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Using Recycled Construction Rubbles to Improve the Properties of Subbase

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ABSTRACT

Demolished concrete structures proven to be a good source of construction materials. This paper studies the utility of using recycled construction rubbles to improve some properties of compacted subbase .Different subbase materials were produced with 0%, 25%, 50%, 75% of recycled construction rubbles aggregate as a partial replacement of natural subbase. The standard tests were conducted on the choosed maerials before and after the replacement. It is found from the test results that the recycled construction rubbles can be used significantly to improve the properties of some types of subbase. The CBR values of the subbase materials prepared with crushed concrete, recycled bricks, and ceramic rubbles as a partial replacement were better than those of natural subbase materials. The performance of subbase containing crushed concrete rubbles was better than the performance of subbase containing crushed clay bricks and ceramics. The CBR values for all subbases were greater than 45%, which is accepted as per the requirements CRB specifications in Iraq.

Keywords: Crushed Concrete, Crushed Clay Bricks, Subbase, CBR

استخدام أنقاض البناءالمعادتدويرها لتحسين خصائص السبيس

الخلاصة

اثبتت المنشات الخرسانية المهدمة بأنها مصدر جيد لمواد البناء. يدرس هذا البحث فائدة اسـتخدام أنقاض البناءالمعاد تدويرها في السـبيس لتحسـين بعـض خصـائص السـبيس المرصـوص. تـم انتـاج مـواد

كنسـبة تعويضـية مـن السـبيس الطبيعـي 75% و50, 25% , 0% مختلفـة وذلـك بخلـط سـ %.
كانت قيم السبيس المهيئة من انقاض الخرسانة المسحوقة وانقاض الطابوق والسيراميك المعاد ت
بيس اجريت الاختبارات القياسية على المواد المختارة قبل وبعد الاستبدال. وجد من نتائج الاختبار ان
دويره كاستبدال جزئي افضل من تلك المهيئة من ان اداء السبيس الحاوي على انقاض
البناءالمعاد تدويرها يمكن استعمالها بشكل جيد في تحسين خواص السبيس. CBR انقاض لمواد
واد السـبيس الطبيعيـة . كـ جزئ

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الخرسانة المسحوقة افضل من اداء السبيس الذي يحتوي على الطابوق الطيني و السيراميك المسحوق. كانت قيم CBR لجميع السبيس اكثر من 45% وهي قيمة مقبولة بموجب الهيئة العامة للطرق و الجسور العراقية.

INTRODUCTION

Pavement is a multi-layered structure. It is composed of a concrete or an asphalt slab resting on a foundation system comprising various layers such as the base, subbase, and subgrade. Conventionally, natural materials such as crushed rocks, selected gravels and stabilized materials are used in road base and subbase[1].

Following a normal growth in population, the amount and type of waste materials have increased accordingly. Many of the non-decaying waste materials will remain in the environment for hundreds, perhaps thousands of years. The non-decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental problems. The problem of waste accumulation exists worldwide, specifically in the densely populated areas. Most of these materials are left as stockpiles, landfill material or illegally dumped in selected areas. Most buildings in Iraq were constructed of reinforced concrete accompanied with brick and tiles materials. Thus, building rubble collected from damaged structures includes bricks and tiles as well as waste concrete [2].

Approximately 20% of the building construction waste consists of glass, plastic, and concrete. Therefore, introducing another means of disposal by recycling is nationally required. Large quantities of this waste cannot be eliminated [2]. For these reasons, researches have been undertaken to investigate the possibility of using recycled construction rubbles as subbase. However, the environmental impact can be reduced by making more sustainable use of this waste.

Chini et al. [3] tested the properties of a road base sample using recycled aggregate produced from a demolished concrete pavement which had designed mix strength of 20 MPa. Test results showed that the roadbase sample passed all standard requirements with the exception of the soundness test using sodium sulfate.

They found that the mortar adhered to the recycled aggregate was reactive to sodium sulfate and contributed to an increased loss in the soundness test.

Nataatmadja and Tan [4] tested the resilient response of a subbase material made with four different recycled aggregates. The materials, obtained by crushing concrete with compressive strength ranging from 15 MPa to 75 MPa, were reconstituted to satisfy the grading requirements for a subbase material. They found that the resilient response of a subbase material made with recycled aggregates was comparable to that made with natural aggregate. Also, the resilient response of a subbase material was found to be dependent on the strength of the original concrete, the amount of softer material in the recycled aggregates and the flakiness index of recycled concrete aggregates (RCA).

