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گۆڤاری زانکۆی سلێمانی ئەیلول ٢٠٠٦ بەرگ ٩(١) ژمارە(١)بەشی A لاپەرە {٥٩–٦٨}

Properties of High-Strength Fibrous Concrete With Crushed Stone as Coarse Aggregate

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Abstract

The influence of volume fraction of steel fiber, amount of crushed stone and type of mixes on the compressive, splitting tensile and flexural strength (modulus of rupture) of high-strength concrete have been studied in this investigation.

Results showed that the increase of (1%) in volume fraction of steel fiber cause an increase in the compressive, splitting tensile and flexural strength (modulus of rupture) by 13.3%, 67.5% and 40.6% respectively for natural aggregate, while increase by 4.8%, 46.7% and 29.8% for crushed stone aggregate respectively . Also one can use crushed stone instead of natural gravel especially in places where no natural gravel is available.

Keywords:- High-strength, Steel fiber, Crushed stone, Concrete

Notation

f'_c : Concrete compressive strength (MPa)

f_{ct} : Concrete splitting tensile strength (MPa).

f_r : Concrete modulus of rupture (MPa).

V_f : Volume fraction of steel fiber (%)

Introduction

Concrete having cylinder compressive strength exceeding 41 MPa is designated as high-strength concrete[1]. In recent years, the use of high-strength concrete has become increasingly popular. It is technically and economically feasible to produce ready-mixed high-strength concrete using conventional methods and materials. The high-strength concrete offers significant economic and architectural advantages over ordinary concrete and also is suited for special constructions that required high durability and leads to the design of smaller sections, this in turn reduces the dead weight allowing longer spans and more usable area of building[2].

High-strength concrete is a brittle material. The increase in concrete strength reduces the ductility. This inverse relation between strength and ductility is a serious drawback for the use of high-strength concrete and a compromise between these two characteristics of concrete can be obtained by adding discontinuous fibers [3]. The idea of using discrete ductile fibers to reinforce brittle materials such as concrete is not new with many studies having been undertaken over the past four decades. Early studies by Romualdi and Batson [4]

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in the United States in the early 1960 indicated that the tensile strength of concrete can be improved by providing suitably arranged and closely spaced wire reinforcement.

Many researches haad been carried out on the use of crushed aggregate or crushed stone concrete containing fibers [5-9], and others on the properties of normal and high-strength fiber reinforced concrete[10-16].

Aggregate has an important role in the matrix, because about three-quarter of the mixture include coarse aggregate, and since there are many places were natural gravel is not sufficiently available, so one can replace it by crushed stone, or now due to the increasing new projects in Iraq especially in Iraq Kurdistan Region, making concrete will requires great quantities of gravel. This will cause a great reduction of this material during the next few years in the region which will have a bad effect on the development and also on the economy. The main objective of this investigation is to study the effect of volume fraction of steel fiber, crushed stone content as coarse aggregate on the compressive, splitting tensile and flexure (modulus of rupture) strengths of high-strength fibrous concrete.

Experimental program

The test program consists of casting and testing 90 standard cylinder specimens (150mm *300mm) to study the compressive and splitting tensile strength of concrete. Also, 45 prism specimens (150mm *150mm *500mm), were tested under two-point loads (third point loading) to study the modulus of rupture of high-strength concrete.

The specimens were divided into 5 groups as shown in Table (1). Mix A (1:1.5:1.5) contains three subgroups to study the volume fraction of steel fibers with different crushed stone aggregate contents and their effects on compressive, splitting tensile strengths and modulus of rupture, while mix B (1:1.5:2) and C (1:2:2) contain one group for each mix to study the effect of volume fraction of steel fibers on the strength of high-strength concrete with crushed stone as coarse aggregate.

Materials

Ordinary Portland cement: The cement used in the investigation from Marden Turkish Company with fineness 3140cm^2/gm (Blaine method), initial setting time140 minutes and final setting time was 3.5 hours (Vicat apparatus).

