Prospect of Using Locally Dolomite Stone to Produce High Performance Concrete Pavement

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Abstract

The fundamental objective of this research is to examine the manufacture of concrete pavement with a high performance by utilizing Samawa dolomite stone as a partial substitution to coarse aggregate (gravel). In this study, five mixes of concrete pavement were made containing Samwah stone as a coarse aggregate with the replacement percentage of (0%, 10%, 20%, 30% & 40%) from gravel at level of strength type C30 (the requirement of concrete pavement). Fresh concrete mixes were subjected to slump test. Compressive strength, flexural strength, static modulus of elasticity was investigated for hardened concrete mixes at age of 28 days. Test results revealed that the inclusion of locally dolomite stone as a replacement to gravel in produced concrete pavement improves the hardened properties especially for flexural strength without any significant effect on workability requirement except at replacement percentage (40% of coarse aggregate). The best performance of produced concrete pavement was adopted with replacement percentage (30%) from gravel by using locally dolomite stone.

Keywords: Concrete pavement, Compressive strength, Flexural strength, Static modulus of elasticity, Dolomite stone.

1- Introduction

Concrete is a material consists of aggregate (fine and coarse) bonded together by utilizing cement as a paste which solidifies within time [1].

The main constituents of concrete are fine and coarse aggregate (50% to 60% of total mix vol.), cement, and water. Depending on the mix proportions [2]. Concrete could be utilized as plain or reinforced to achieve the required strength like in the bridge deck slab or simply reinforced with temperature requirement as in highway pavement construction. It is utilized in huge quantities in nearly every construction work. The compressive and flexural strengths of concrete are the main characteristics that consider by the structural engineer. They depend on the w/c ratio, degree of compaction, cement to aggregate ratio, bond between aggregate and mortar, and grading, strength and shape of aggregate [3].

Aggregates on the most mixed material in the world are controlling the unit weight of concrete, its elastic modulus and other mechanical characteristics. Samawa dolomite stone located in Samawa governorate which is located in southern Iraq in large quantities and have high percentage of magnum oxide (MgO). This locally dolomite is characterised by high hardness and excellent resistance to heat [4].

This research will be carried out on the production of high performance concrete (for highway pavement and bridge deck slab) by using Samawa dolomite stone as partial replacement of the coarse aggregate.

However, the thickness of concrete pavement is significantly depended on the flexural strength and modulus of elasticity. These properties are much affected by using hard dolomite stone in concrete production [5].

2- Experimental Work

2-1 Materials

2-1-1 Cement:

Sulfate resisting cement type v produced in Iraq was used according to the specification (No.5/1984) [6]

2-1-2 Aggregate:

Fine aggregate in this study was Al-Ekhader natural sand. The grading and characteristics were within the requirement of this specification (No.45/1984) [7].

Al-Nebaee crushed gravel with maxi size of 20 mm was utilized as coarse aggregate. Also, the grading and properties were within the requirement of the specification (No.45/1985) [7].

Dolomite stone was prepared by manually crushing Al-Samawa dolomite rock, the crushing product was screened by using a various size sieve and recommended to give a grading similar to that of the natural gravel.

2-1-3 Water:

Portable water taken from water supply network system (tap water) was used for mixing and curing throughout the experimental work.

2-1-4 Superplasticiser:

High performance super plastering concrete admixture (Hyperplast PC 200) was used to enable the water content of the mix to perform more efficiently to achieve the highest concrete durability and performance. The dosage recommended by the manufacture was (0.5- 2.5 liters/ 100 kg of cementitious materials)

2-2 Concrete Mix Design

Five mixes of concrete were designed according to ACI committee 211-1-2008 C30 [8].

The mixes were with different replacement percentages for coarse aggregate by locally dolomite stone (0, 10, 20, 30, and 40%). All these mixes were investigated at 28 days. Mixes compaction was made by using vibratory table for about 30-45 sec.

2-3 Experimental Test

2-3-1 Fresh Concrete Test

For each mix, the slump test was conducted directly after mixing in accordance with (ASTM C-143 -89) [9].

2-3-2 Hardened Concrete Test

- For Compressive strength test: Cubic samples were manufactured with dimensions (150*150*150 mm) to test the compressive strength in accordance with (ASTM C39-83) [10].
- Flexural strength (modulus of rupture) test: The modulus of rupture was carried out in accordance with (ASTM C78-2002) [11]. Samples were manufactured with dimensions (100*100*400 mm)
- Static modulus of elasticity: The (ASTM C469-2002) [12] was used for performing the elasticity modulus. Cylindrical shape (150 mm D x 300 mm H) specimens were fabricated for this purpose.