Molenaar and van Niekerk[5] found that the mechanical characteristics of an unbound base course made with recycled concrete and masonry rubble were mainly governed by the degree of compaction.

Park [6] tested the physical and compaction properties of two different recycled aggregates obtained from a housing redevelopment site (RCA-1) and a concrete pavement rehabilitation project (RCA-2). Moisture and density relationships were obtained for both RCA-1 and RCA-2. The optimum moisture contents were found to be 9% and 12.8% and the corresponding dry densities were (2.21 and1.81) Mg/m3 for RCA-1 and RCA-2, respectively. It was apparent that the optimum moisture content increased with an increase in water absorption of the aggregates. The bulk specific gravity and water absorption values were 2.53 and2.54 and 1.43% and 1.77% for RCA-1 and RCA-2, respectively.

Chi Sun Poon and Dixon Chan [1] studied the possibility of using recycled concrete aggregates and crushed clay brick as aggregates in unbound subbase materials. The results showed that the use of 100% recycled concrete aggregates increases the optimum moisture content and decreased the maximum dry density of the subbase materials compared to those of natural subbase materials. Moreover, the replacement of recycled concrete aggregates by crushed clay brick further increases the optimum moisture content and decreased the maximum dry density. This was mainly attributed to the lower particle density and higher water absorption of crushed clay brick compared to those of recycled concrete aggregates. Natural aggregate had the highest density. The soaked CBR values for all recycled subbases were greater than 30%(minimum strength requirement in Hong Kong).

Furthermore, Hansen and Angelo [7] found that it was possible to enhance the engineering properties of clayey soils for earthwork purposes by mixing the soils with recycled concrete fine aggregates.

In this paper, the feasibility of recycled construction rubbles as subbase materials was studied. The results were compared with the subbase materials prepared with natural subbase.

If recycled construction rubbles can be re-used as subbase materials, it would greatly alleviate the demand and extend the service life of the dumping facilities in Iraq.

MATERIALS

Natural Subbase

The natural subbase obtained from AL-Nebai source was used. Table (1) shows the grading of natural subbase.

Recycled Construction Rubbles

Building rubble collected from damaged structures contains waste concrete, tiles, bricks, steel, wood, plastic, and other substances which used to produce subbase. Among these substances, wood, plastic and paper impurities seriously affect the strength of aggregate. Fortunately, the impurities present in building rubble have far less affect after recycling treatment. After proper treatment, only waste concrete, bricks, tiles were used and a few impurities are left in the building rubble [8].

In this research, two groups of recycled construction rubbles from different regions in Baghdad were selected to be used in this study.

Recycled concrete aggregates

The recycled concrete aggregates were taken from a waste recycling area. They were obtained by crushing different types of waste concrete by use of an impact crusher.

The composition of recycled concrete determined by visual inspection were defined as 92.1% crushed concrete (49.1% of original aggregate plus adhered mortar and 43% of original aggregates),1.6% of ceramic aggregates and 5.5% of bituminous sand 0.8%of other.

Recycled concrete sourced from a demolition site in Baghdad was delivered to Laboratory of Building and Construction Departments for this study.

The recycled concrete was crushed manually using a hammer to produce both coarse and fine aggregates with maximum size 50mm and they are referred to as crushed concrete (CC) in this study.

Since the blend ratio was the same for each subbase material, the blended subbases with recycled concrete aggregate had similar grading properties as shown in Table (2).

Recycled clay bricks and ceramic

Recycled clay bricks sourced from a demolition site in Baghdad were delivered to Laboratory of Building and Construction Departments for this study. The recycled clay bricks were crushed manually using a hammer to produce both coarse and fine aggregates with maximum size 25mm. It is referred to as crushed clay bricks (CB) in this study. Crushed clay brick mainly contained brick rubble and also some tiles.

Since the blend ratio was the same for each subbase material, the blended subbases with recycled clay bricks had similar grading properties as shown in Table (3).

Subbase Mixtures

Recycled concrete aggregate and crushed clay brick rubble were blended to produce three series of subbase materials.