Natural sand: The sand used from Khankey pit (Duhok Government) having a fineness modulus 2.74 and specific gravity equal to 2.7 with good gradation.

Natural gravel: The gravel with maximum size 9.5mm and specific gravity equal to 2.71 from Khankey pit was used as coarse aggregate.

Crushed stone (limestone): Lime as coarse aggregate, near Lumana village in Duhok was used with the following properties: In general it is of white color, medium rough-surface, angular shape, absorption 2.07%, specific gravity 2.66 and loss of ignition equal to 43.07.

Steel fibers: Smooth steel fibers were used of 0.2mm in diameter and 20mm in length (aspect ratio=100) from National British Company, with ultimate tensile strength of 1150 MPa. High water-reducer (superplastisizer) millamin-10: and drinking water

Casting and curing

Rotary concrete mixer with 0.1 m^3 were used for mixing the concrete, also an electric vibrator used for compaction. Aggregate were mixed with cement dry inside the mixer for nearly one minute, then water were added to the mixture after re-solved the super-plasticizer powder in it, spreading the steel fibers by hand inside the mixer to avoid balling and to attain a homogenous mixture.

The moulds which are used were oiled first. The cylinder specimens were cast in three layers and each layer compacted by the vibrator until no further air bubbles appeared on its surface, while the beam specimens were casted in two layers and compacted as the same manner. After 24 hours the specimens were demoulded and submerged in clean fresh water for 28 days.

Testing specimens Compressive strength testing:

The cylinder specimens were placed vertically under test, then capped by the machine caps and the load was applied without shock and increasing continuously at the constant rate (0.5MPa/s) until failure. Fig.(1) shows the testing specimen under the compression machine.

Splitting tensile strength testing:

In this test, a concrete cylinder specimen was placed with its axis horizontal between the platens of a testing machine, and the load increased until failure by indirect tension in the form of splitting along the vertical diameter occurred.

Flexural strength testing:

In this test, a concrete beam was subjected to flexural using symmetrical two point loading until failure occurred. Fig.(2) shows the specimen under the rupture testing machine.

Table 1: Details of Tested Specimens
First letter refers to type of the mix.
Second letter refers to type of aggregate.
N: Natural aggregate. C: Crushed stone aggregate

Speci	V_f %	Slump (mm)	Remarks
AN1	0	31	Mix(A)ratio 1:1.5:1.5 (natural aggregate), w/c = 0.35+1.5% superplastisizer
AN2	0.5	25	
AN3	1	20	
ANC1	0	24	50% Crushed stone content
ANC2	0.5	20	
ANC3	1	16	
AC1	0	22	100% crushed stone content
AC2	0.5	17	
AC3	1	14	
BC1	0	18	Mix(B)ratio 1:1.5:2 (100% crushed stone content), w/c =0.35+1.5% superplastisizer
BC2	0.5	14	
BC3	1	11	
CC1	0	14	Mix(C)ratio 1:2:2 (100% crushed stone content), w/c= 0.35+1.5% superplastisizer
CC2	0.5	11	
CC3	1	7	

