A Study on Stabilization of Base Course Material with Portland Cement

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ABSTRACT

The base road material sources are distributed in many locations of Erbil Governorate. Generally most of them having sound engineering properties, so it dose not need to stabilized chemically. But recently in several constructed roads rutting phenomenon are appeared soon after construction and usage. For this reason in this study, materials in four quarries are taken and treated with Portland cement (0% to 7% contents). Engineering properties and unconfined compressive strength are studied. The results indicated that the unconfined compressive strength increased more than 10 times (from1069 kPa to 11238kP) for Kasnazan materials, about 3 times (from 1999 kPa to 5881 kPa) for crushed (Kalak) gravel, about 4 times (from 793 kPa to 3337 kPa) for Zurgazraw materials and more than 3 times (from 1744 kPa to 6640 kPa) for crushed (Darabezmara) stone. It was found that the optimum cement content to be equal to 2.9%, 0.6%, 4.8% and 0.6% of dry weight of Kasnazan, Kalak (crushed gravel), Zurgazraw, and Darabzmara (crushed stone) materials respectively.

Keywords: soil stabilization, cementations, Portland cement.

دراسة على تثبيت مواد طبقة الأساس بالسمنت البورتلاندي

الخلاصة:

ان مصادر مواد طبقة اساس الطرق متوزعة في محافظة اربيل في عدة مواقع. بصورة عامة معظم هذه الموادلها خصائص هندسية صحيحة (سليمة)، لذا لا تحتاج الى تثبيتها كيمياويا. لكن في الأونة الأخيرة في العديد من الطرق المشيدة لوحظ نشوؤ الأخاديد بعد التشييد و استخدامه. لهذا السبب تم في هذه الدراسة أخذ المواد في اربعة مقالع و تم تعاملها (بخلطها) مع السمنت البورتلاندي (بنسب ما بين 0% الى 7%). تم دراسة الخصائص الهندسية و مقاومة انضغاط المحصور. أظهرت النتائج بأن مقاومة الأنضغاط ازدادت اكثر من عشرة اضعاف (من 1069 الى 11238كيلوباسكال) لمواد كسنزان و حوالي ثلاثة اضعاف (من 1999 الى 5881 كيلوباسكال) لمواد كلك (حصى مكسر) و حوالي اربعة اضعاف (من 793 الى 3337كيلوباسكال) لمواد زوركزراو و اكثر من ثلاثة اضعاف (من 1744 الى 6640 كيلوباسكال) لمواد داره بزمارة (حجر مكسر). و قد وجد بأن محتوى السمنت المثلى تقدر ب 2.9% و 0.6% و 4.8% و 0.6% من الوزن الجاف لمواد كسنزان و كلك و زوركزراو و داره بزماره على التوالي.

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INTRODUCTION

Overview

As new quarry locations are opened, and new materials are used, it becomes more and more important to carefully monitor these materials to insure that the required specifications are being properly met. Recent studies of base course materials have been one of many areas of focus[1]. It is important that managers of local street and highway departments know that all gravel is not the same. You can tell a little about it by visual inspection or by running your hands through the material, but the quality of the aggregate only can be determined through testing [2].The thickness of base course needed in any particular road-construction application is a function of the load-carrying capability of the base course and the underlying sub-grade soils as well as the thickness of overlying pavement[3].The highway engineer is continually facing the problem of increasing the strength and stability of the natural soil in order to improve its load-bearing properties. In addition to compaction, soil characteristics may sometimes be further improved by applying one of a number of procedures known collectively as soil stabilization techniques[4]. The most common improvements achieved through stabilization include; better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and strength. The strength and stiffness of a soil layer can be improved through the use of additives like cement, lime, bitumen … etc, to permit a reduction in design thickness of the stabilized material compared with an unstabilized or unbound material.

Mechanical stabilization are usually method are used being materials engineering properties are sound in Kurdistan Region, while in other parts of Iraq chemical stabilization are required to improve their properties. For this reason so many research works conducted(7,8).

Stabilization

Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil. In the broadest sense, soil stabilization is the alteration of any property of a soil to improve its engineering performance. According to Portland Cement Association (PCA) cement-treated base (CTB) has provided economical, long lasting pavement foundations for over seventy years [4].