Each series contained three mixtures. The first series used recycled concrete aggregate as a partial replacement of the natural subbase. The second series used recycled brick and ceramic rubble as a partial replacement of the natural subbase and the third series used recycled concrete aggregate and recycled brick rubble as a partial replacement of the natural subbase.

Furthermore, natural aggregates were used to produce a control mixture. The replacement levels were 25%, 50%, and 75% by weight of the natural subbase for each series.

Each series contained three mixtures. Since the blend ratio was the same for each subbase material ,the blended subbases had similar grading as shown in Tables (1-4).

The blend ratios (by weight) for the three mixtures in each series are summarized in Table (5)

RESULT AND DISCUSSION

Optimum Moisture Content (%)

The blended materials were compacted in a CBR mold using a vibratory hammer in accordance with ASTM D-1883-87 [9].

The optimum content for the nine recycled subbase mixtures and the control mixture are shown in Figures (1-4). It is clear that the shape of the curves and the obtained values differed considerably.

The control mixture with natural aggregates had the lowest optimum moisture content. Since the grading of each blended subbase was similar, the difference in the optimum moisture content was mainly attributed to the physical properties of recycled concrete aggregate and crushed clay brick compared to those of natural aggregates.

It was found that the incorporation of crushed clay brick and ceramics increased the optimum moisture content and as a result of the high water absorption of the crushed clay brick and ceramic particles.

The irregular shape of the crushed clay brick and ceramic particles increased the amount of voids within the mixtures.

Furthermore, the results revealed that the mixtures containing recycled concrete aggregate were more sensitive to the change in the moisture compared to the mixtures containing fine crushed clay brick rubbles. Therefore, it is essential to compact the blended materials prepared with recycled concrete aggregate at as close to the optimum moisture content as possible in order to achieve better compaction.

Dry Density

The blended materials were compacted in a CBR mold using a vibratory hammer in accordance with AASHTO requirement in order to produce the conventional convex Moisture–dry density curves [10].

The dry density for the nine recycled subbase mixtures and the control mixture are shown in Figures (5-8). The shape of the curve and the obtained values differed considerably.

The control mixture with natural aggregates had the highest maximum dry density. Since the grading of each subbase was similar, the difference in the maximum dry density was mainly attributed to the physical properties of natural aggregates which had the highest particle density and were less porous compared to those of recycled concrete aggregate and crushed clay brick.

It was found that the incorporation of crushed clay brick decreased the maximum dry density as a result of the low particle density of the crushed clay brick particles.

The irregular shape of the crushed clay brick particles due to manual crushing possibly increased the amount of voids within the material and led to a decrease in the maximum dry density as well.

The results also showed that the mixtures with fine recycled concrete aggregate had higher maximum dry densities .

California Bearing Ratio (CBR %)

CBR tests were performed for all ten subbase materials after they were compacted at their corresponding optimum moisture contents.

The subbase in Series (1) that using recycled concrete aggregate materials had the highest CBR values than the other series.

The mixtures 25RC, 50RCA and75RCA in Series (1) achieved CBR values of 53%, 58%, and 56 %, respectively. On the other hand, control mixture (con) achieved CBR value of 48%.

The mixtures 25BC, 50BC and 75BC in Series 2 achieved CBR values of 49%, 50% and 46%, respectively.

The CBR value gradually decreased as the crushed clay brick content increased in Series (2) comparing with series (1). One possible reason was the lower intrinsic particle strength of clay brick and ceramic rubble which led to a decrease in the overall bearing strength of the subbase materials [1].

On the other hand, mixtures 25RCA, 50RCA and75RCA in Series 3 achieved CBR values of 51%, 55%and 54%, respectively.

The CBR value gradually decreased as the coarse crushed clay brick content increased in series (3). Furthermore, blending crushed clay brick with recycled concrete aggregate possibly led to a poorer interlocking system which decreased the load transfer capability of the subbase materials.

The use of crushed clay brick as a partial replacement of natural subbase obviously decreased the strength of the subbase materials. Although the same blend ratios (by weight) were used for both series, the difference in density between the two materials resulted in a totally different material volume. Due to the lower particle density of crushed clay brick, the volume of the fine aggregate in Series 2 was greater than the volume of the fine aggregate in Series 1. As a result, the volume ratio of coarse to fine aggregates was lower for the mixtures in Series 2 than that of the mixtures in Series 1.