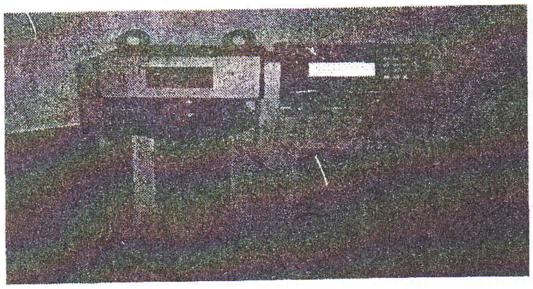

Fig. (1): Compression machine

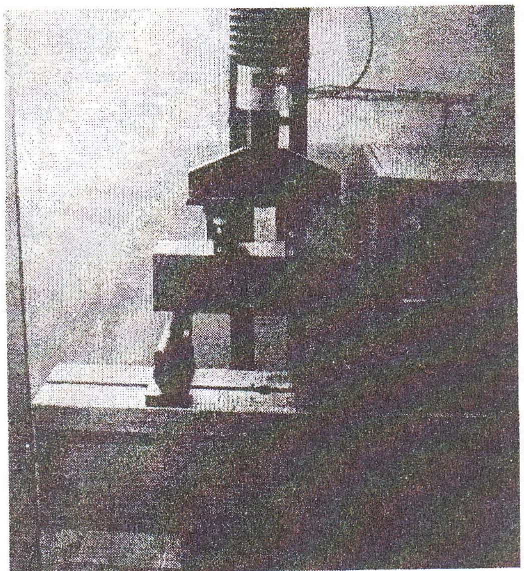
Fig. (2): Rupture testing machine

Results and Discussion

The values of ultimate compressive, splitting tensile and flexural strengths obtained from experimental tests and ACI formulas are listed in Table (2). All strengths were increased by increasing of volume fraction of steel fiber for both natural gravel and crushed stone concrete as shown in (Figs.3, 4 and 5). The compressive strength was increased by (13.3%, 9.8% and 4.8%) and splitting tensile strength was increased by (67.5%, 56.9% and 46.7%) while the flexural strength (modulus of rupture) was increased by (40.6%, 33.7% and 29.8%) for crushed stone content (0%, 50% and 100%) respectively. This means that the compared with the second one as shown in Table (1). Also results showed that the average increase in compressive strength of 13.3% for natural gravel and 4.8% for crushed stone when volume fraction of steel fiber increased from 0.0% to 1.0% and for tensile strength 67.5% & 46.7%, while the flexural strength is increased by 40.6% and 29.8% for both natural gravel and crushed stone.The effect of steel fiber on the natural gravel high-strength concrete was more than the crushed stone high-strength concrete, this is due to suitable workability for first mix. The increase in compressive strength was small when compared with splitting tensile and flexural strengths due to different mechanisms in three cases and this is a good agreement with the results of the other researches [6, 8, 10]. Also these figures indicate that the concrete strengths increased by increasing the crushed stone content. Figures (6, 7 and 8) show a comparison between mixes (A, B and C) for different volume fraction of steel fibers and show that the first mix has greater strength compared with the other two mixes, because the cement/aggregate ratio is the higher one. At last, Figs. (9, 10 and 11) show the relationship between the ratios of (f'_c/f_{ct}, f'_c/fr and f_{ct}/fr) and volume fraction of steel fibers (V_f) for different percentages of crushed stone content. These figures indicate that the f'_c/f_{ct} and f'_c/fr ratios decreased by increasing V_f, while the f_{ct}/fr ratio increased by increasing V_f and that is due to the compressive strength being less affected than the splitting tensile and flexural strengths by V_f. Table (2) also show the computed values of splitting tensile strength and modulus of rupture for concrete using ACI-Code formulas. The values which are obtained from testing of specimens in general were higher than the values computed from ACI- formulas especially for steel fibrous concrete, because these formulas do not take into consideration the contribution of steel fibers, this contribution exceeds 54%for splitting tensile concrete strength and 38% for modulus of rupture, while one can be applied these formulas for high-strength crushed stone concrete without steel fibers. Modulus of rupture test results of HSC beams showed that, beams without fiber had little ductility, and once the maximum tensile stress was reached, the beams failed suddenly after the occurrence of the first crack without warning. The failure characteristics were however, completely changed as a result of the addition of fibers. After the occurrence of initial cracking, the specimen did not fail suddenly. The randomly oriented fibers crossing the cracked section resisted the propagation of cracks and separation of the section. This caused an increase in the load-caring capacity beyond the first cracking

Table 2: Compressive, Splitting Tensile Strengths and Modulus of Rupture of the Tested Specimens.