A cement-treated base provides excellent support for asphalt surfaces. The stabilized base material is stronger, more uniform and more water resistant than an unstabilized base, loads are distributed over a larger area and stresses on the sub-grade are reduced. The use of cement stabilized bases such as soil-cement, cement treated aggregate base, or full-depth recycling actually reduce the occurrence of base and sub-grade failure-related cracking [5].

The purpose of the stabilization design is to select the optimum combination of geological material and stabilizer that will provide the required strength and durability to ensure that the structural capacity of the layer is adequate (but not excessive as this could lead to other problems) over the design life of the road. This requires that the correct type of stabilizer to be used for the specific material and that a sufficient quantity of stabilizer added[6].

Testing methodology

This research characterizes the materials used as base course material and cement stabilization of these materials. Four quarries were selected for this purpose, namely, crushed gravel from Kalak (38 kilometers North West of Erbil city center) quarry, crushed lime stone from Darabzmara (34 kilometers North East of Erbil city center) rock quarry, gravel and sand deposits from Kasnazan (12.5 kilometers North East of Erbil city center), and Zurgazraw (30 kilometers South West of Erbil city center) quarries. gravel and sand deposit Laboratory tests were conducted to evaluate their physical properties, strength and durability characteristics. Cement treating consisted of adding 3, 5, and 7 percent of weight of dry sample and seven days curing. Table (1) shows the tests and the methods applied in this research.

Table(1) Tests versus test method

Physical		**Strength**		**Durability**		**Chemical**	
Test	**Method**	**Test**	**Method**	**Test**	**Method**	**Test**	**Method**
Particle size distribution	ASTM C136 & ASTM C117	California Bearing Ration (CBR)	ASTM D1883	Abrasion	ASTM C131	Organic Mater Content	BS 1377 (No. 8)
Atterberg Limits	ASTM D4318	Unconfined Compressive Strength	ASTM D558	Soundness	ASTM C88	Sulphate Content (SO3)	BS 1377 (No. 9)
Specific gravity and Absorption	ASTM C127 & ASTM C128			Freezing - Thawing	ASTM D558	Total Soluble Salt	Earth Manual of U.S. Bureau
Optimum moisture content (OMC)&maximum dry density (MDD) (Untreated)	ASTM D1557					pH Value	BS 1377 (No. 11)
OMC & MDD (Treated)	ASTM D558					Gyps. Content	Dilution

Result analysis

Material characteristics

Laboratory tests which are carried out in Highway Laboratory of Civil Engineering Department of University of Salahaddin- Hawler of material characterization conducted included particle size distribution, Atterberg limits, specific gravity, absorption, and moisture-density relations. Table (2) through (6).

Table (2) shows the particle size distribution of materials which indicate that the particle size distribution of all material sources are within the limits of Iraqi specifications and ASTM gradation for base course material[9,10]. Kalak material has more medium and fine particles than Kasnazan material. Kasnazan material has diversion from ASTM gradation requirements. All other physical characteristics of all materials shown in Table (3) to Table (6) met the specifications requirements.

Table (2) Particle size distribution

Sieve Size	Percent Passing (%)					
	Kasnazan	Kalak	Zurgaziraw	Darabz-mara	Iraqi [9] Specifi-cation	ASTM[10] specific-ation
2 in. (50.0mm)	100	100	100	100	100	100
1.5 in. (37.5mm)	94	100	97	100	100	95–100
1 in. (25.4mm)	83	96	88	95	80 –100	–
3/4 in. (19.0mm)	71	90	78	86	–	70–92
1/2 in. (12.7mm)	58	68	64	70	50–80	–
3/8 in. (9.5mm)	46	57	54	60	–	50–70
No.4 (4.75mm)	30	46	37	34	30–60	–
No.8 (2.36mm)	24	36	31	24	–	–
No.10 (2.0mm)	22	34	30	22	–	–
No.30 (0.6mm)	17	23	24	16	–	12–25
No.40 (0.42mm)	15	21	21	13	10–30	–
No.50 (0.30mm)	12	17	17	11	–	–
No.200 (0.075)mm	5	10	7	6	5–15	0–8