The CBR values for all recycled subbases were greater than 45%, which is a minimum strength requirement for (type A) of the subbase in Iraq [10] as shown in Figures (9-12).

Moisture Density Relationship

The blended subbases were compacted in a CBR mold using a vibratory hammer in order to produce the moisture - density relationship. The relationship between the optimum moisture content and dry density is an indications of the sensitivity of the density with respect to the variations of moisture content for the materials.

The moisture and dry density relationships for the nine recycled subbase mixtures are shown in Figure (13).

The control mixture with natural aggregates had the highest maximum dry density and the lowest optimum moisture content. Since the grading of each subbase was similar, the difference in the maximum dry density and the optimum moisture content was mainly attributed to the physical properties of natural subbase which had the highest particle density and was less porous compared to those of recycled concrete and clay brick rubble.

It is found from Figure (13) that the incorporation of crushed clay brick increased the optimum moisture content and decreased the dry density due to the high water absorption and low particle density of crushed clay brick particles. The results also showed that the mixtures with recycled concrete had higher maximum dry densities and lower optimum moisture content compared to the mixtures containing crushed clay brick. This was mainly caused by the difference in the density and the water absorption between these two materials.

CONCLUSIONS

This paper presents the result of an investigation on the use of recycled concrete aggregate and crushed clay brick as aggregates in subbases materials. Prior to the study, the aggregate properties were first evaluated.

The results of this study proved that recycled concrete aggregate and crushed clay brick rubble can be blended to produce a subbase which meets Iraqi requirement.

The results of this study also proved that recycled concrete aggregate and crushed clay brick can be blended together to produce a subbase which meets the prescribed requirement.

The following differences were found between the natural, recycled concrete and crushed clay brick subbase:

1. Natural aggregate had the highest density, followed by recycled concrete aggregate and crushed clay brick.
2. Crushed clay brick had the highest water absorption value, followed by recycled concrete aggregate and natural aggregate.

On the other hand, the following conclusions can be made for subbase materials prepared with recycled concrete aggregates and crushed clay brick:

1. The recycled subbase had a lower dry density and a higher optimum moisture content when compared with the subbase prepared with natural materials.
2. As the coarse crushed clay brick rubble content increased, the maximum dry density decreased and the optimum moisture content increased.
3. The subbase using crushed clay brick as a partial replacement was less to moisture variations when compared to the subbase using recycled concrete aggregate as a partial replacement.
4. The use of crushed clay brick lowered the CBR value compared with the subbas made with recycled concrete as a partial replacement of natural subbase.
5. The subbase using crushed clay brick as a partial replacement of natural subbase had a lower CBR value compared to the subbase using recycled concrete aggregate and clay bricks rubble as a partial replacement of natural subbase.
6. It was feasible to blend recycled concrete aggregate and crushed clay brick to produce a subbase with aCBR value more than 45%which is a minimum requirement in Iraq.

7. All recycled subbases had a CBR value more than 45%which is which achieved the requirement in iraq.
8. The subbase made with recycled concrete as a partial replacement up to 50% in mix3 had a higher CBR% than the other mixes as shown in Fig (12).

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Table (1) Grading of natural subbase compared with Iraqi requirements.

Sieve size	Passing %	Type A	Type B	Type C	Type D
75	100	100			
50	96.6	95-100	100		
25			75-95	100	100
9	46.5	30-65	40-75	50-85	60-100
4.75	38.2	25-55	30-60	35-65	50-85
2.36	27.8	16-42	21-47	26-52	42-72
0.3	11.1	7-18	14-28	14-28	23-72
0.075	3.5	2-8	5-15	5-15	5-20

Table (2) Grading of subbase made with recycled concrete and compared with Iraqi requirements.

Sieve size	Passing %	Type A	Type B	Type C	Type D
75	100	100			
50	96.5	95-100	100		
25			75-95	100	100
9	46.9	30-65	40-75	50-85	60-100
4.75	38	25-55	30-60	35-65	50-85
2.36	30	16-42	21-47	26-52	42-72
0.3	12	7-18	14-28	14-28	23-72
0.075	5	2-8	5-15	5-15	5-20

Table (3) Grading of subbase made with recycled brick and ceramic rubble and compared with Iraqi requirements.