Spec.	V	f'_c	f_{ct}	ACI f_{ct}	f_{ct}/ ACI	f_r	ACI f_r	f_r/ ACI	f'_{ct} /f_t	f'_c /	f_{ct} /
AN1	0	42.	3.75	3.82	0.98	6.36	6.09	1.04	11.2	6.6	0.5
AN2	0.	45.	4.98	3.97	1.25	8.45	6.33	1.33	9.10	5.42	0.6
AN3	1	47.	6.28	4.07	1.54	8.94	6.48	1.37	7.58	5.33	0.6
ANC1	0	47.	4.11	4.05	1.01	7.01	6.45	1.09	11.46	6.71	0.5
ANC2	0.	49.	5.35	4.15	1.28	8.60	6.61	1.30	9.25	5.76	0.6
ANC3	1	51.	6.45	4.24	1.52	9.37	6.76	1.38	8.02	5.52	0.6
AC1	0	55.	4.71	4.38	1.07	7.49	6.99	1.07	11.74	7.38	0.6
AC2	0.	56.	5.75	4.44	1.29	8.91	7.09	1.25	9.89	6.38	0.6
AC3	1	57.	6.91	4.49	1.54	9.72	7.16	1.35	8.39	5.97	0.7
BC1	0	55.	3.98	4.38	0.907	6.93	6.99	0.99	13.14	7.55	0.5
BC2	0.	55.	4.89	4.4	1.11	8.02	7.01	1.14	10.99	6.70	0.6
BC3	1	56.	6.12	4.44	1.37	8.92	7.08	1.25	9.12	6.26	0.6
CC1	0	49.	3.81	4.14	0.92	6.12	6.60	0.92	12.96	8.08	0.6
CC2	0.	50.	4.26	4.2	1.01	6.70	6.69	1.00	11.92	7.58	0.6
CC3	1	52.	5.82	4.27	1.36	7.62	6.8	1.12	9.00	6.88	0.6

$f_{ct} = 0.59\,(f'_c)^{1/2}$ ……………………(MPa)

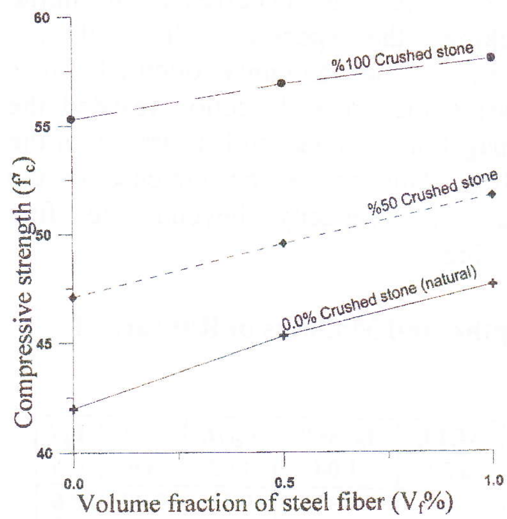

Fig. 3: Compressive strength of concrete and volume fraction of steel fiber relationship

$f_r = 0.94\,(f'_c)^{1/2}$ ……………………(MPa)

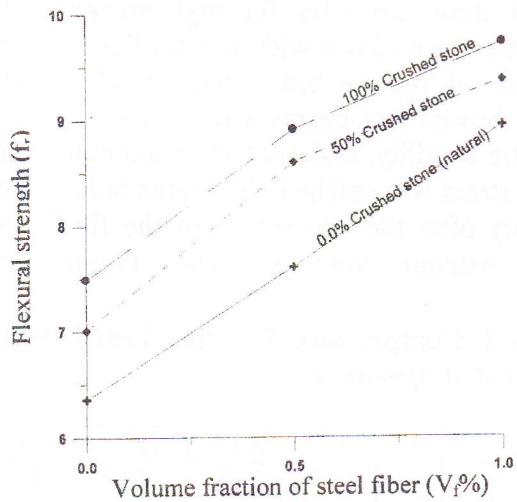

Fig. 5: Flexural strength of concrete and volume fraction of steel fiber relationship