When using crushed gravel the percentage passing the 0·075 (No. 200) sieve shall be 5-12% according to SORB, 2003 specification

Table (3) Atterberg limit results, and classification of these quarry materials according to AASHTO and USCS

Source	Liquid limit, LL%	Plastic limit, PL%	Plastic index, PI%	AASHTO[11]	USCS
Kasnazan	–	–	NP	A-1-a	GP-GM
Kalak	22	17	5	A-2-4	GW-GC
Zurgazraw	26	20	6	A-2-4	GW-GC
Darabzmara	19	14	5	A-2-4	GP-GC

Iraqi sp. Limit	25 Max	–	4 Max	–	–

Table (4) Specific gravity and absorption

Source	Bulk Specific Gravity	Bulk Specific Gravity(SSD)	Apparent Specific Gravity	Water Absorption (%)
Kasnazan	2.45	2.52	2.62	2.75
Kalak	2.36	2.46	2.60	3.84
Zurgazraw	2.27	2.39	2.57	6.01
Darabzmara	2.31	2.47	2.63	5.16

Table (5) Chemical test results

Source	Granular material sub-base course according to Iraqi specification				
	pH measurement	Organic materials content, %	Gypsum content%	Sulphate content(SO3)%	Total soluble salts%
Kasnazan	7.31	0.84	0.50	0.043	0.48
Kalak(crushed gravel)	7.77	0.54	0.59	0.024	0.38
Zurgazraw	7.81	0.39	0.25	0.026	0.37
Darabzmara(crushed stone)	7.74	–	0.227	0.105	0.242
Iraqi Sp. Limit	–	(2) max	(10.75) max	(5) max	(10) max

Table (6) Los Angeles abrasion and soundness results

Source	Abrasion loss according to Iraqi specification (%)	Soundness (%)
Kasnazan	18	0.91
crushed gravel	18	2.47
Zurgazraw	19	4.92
Crushed stone	22	14.79
Iraqi Sp. Limit[#]	45 max	18 max

Optimum moisture ontent (OMC) and maximum dry density(MDD)

Optimum moisture content (OMC) and maximum dry density (MDD) relations for the selected materials are shown in Figure (1). It shows that Kasnazan material gives the highest dry density at the lowest optimum moisture content while Zurgazraw material have the lowest dry density at optimum moisture content of 6.2%. This relationship of dry density versus moisture content after treating with

Portland cement are changed in quantity and pattern as shown in Table (7) and Figure (3). Increasing cement content caused significant increase in dry density of Kasnazan material, while for other materials, this leds to decrease in their dry densities. Any increment in percentage of cement increase both MDD and in OMC except for the case of Kasnazan materials, which showed contradicting result of OMCs. To compare treated materials for maximum dry density (MDD) and optimum moisture content (OMC) based on specified cement content, Figure (4) shows these variations. It is clear that Kasnazan material has the highest MDD and the Zurgazraw material the lowest. The OMC of all materials was close to each other except for Kasnazan which had Lower OMC of Kasnazan was attributedto its non-plasticity characteristics, because it is clear that the OMC of clayey materials or aggregates with clay is higher than silty material or aggregates with silt. An increase in percentage of cement for all materials, resulted in an increase in OMC.

