Gel	1.00	Applicable	27.75	20.98	1.25	1.00
3	MG2	Gel	3.00	Applicable	28.5	21.35	1.28	1.01
4	MG3	Gel	5.00	Applicable	28.6	20.90	1.29	0.99
5	MG4	Gel	10.00	Applicable	30.4	21.56	1.37	1.02
6	MG5	Gel	3.00	Applicable	26.43	20.84	1.19	0.99
7	MG6	Gel	5.00	Applicable	24.8	20.86	1.12	0.99
8	MG7	Gel	10.00	Non-Applicable	17.87	20.14	0.80	0.96
9	MP1	Powder	0.50	Applicable	21.27	20.71	0.96	0.98
10	MP2	Powder	0.70	Applicable	20.2	20.20	0.91	0.96
11	MP3	Powder	1.00	Applicable	24.7	19.78	1.11	0.94
12	MP4	Powder	1.30	Applicable	27.4	19.86	1.23	0.94
13	MP5	Powder	1.50	Applicable	25.5	19.83	1.15	0.94
14	MP6	Powder	3.00	Applicable	13.5	16.87	0.61	0.80
15	MP7	Powder	3.00	Non-Applicable	4.8	15.77	0.22	0.75

5.1 Mortar Compressive Strength

The effect of use sodium polycraylate gel as self-curing additive is shown in Fig. 2 , the strength increasing for specimens without curing with respect to these of curing specimens were 1.25, 1.19 and 1.12 for different S/C ratio varying as 1% , 3% and 5% (MG1, MG5, and MG6) respectively, while strength dropping indicated for 10% (MG7) for the same W/C ratio (50%) that could be related to relatively high extraction of sodium polycraylate particles after costuming of locked water. The maximum improvement assigned for specimen of 10%, S/C ratio and 35%, W/C ratio (MG4). The excellent upgrading ratio (1.37) associated with positive effect of limited w/c ratio beside sodium polycraylate effect.

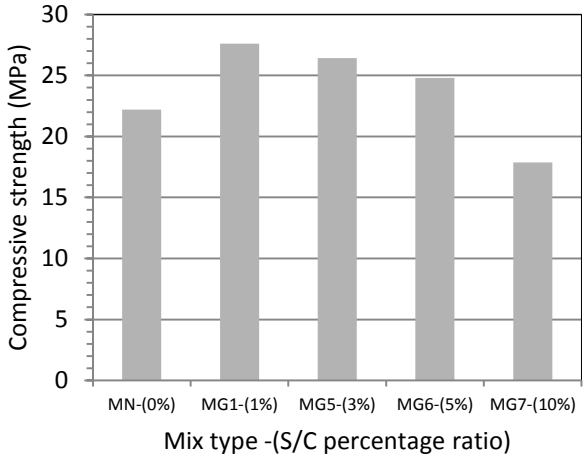

Figure 2. Effect of sodium polycraylate gel as self-curing additive for different S/C ratio

The comparisons of used sodium polyacrylate as self-curing agent for specific S/C ratios (1%, 3%) are shown in Fig.3 which is demonstrated that the compressive strength had been improved when additive used as gel rather than powder, the strength increment ratios are 1.25 - 1.19 verse 1.1 - 0.61, respectability.

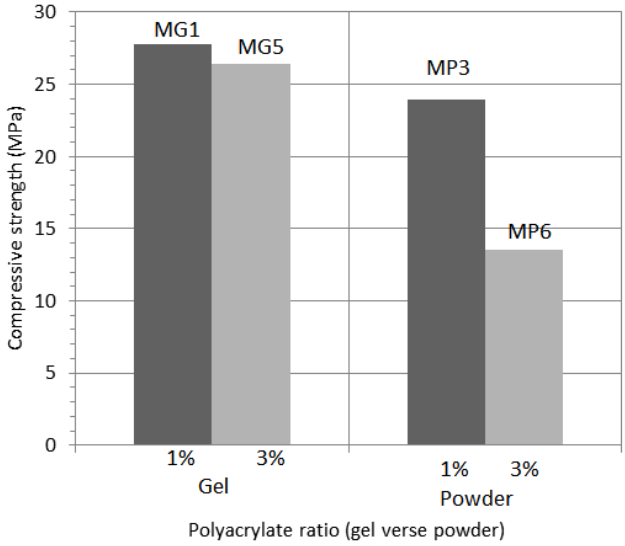

Figure 3. Variation of compressive strength with Sodium Polyacrylate ratio (gel verse powder).