Sieve size	Passing %	Type A	Type B	Type C	Type D
75	100	100			
50	97	95-100	100		
25			75-95	100	100
9	47.5	30-65	40-75	50-85	60-100
4.75	40	25-55	30-60	35-65	50-85
2.36	29	16-42	21-47	26-52	42-72
0.3	12.5	7-18	14-28	14-28	23-72
0.075	5	2-8	5-15	5-15	5-20

Table (4) Grading of subbase made with recycled concrete and brick rubble and compared with Iraqi requirements.

Sieve size	Passing %	Type A	Type B	Type C	Type D
75	100	100			
50	97.5	95-100	100		
25			75-95	100	100
9	49.5	30-65	40-75	50-85	60-100
4.75	40.3	25-55	30-60	35-65	50-85
2.36	29	16-42	21-47	26-52	42-72
0.3	11.5	7-18	14-28	14-28	23-72
0.075	5.5	2-8	5-15	5-15	5-20

Table (5) control subbase and blend subbase mixtures.

	Mix No.	Mix Title	Percent of Replacement (by weight %)
control	1	CON	0%
Series (1) With recycled concrete	2	25RC*	25%
	3	50RC	50%
	4	75RC	75%
Series (2) With recycled clay brick and ceramic	5	25CB-	25%
	6	50CB	50%
	7	75CB	75%
Series (3) With both recycled concrete and clay brick and ceramic rubble	8	25R+	25%
	9	50R	50%
	10	75R	75%

*RC: made with recycled concrete -CB: made with recycled brick
+ R made with recycled concrete and with recycled brick

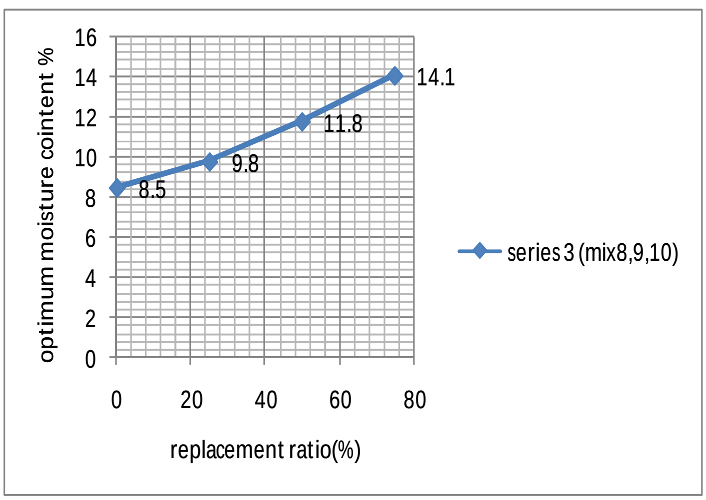


Figure (1) optimum moisture content with subbase mixture Made with recycled concrete (mix1,mix2,mix3,mix4).

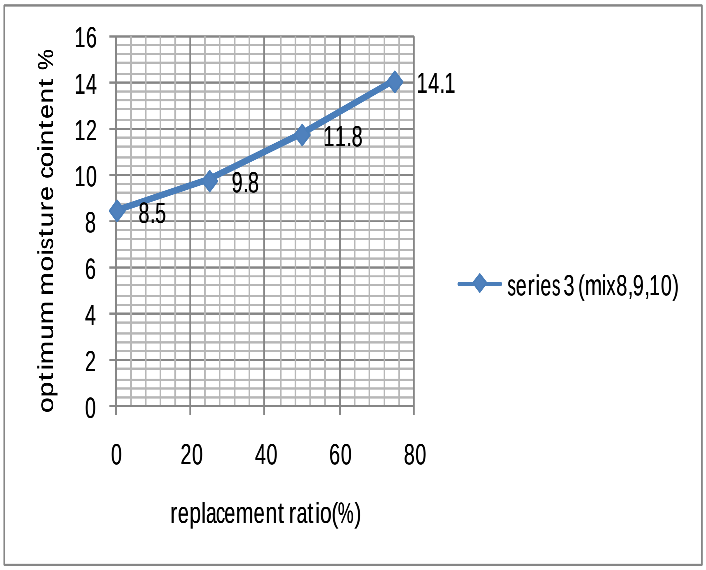


Figure (2) optimum moisture content with sub base Mixture made with recycled brick and Ceramic (mix1, mix5, mix6, mix7).