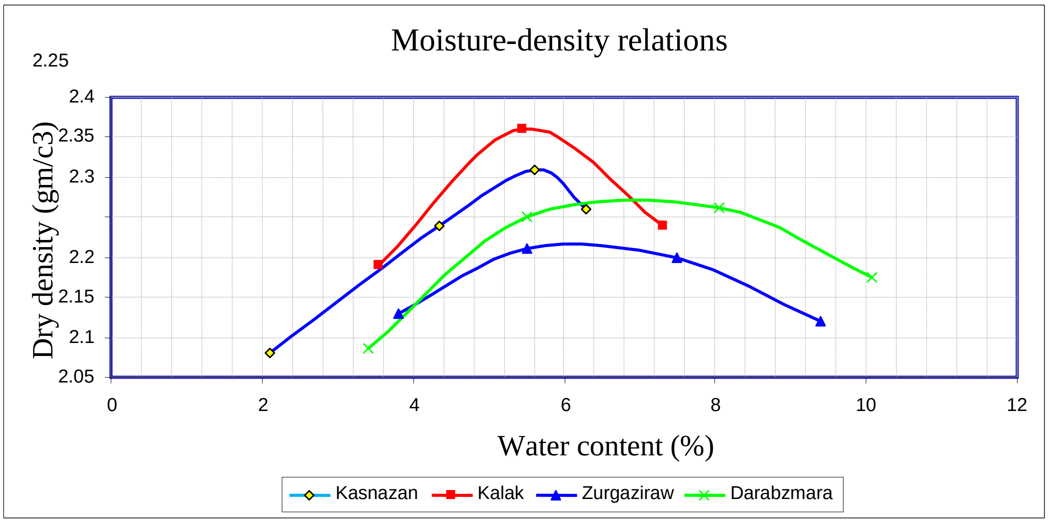


Figure (1) Dry density variation with moisture contents of natural (0% cement content materials)

The optimum cement content for these four quarries determined from minimum UCS suggested by PCA of 300 psi alone. The values were 2.9%, 0.6%, 4.8%, and 0.6% by dry weight of sample for Kasnazan, Kalak, Zurgazraw, and Darabzmara materials respectively.

Strength Properties

The OMCs are utilized for preparing samples of unconfined compressive strength (UCS). Unconfined compressive strength (UCS) test results presented in Table (8) and Figure (5). Generally, an increase in cement content gave rise to unconfined compressive strength(UCS). Kasnazan material showed the highest strength (more than 10 times of its untreated material) with increase in cement content more than 4%. Kalak and Darabzmara materials are close in this aspect and Zurgazraw material less affected by increase in cement content. Untreated (0%) samples showed low UCSs.

Table (7) Moisture-density relations of treated and untreated materials

Source	OMC (%)	MDD(gm/cc)
Kasnazan		
0% cement content	5.6	2.31
%3 cement content	6.7	2.338
%5 cement content	6.4	2.353
%7 cement content	6.0	2.353
Kalak		
0% cement content	5.6	2.36
%3 cement content	8.0	2.258
%5 cement content	8.3	2.265
%7 cement content	8.1	2.271
Zurgaziraw		
0% cement content	6.2	2.216
%3 cement content	7.4	2.183
%5 cement content	7.9	2.201
%7 cement content	8.7	2.207
Darabzmara		
0% cement content	6.9	2.273
%3 cement content	7.6	2.223
%5 cement content	8.0	2.263
%7 cement content	8.8	2.274