3- Results and Discussion:

Table (1) shows all the results of fresh and hardened concrete properties including sump test, flexural strength test, compressive strength test, in addition to the elasticity modulus test, for all mixes (control: 0% dolomite stone replacement from gravel Mo) and (10% M10, 20% M20, 30% M30, 40% M40) replacement percentages by dolomite stone from gravel.

Table (1): The results of all fresh and hardened properties at 28-day age

Concrete mix type	Slump (mm)	Compressive strength (MPa)	Modulus of rupture (MPa)	Modulus of elasticity (Gpa)
Control M0	70	34.2	4.95	28.3
M10	50	35.8	5.40	29.9
M20	45	37.9	5.98	31.2
M30	35	38.8	6.14	32.9
M40	20	40.0	6.29	33.3

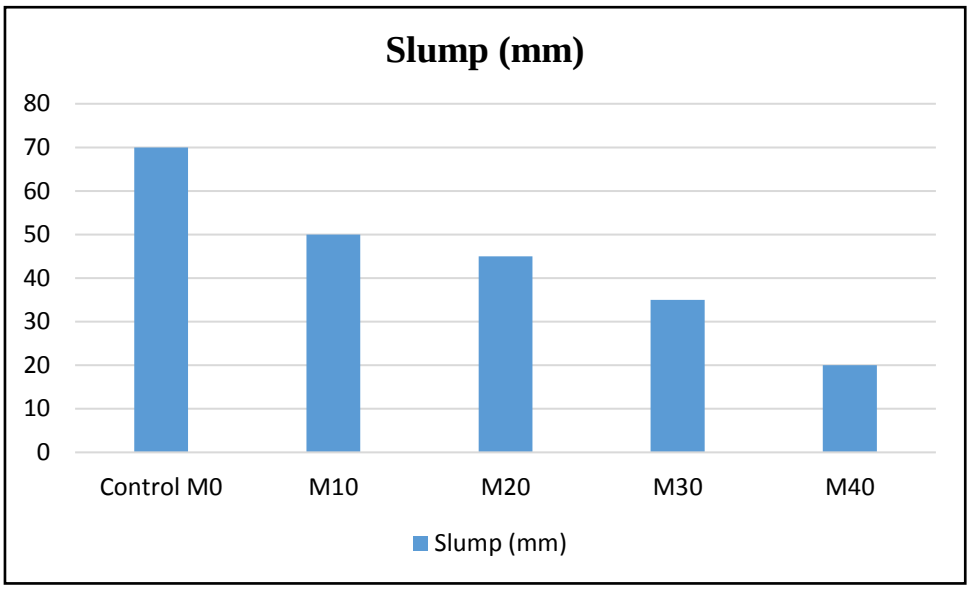

Figure 1: Effect of replacement dolomite stone percentage on slump of concrete

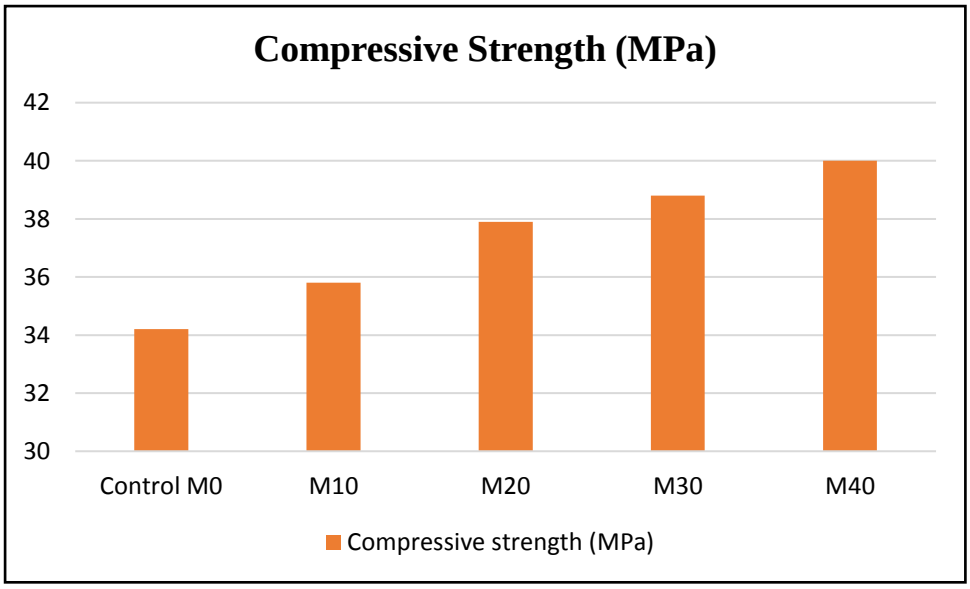

Figure 2 : Effect of replacement dolomite stone percentage on compressive strength of concrete