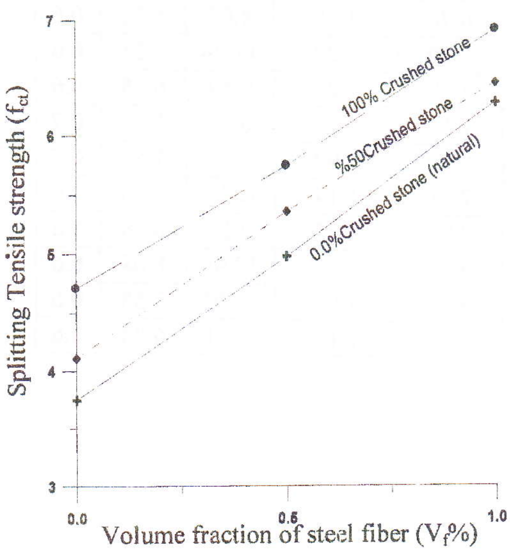

Fig. 4: Splitting tensile strength of concrete and volume fraction of steel fiber relationship

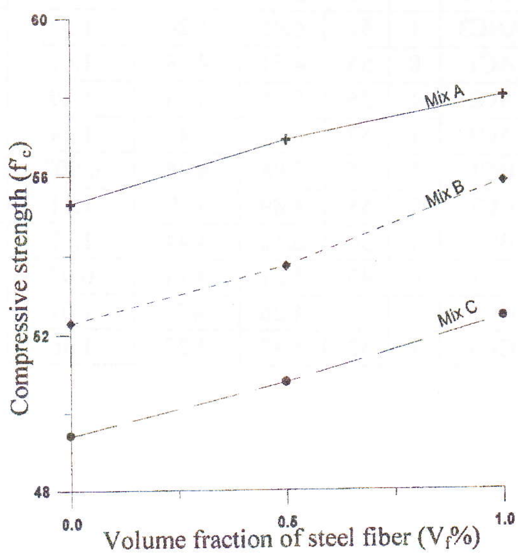

Fig.(6): Compressive strength of concrete and volume fraction of steel fiber relationship

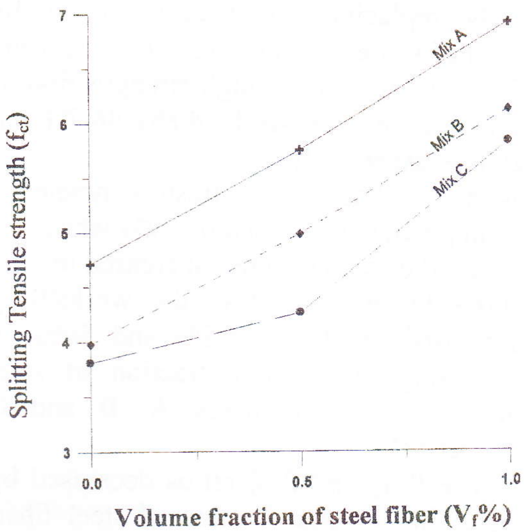

Fig.(7): Splitting tensile strength of concrete and volume fraction of steel fiber relationship