Fig.4 clearly assigned the effect of sodium polyacrylate gel within specimens without curing upon mortar compressive strength, it is showed that there is an optimum ratio for S/C which is 1% (for constant W/C ratio, 50%) beyond it the strength had been dropped. The strength decreased from 27.6 MPa to 17.85 MPa as S/C ratio increased from 1% to 10%.

It is important to be verified that because of extreme water locking of sodium polyacrylate as powder, high W/C ratio required for applicable consistency and so compressive strength dropped-off in samples of high S/C ratio and/or high W/c ratio as noted in MP1, MP2, MP6,and MP7 as shown in Table 5.

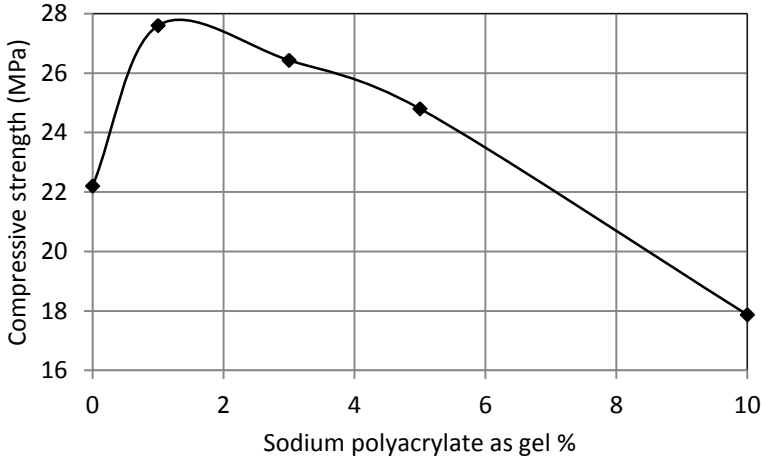

Figure 4. Variation of compressive strength for w/c =50% of different sodium polyacrylate gel ratio (without curing)

5.2 Mortar Consistency

Figs. 5 and 6 assign that the mixes of high dose of sodium polyacrylate need more water cement ratio in order to get acceptable consistency because of high absorbed and water locked within used sodium polyacrylate.

The range of water cement ratio were (35 to 50%) when sodium polyacrylate used as gel while the range extremely change (60 to 80) % as sodium polyacrylate added initially within mixes as powder.

The outcomes demonstrate that in case of using sodium polyacrylate gel, the w/c ratio will be in reasonable range while using sodium polyacrylate powder need high and unreasonable water cement ratio.

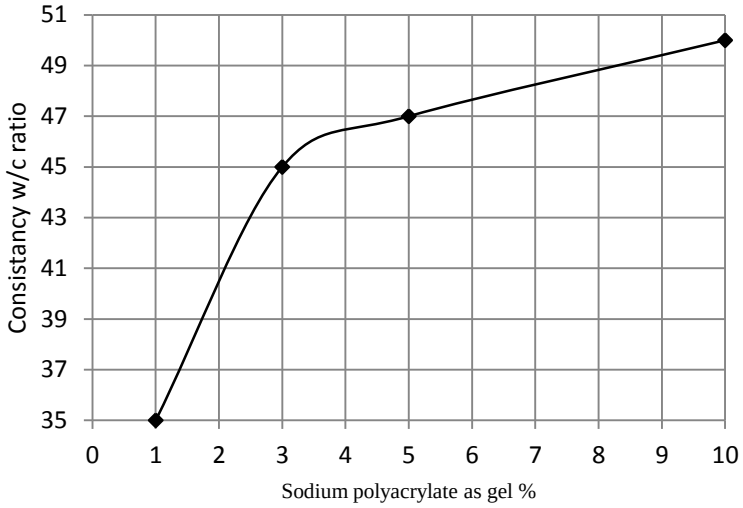

Figure 5. Variation of W/C for applicable mortar consistency verse Sodium Polyacrylate gel ratio

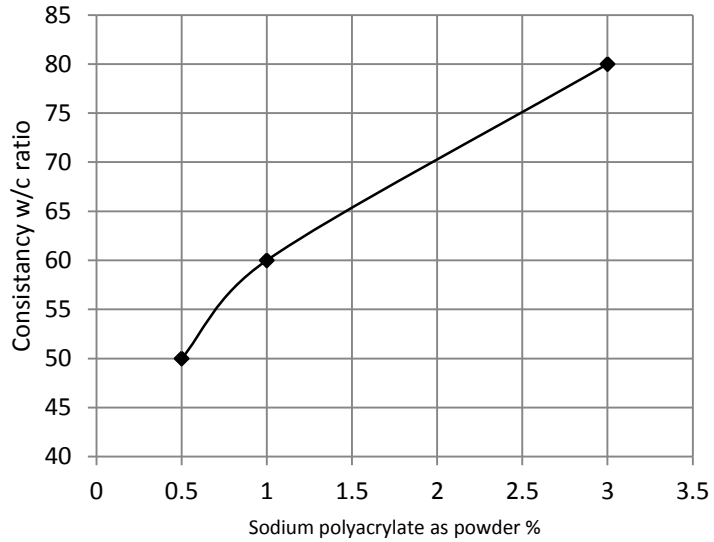

Figure 6. Variation of W/C for applicable mortar consistency verse sodium polyacrylate powder ratio