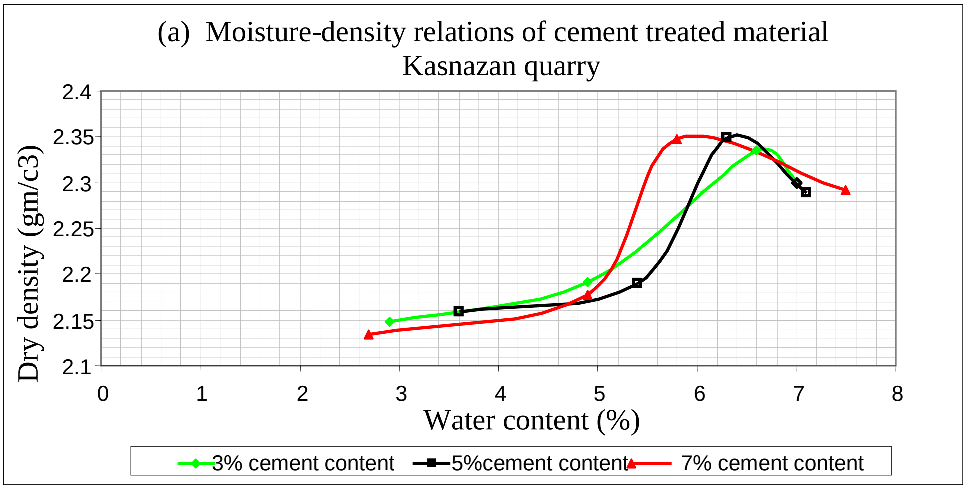
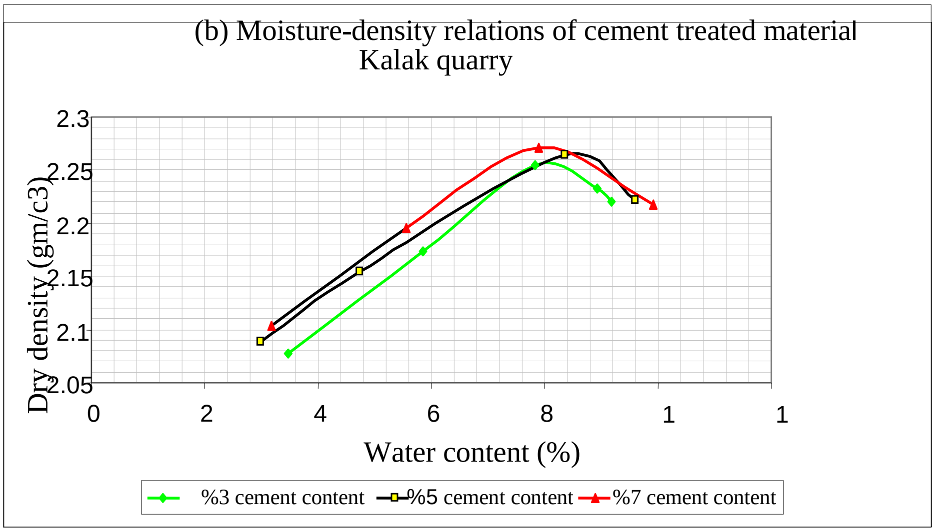
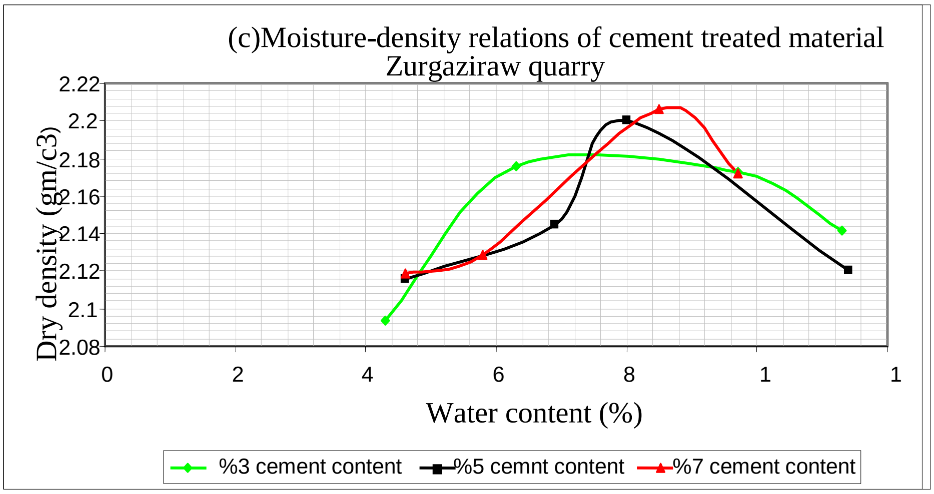


Figure (3) To be Continued





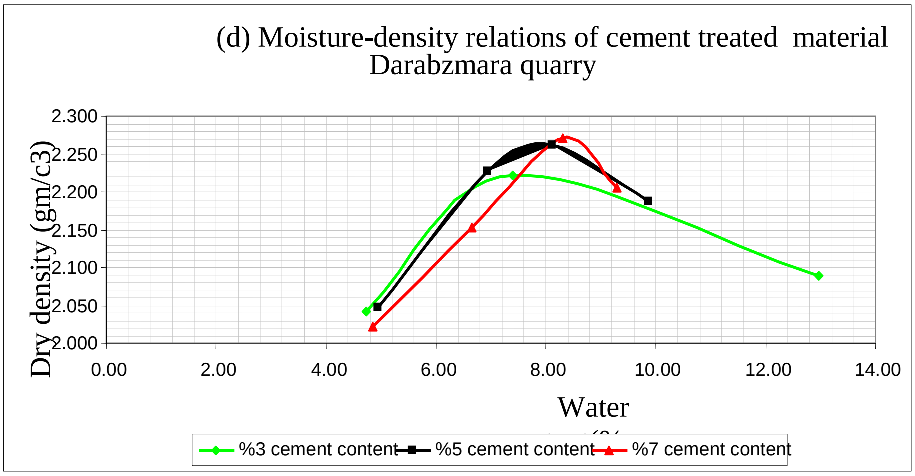


Figure (3) Dry density variation with moisture contents with cement content increments