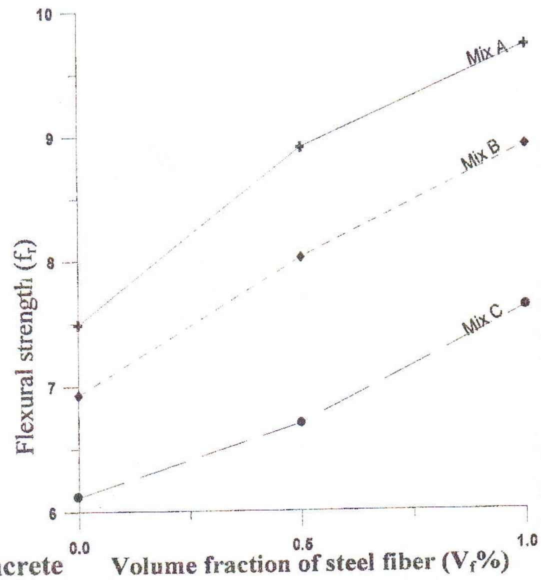

Fig. (8): Flexural strength of concrete and volume fraction of steel fiber relationship

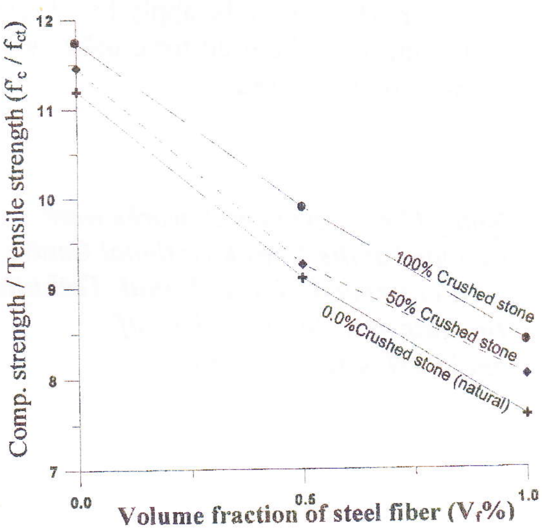

Fig. (9): f'_c / f_{ct} & V_f% relationship for different percentages of crushed stone content

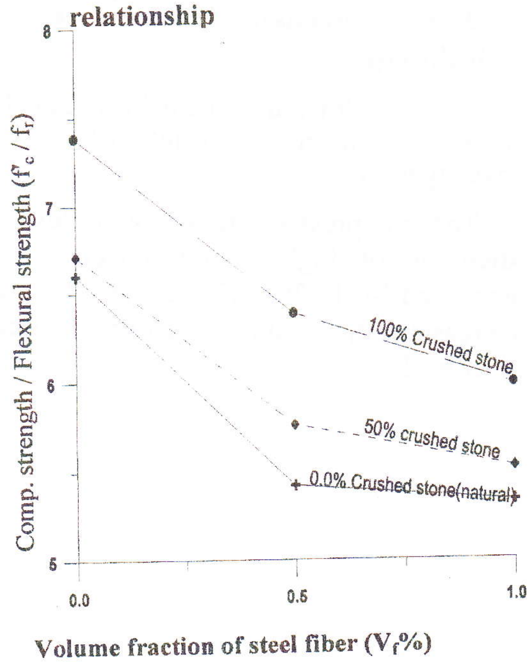

Fig. (10): f'_c / f_r & V_f% relationship for different percentages of crushed stone content

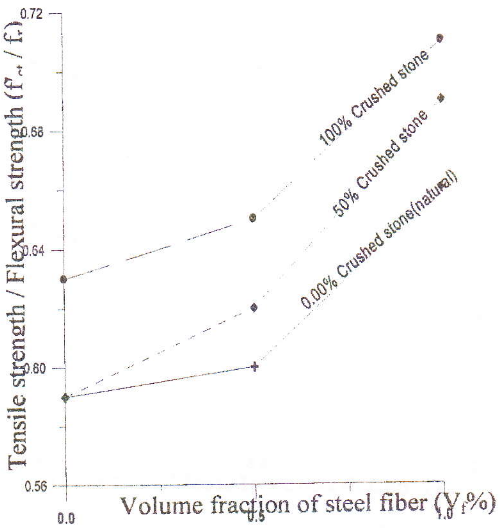

Fig. (11): f_{ct} /f_r & V_f% relationship for different percentages of crushed stone content

Conclusions

The following conclusions can be drawn from the results of this investigation:

1- The compressive, tensile and flexural strengths of high-strength concrete are improved by 13.3%, 67.5% and 40.6% at increasing the volume fraction of steel fiber by 1%.