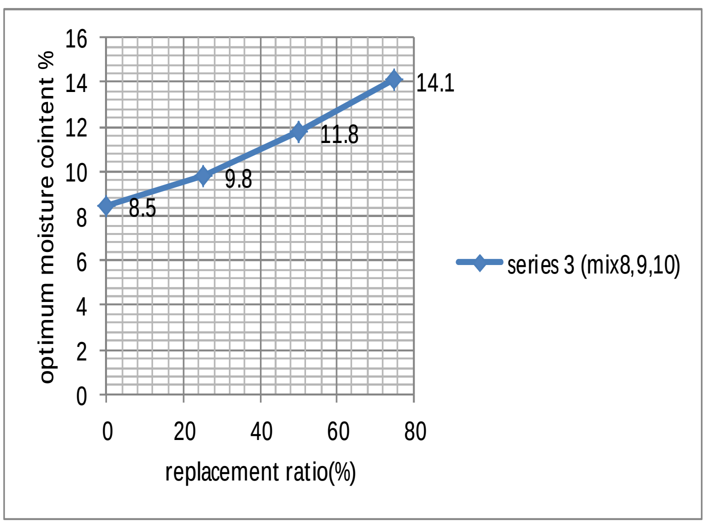


Figure (3) optimum moisture content with subbase mixture made with recycled concrete and brick rubble (mix1, mix8,mix9,mix10).

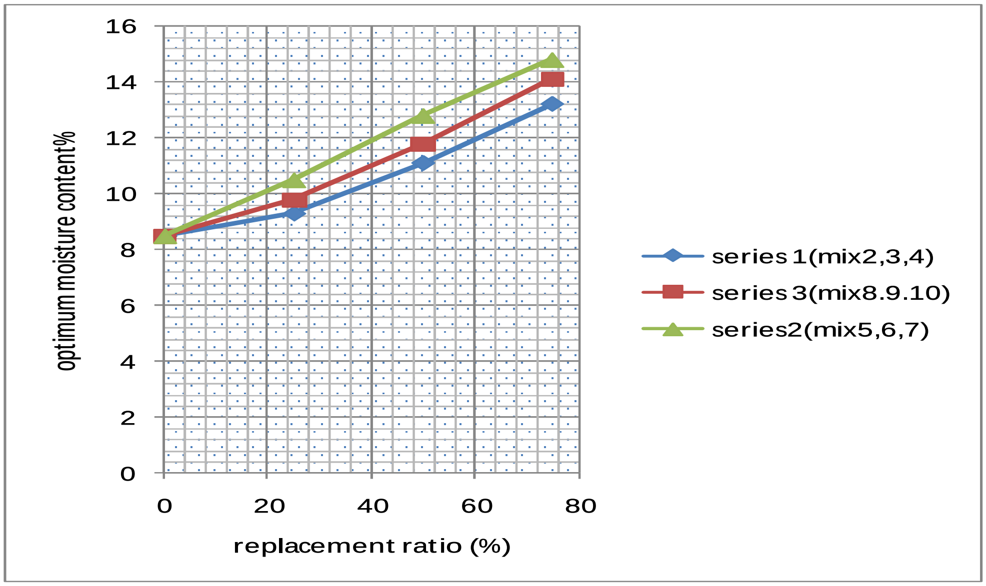


Figure (4) optimum moisture content with all subbase mixtures.
Figure (5) dry density (gm/cm3)with subbase mixture made With recycled concrete (mix1,mix2,mix3,mix4).