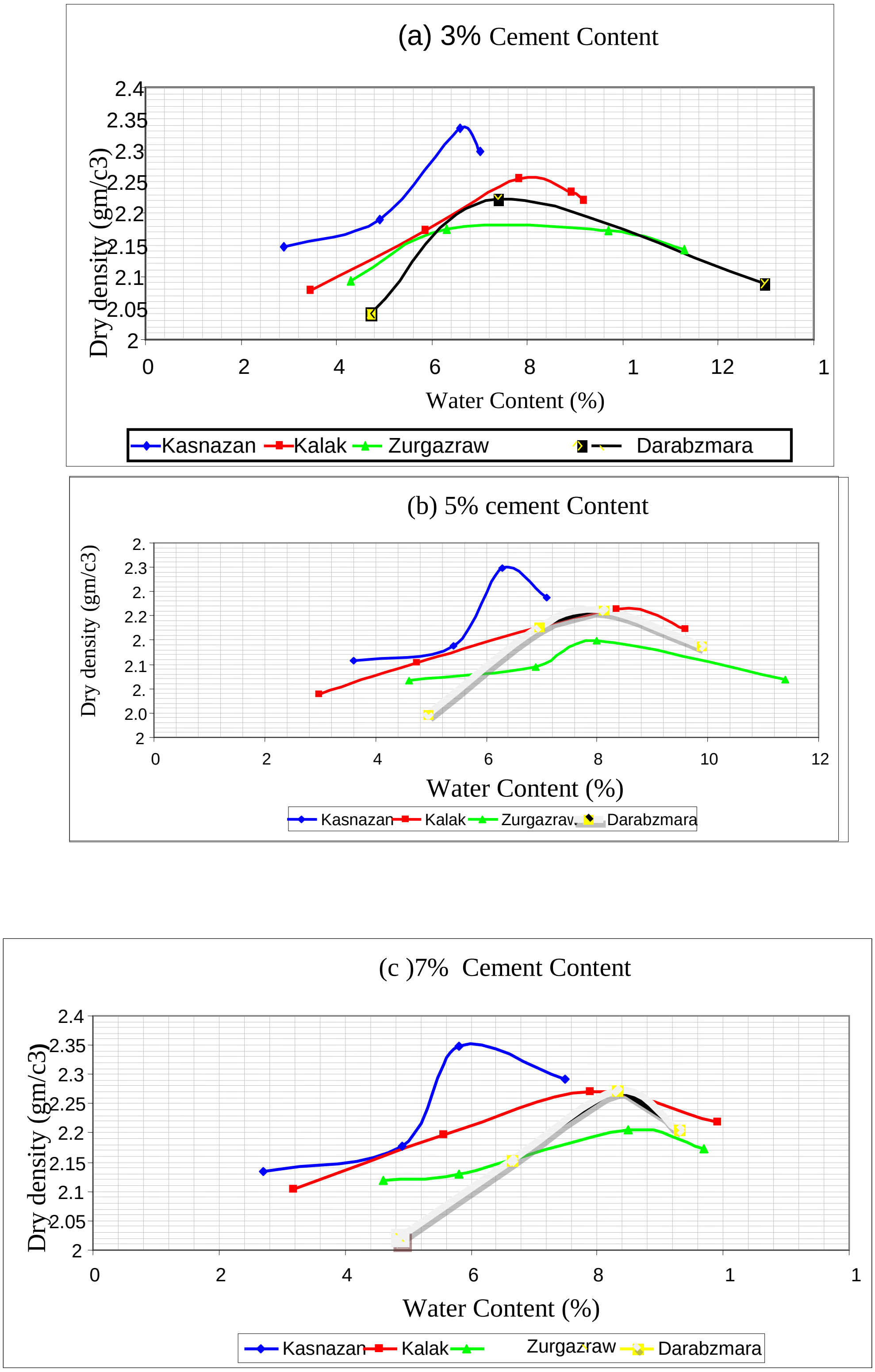


Figure (4) Dry density with moisture contents with variations of specified cement contents