2-By replacing the natural gravel by crushed stone, the compressive, tensile and flexural strengths of high-strength fibrous concrete are increased by 4.8%, 46.7% and 29.8% respectively.

3-The workability of fresh concrete (slump value) decreased by 29% when the crushed stone content increased by 100% for mix A. Also the workability decreased by 36%, 38.8% and 50% by increasing the volume fraction of steel fiber by 1% for mixes A, B and C respectively.

4- The f'_c/f_{ct} and f'_c/f_r ratios decreased by increasing volume fraction of steel fiber, while the f_{ct} / f_r ratio is increased, because of the different mechanisms of failure in all three cases.

5- The ACI-Code formulas for computing splitting tensile strength (f_{ct}) and modulus of rupture (f_r) can not be apply for HSFC. However, it can be used for crushed stone high-strength concrete.

***Note:** The experimental works were executed at the Dohuk National Centre for Construction Labs., Dohuk Technical Institute and Dohuk college of engineering laboratories.*

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ڕەوشتی كۆنكریتی بەهێز و دارێژراو بە ریشاڵی ئاسنین

شلێر سەعید قادر

پەیمانگای تەكنیكی دهۆك/ هەرێمی كوردستان - عێراق

پوختە

لەم لێكۆڵینەوەیەدا كارتێكردنی ڕێژەی قەبارەیی ریشاڵی ئاسنین و بری بەردی شكاو لەسەر بەرهەڵستی كۆنكریت لە ڕووی (پەستاندن، راكێشان و چەمانەوە) ڕوون كراوەتەوە. ئەنجامەكان دەریان خست كە زیادكردنی ریشاڵی ئاسنین بە ڕێژەی ١٪ دەبێتە هۆی زیادبوونی بەرگریپەستان، راكێشان و چەمانەوە بەڕێژەی (١٣,٣، ٦٧,٥ و٤٠,٦٪)بەدوایەكدا بۆ چەویسروشتی و (٤,٨، ٤٦,٧ و ٢٩,٨٪) بۆ چەوی بەردی شكاوا. وەلەكۆتاییدا دەتوانرێت بەردی شكاو لە بری چەو بەكاربهێنرێت لە كۆنكرێتی بەهێزدا بە تایبەتی لەو شوێنانەی كە چەوی سروشتیان كەمە.

مقاومة خرسانة عالية المقاومة و المعززة بالألياف الفولاذية والتي تحتوي على الحجر المكسر

شلير سعيد قادر

المعهد التقني دهوك/ اقليم كوردستان -العراق

الخلاصة

تم في هذا البحث دراسة تأثير النسب الحجمية للألياف الفولاذية و كمية الحجر المكسر على خواص خرسانة عالية المقاومة في حالات الضغط، الشد و الانثناء. وقد أظهرت النتائج بان زيادة الألياف الفولاذية بنسبة حجمية ١٪، تؤدي الى زيادة مقاومة الضغط، الشد و الانثناء بنسب (١٣,٣، ٦٧,٥ و ٤٠,٦ ٪) على التوالي عند استعمال الحصى الطبيعي، و عند استعمال حجر المكسر بنسب (٤,٨، ٤٦,٧ و ٢٩,٨ ٪). وفي النتيجة فان بالإمكان استخدام الحجر المكسر بدلا من الحصى الطبيعي في إنتاج خرسانة عالية المقاومة في الأماكن التي تعاني من عدم توفر الحصى الطبيعي.

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وەرگرتن ٢٠٠٥/٤/١٢ دا پەسەندكردن ٢٠٠٥/١٢/٣.