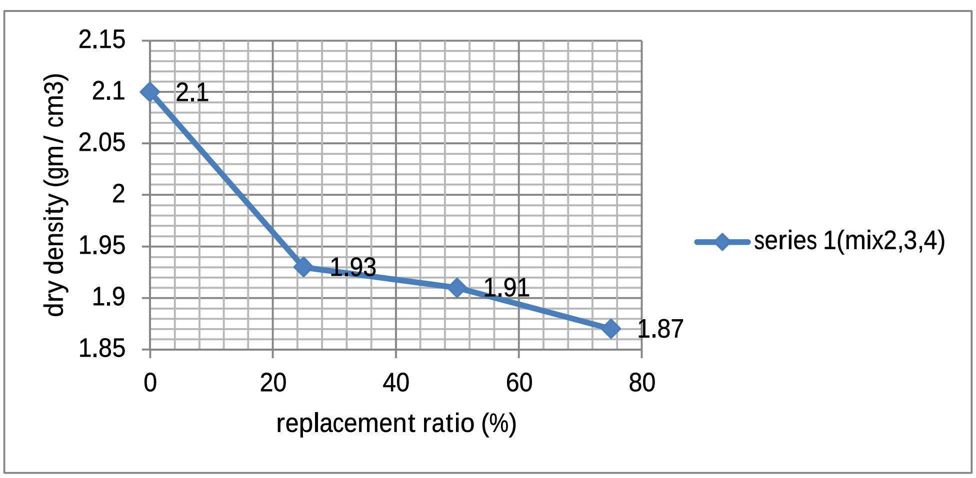
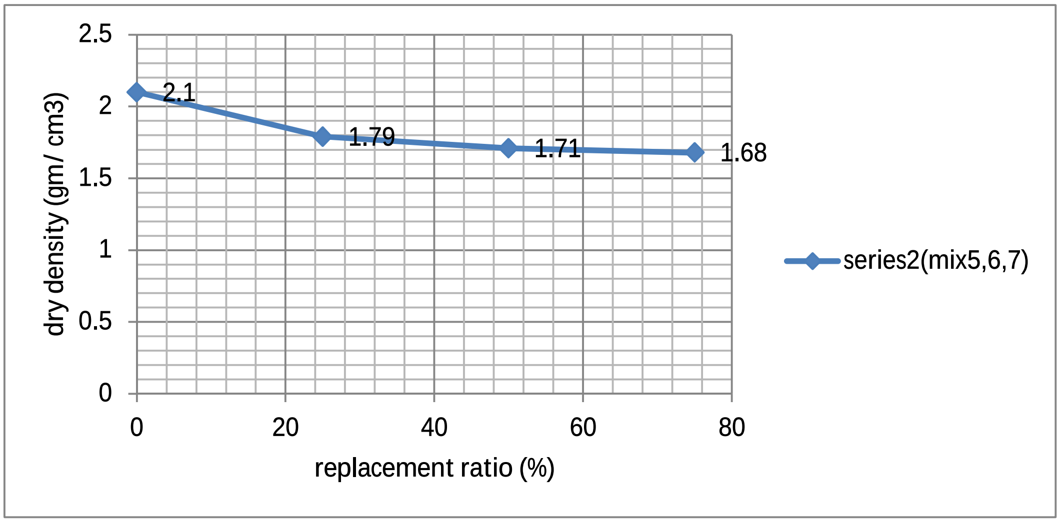


Figure (5) dry density(gm/cm3)with subbase mixture made with recycled concrete (mix1,mix2,mix3,mix4).



Figure(6) dry density(gm/cm3)with subbase mixture made withrecycled brick and ceramic (mix1,mix5,mix6,mix7).