The most significant negative effect on density dedicated in specimens with Sodium polyacrylate powder. Density reduction ratio changed from 0.96 to 0.8 when S/C ratio

changed between 0.7% and 3% which them corresponding to strength reduction ratio range between 0.91 to 0.61 for MP2 and MP6 mixes, the density reduction could be related to relatively high extraction of sodium polycraylate particles after costuming of locked water .

For applicable mixes of acceptable consistency, the reduction of (W/C) beside sodium polyacrylate cement ratio (S/C) as gel maximized sodium polyacrylate effect. Fig. 7 indicated that the high strength had been noted 30.4 MPa with strength increasing ratio 1.37 for MG4 specimens which have minimum W/C ratio 35% and maximum S/C ratio 5% for applicable consistency.

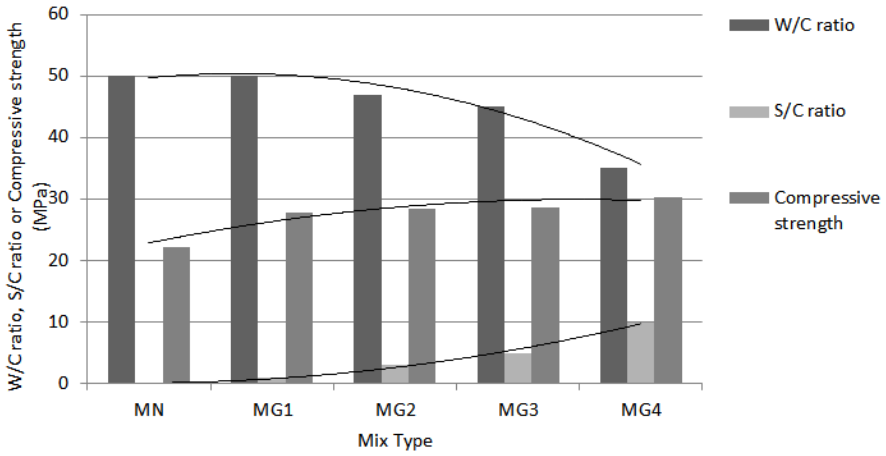

Figure 7. Inter- effect of W/C and S/C as gel upon cement sand mortar compressive strength

6. Conclusions

1. In scope of strength improving, the using of sodium polyacrylate gel is more efficient than using of sodium polyacrylate powder.
2. The sodium polyacrylate is efficient agent as self-curing additives, the strength increasing for specimens without curing with respect to that of cured specimens were 1.25,1.19 and 1.12 for different gel ratio varying as 1% , 3% and 5%, respectively.
3. The S/C ratio of sodium polyacrylate gel was limited for 1% as workability improving not applicable beyond it, which it assigned as best ratio among the ratios used in this work, beyond it the strength will be dropped. The strength decrease from 27.6 MPa to 17.85 MPa as additive ratio increase from 1% to 10%.
4. The adding of sodium polyacrylate initially within mix as powder is unuseful practically as the acceptable consistency need high water cement ratio and so dropping in strength.
5. Sodium polyacrylate gel is improved water locking in cement sand mortar as excellent self-curing agent and improved its workability as superplasticizer agent.
6. Sodium polyacrylate powder could be useful in light weight mortar productions utilities in non- structural applications such as partitions. Density reduction ratio changed from 0.96 to 0.8 when S/C ratio changed between 0.7% and 3% which them corresponding to strength reduction ratio range between 0.91 to 0.61 for MP2 and MP6 mixes

7. For applicable mixes of acceptable consistency, the reduction of water cement ratio (W/C) beside sodium polyacrylate gel ratio (S/C) up to 5% is maximized sodium polyacrylate effect on compressive strength.

Abbreviations

f_{cu}	Cubic compressive strength
E	modulus of elasticity
R	Density ratio
γ	unit weight of material
W/C	Water cement ratio
S/C	Sodium polyacrylate cement ratio
MN	Mortar designation without soudium polyacrylate
MG_i	Mortar with soudium polyacrylate as Gel
MP_i	Mortar with soudium polyacrylate as Powder

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