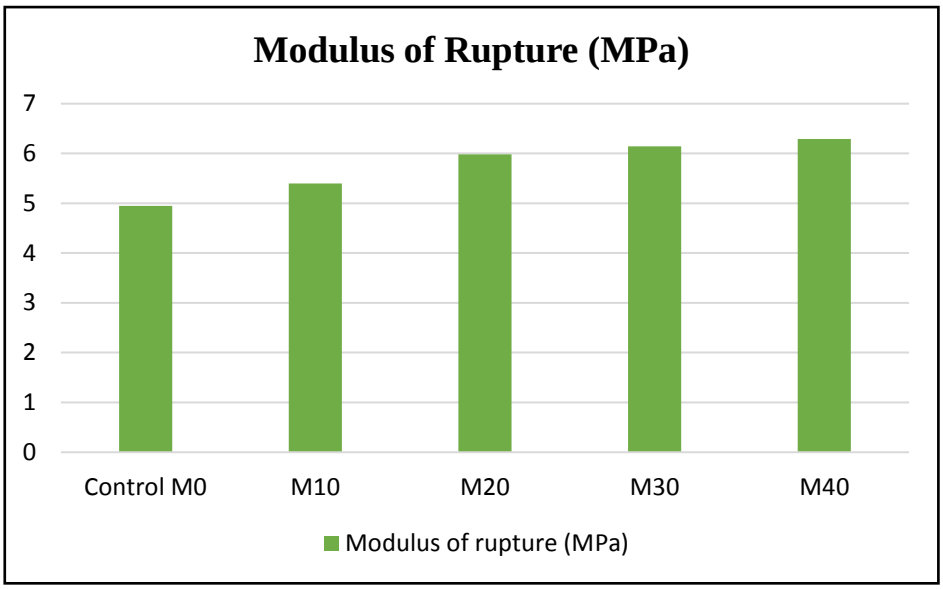

Figure 3 : Effect of replacement dolomite stone percentage on flexural strength of concrete

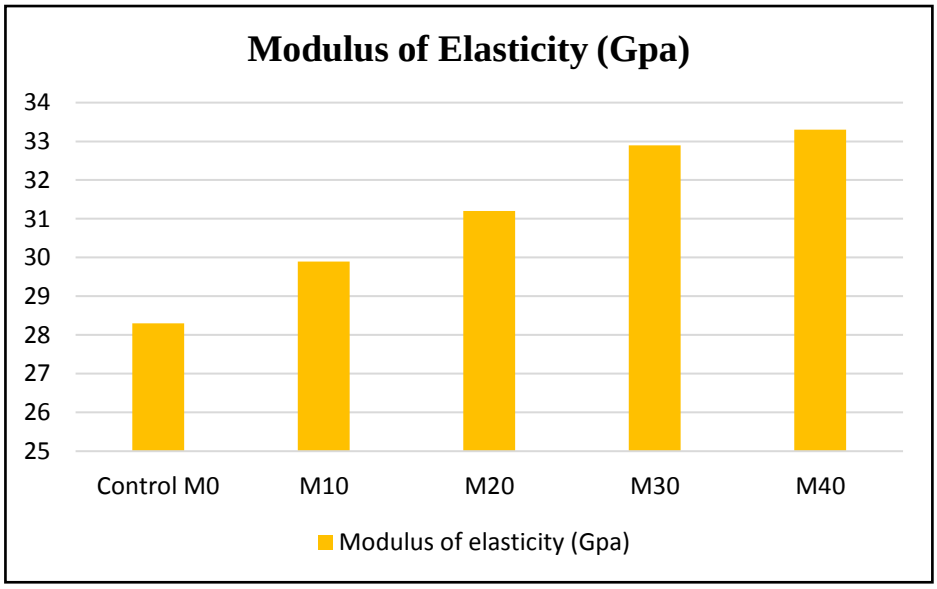

Figure 4: Effect of replacement dolomite stone percentage on static modulus of elasticity of concrete

3.1 Workability Test (Slump Test)

Workability represents a very significant fresh property of concrete, defined as a measure of the concrete ability to be mixed, transported or handled.