Table (8) Unconfined compressive strength (UCS) results

Source	**Average** (psi)	**Average** (kPa)
Kasnazan		
Untreated (at OMC)	0	0
Untreated (oven dried)	155	1063
Treated		
3% cement content	306	2109
5% cement content	816	5614
7% cement content	1631	11223
Crushed Gravel		
Untreated (at OMC)	0	0
Untreated (oven dried)	290	1993
Treated		
3% cement content	306	2107
5% cement content	535	3687
7% cement content	853	5881
Zurgazraw		
Untreated (at OMC)	0	0
Untreated (oven dried)	115	792
Treated		
3% cement content	182	1256
5% cement content	317	1966
7% cement content	484	3339
Crushed Stone		
Untreated (at OMC)	0	0
Untreated (oven dried)	253	1738
Treated		
3% cement content	499	3441
5% cement content	465	3897
7%	963	6637

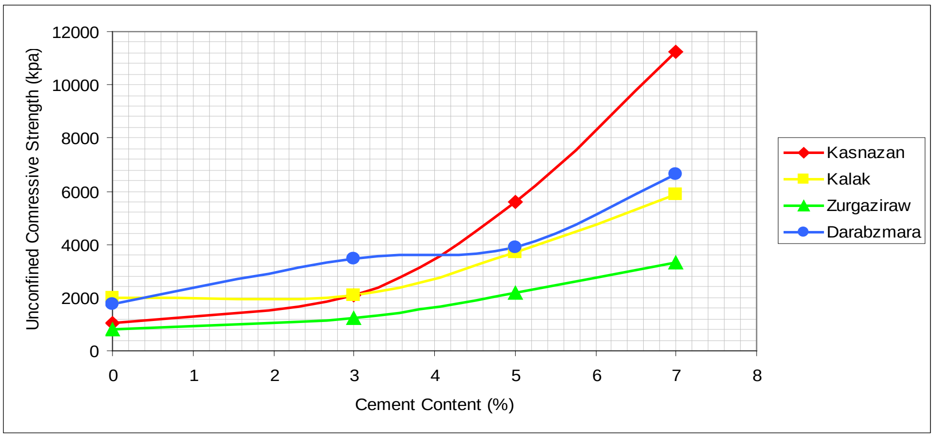


Figure (5) Unconfined strength variation with cement content increments
[Kas: Kasnazan, Kalk: Kalak, Zurg: Zurgazraw, and Dara: Darabizmara]

Conclusions and Recommendations

CONCLUSIONS

1.As cement content increases from 0 to 7 percent, the unconfined Compressive strength (UCS) increases more than 10 times (from 1069 to 11238 kPa) for Kasnazan, about 3 times (from 1999 to 5881 kPa)for Kalak, about4times (from 793 to 3337 kPa) for Zurgazraw, and more than 3 times (from 1744 to 6640 kPa) for Darabzmara. The Kasnazan is the most response material with Portland cement. So Kasnazan material considered to be highest respondent to cement stabilization.

2**.** Results of UCS test for samples at OMC showed zero readings, but they Showed high values when oven dried; therefore the base course should be kept dry, good shoulders confine base courses and protect them from ingress of water, consequently prevent occurrence of permanent deformation.

3**.** Tests conducted for all materials showed acceptable properties of these Materials based on Iraqi specification (SORB, 2003), but construction of roads using these materials need a good field quality control and construction requirements.

4**.** Kasnazan gains more strength as cement content increases, Kalak and Darabzmaraare close to each other in this aspect, and Zurgazraw less affected by increase in cement content.

Recommendations

The most important characteristic of base course and other components of pavement which is depended on in 2002 AASHTO guide design resilient modulus, therefore more studies are needed to determine this property of materialsand find correlations of this property with other physical and strength properties to predict resilient modulus.

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