Figure (1) shows the workability results for the different mixtures. The results showed that there is a decrease in the workability of the concrete specimens that contains Samaow dolomite as coarse aggregate replacer, though remaining within the specified requirements of concrete pavement (25-75 mm), excepting mix M40. That means the high percentage of dolomite stone caused an increase to superplasticizers content. This behavior may be attributed to the surface texture of Samaow dolomite having more roughness than that of gravel in the concrete mix, the much higher angularity of dolomite

stone in comparison to that of the gravel used in the mixes, in addition to the high absorption percentage (2%) of locally dolomite comparing to that of gravel (0.8%) [4].

3.2 Hardened Properties

Compressive strength represents a major hardened property of concrete and it is strongly related to other physical properties and should be checked for ensuring that the concrete mixes satisfy the requirement of concrete pavement. While elasticity modulus and flexural strength had significant effect on thickness design of concrete pavement [12].

Figures (2), (3), and (4) show the compressive and flexural strength results in addition to the results of the elasticity modulus respectively. The results indicate that for all measured properties (at age 28 days), the concrete mixtures with Samawa dolomite as a replacement of coarse aggregate have greater values than that of the control mix. The percentages of increment reach to 16% for compressive strength, 27% for flexural strength, and 18% for elasticity modulus (the length of failure path is the longest in the flexural state). This behavior is attributed to the strength of dolomite crushed Stones stone (abrasion value 11.74, crushing value 13.88) being higher than the strength of gravel (abrasion value 17.35, crushing value 21.4). It is also because of the surface texture of crushed stone having more roughness than the surface texture of crushed gravel, which improves the bond between the gravel and the paste, meaning also the need for superplasticizers for concrete mixes [4].

3.3 Impact on Concrete Pavement Thickness

The concrete pavement thickness is designed in accordance to AASHTO-1993 [12]. All mixes are designed for the same environment.

Due to the increment in hardened properties values especially flexural strength and modulus of elasticity than induced reflects on the thickness values of concrete pavement. The decrements are about 6-11% of the original thickness of prevailing control concrete pavement, which is associated to the increments in the replacement percentages of dolomite stone. This can be estimated by utilization of rigid pavement thickness design chart [12] for characteristics of prevailing traffic loads and environmental condition in locally urban arterials network.

4- Conclusion

From the results of tests performed in this research in addition to the theoretical analysis, the following general conclusions can be drawn:

1. Increasing the ratio of dolomite stone replacement decreases the workability of concrete, giving that all other factors are held constant.
2. The experimental work indicated the increase in the compressive strength with the increment in the percentages of gravel replacement by the dolomite stone in the mix. In addition, flexural strength and modulus of elasticity have the same behavior but with different increment percentages which about (16%, 27%, and 18%) for compressive, flexural strengths and modulus of elasticity respectively.
3. It can be concluded that the decrease in the thickness of concrete pavement was related to the percentage increase of the replacement of gravel by the dolomite stone in concrete mixes. The decrement percentage was about (6-11%) of the original control pavement.
4. From all results and above conclusions, it is indicated that the performance of concrete containing dolomite stone is higher than that of the control one, with 30% replacement being the preferred percentage for achieving enhanced use and good pavement performance for both fresh and hardened characteristics of produced concrete pavement.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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إمكانية استخدام حجر الدولومايت المحلي لإنتاج خرسانة التبليط عالية الأداء

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الخلاصة

أن الهدف الرئيسي من هذا البحث هو اختبار إنتاج خرسانة تبليط عالية الأداء من خلال استخدام حجارة الدولومايت من السماوة كبديل جزئي عن الركام الخشن (الحصى)

في هذا العمل تم عمل خمس خلطات للتبليط الخرساني يحتوي على حجارة الدولومايت كركام خشن وبنسبه استبدال (0، 10، 20، 30، 40) % من الحصى ولمستوى مقاومه 30C والتي تمثل متطلبات خرسانة التبليط.

تم أداء فحص الهطول للخرسانة الطرية وفحوصات مقاومة الانضغاط والانثناء ومعامل المرونة واختبارها للخرسانة الصلدة ولعمر 28 يوم.

أظهرت النتائج أن تضمين حجارة الدولومايت من السماوة للركام الخشن في خرسانة التبليط تطورا واضحا في الخواص الصلبة وخاصه مقاومة الانثناء وبدون تأثير واضح على قابلية التشغيل عدا نسبه الاستبدال 40%.

إن أفضل أداء لخرسانه التبليط المنتجة تحققت بنسبه استبدال 30%من الحصى وباستخدام تلك الحجارة المحلية (حجارة السماوة الدولومايت).

كلمات الداله: خرسانة التبليط، مقاومة الانضغاط، مقاومة الانثناء، معامل المرونة الساكن، حجارة الدولومايت.