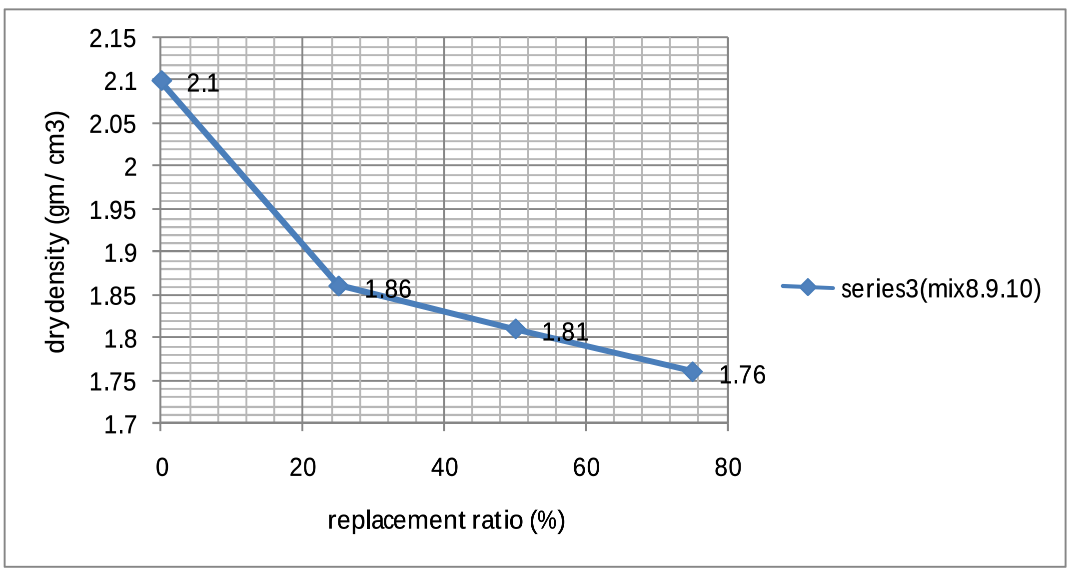


Figure (7) dry density (gm/cm3)with subbase mixture made withwith recycled concrete and brick rubble (Mix1, mix8, mix9, mix10)

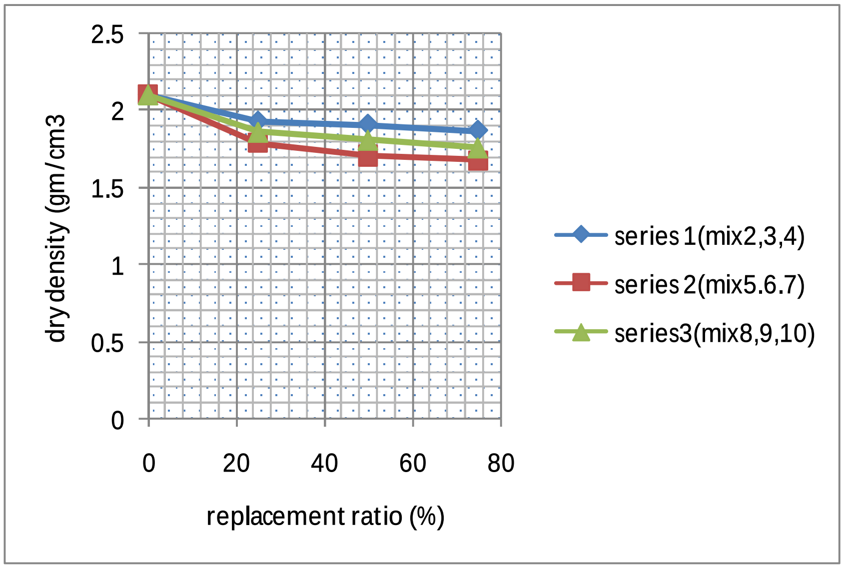


Figure (8) dry density (gm/cm3) with all subbase mixtures.

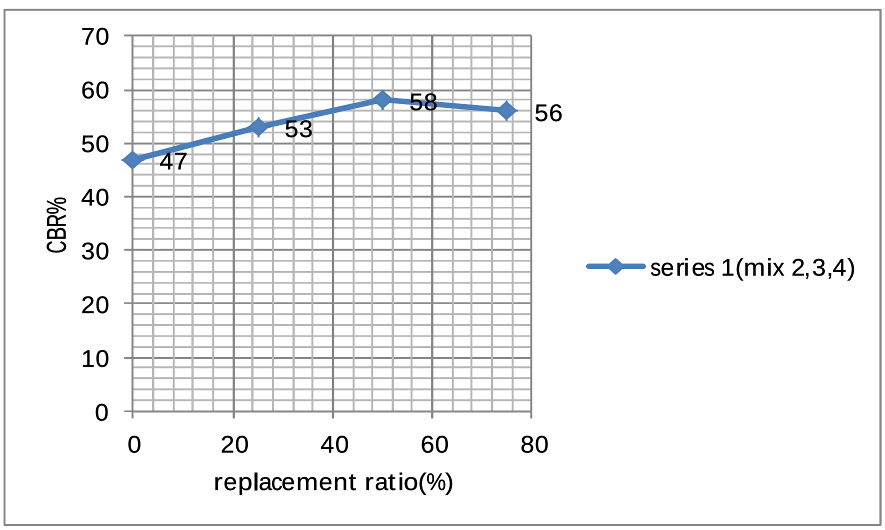


Figure (9) CBR % with subbase mixture made with recycled concrete (Mix1, mix2, mix3, mix4).

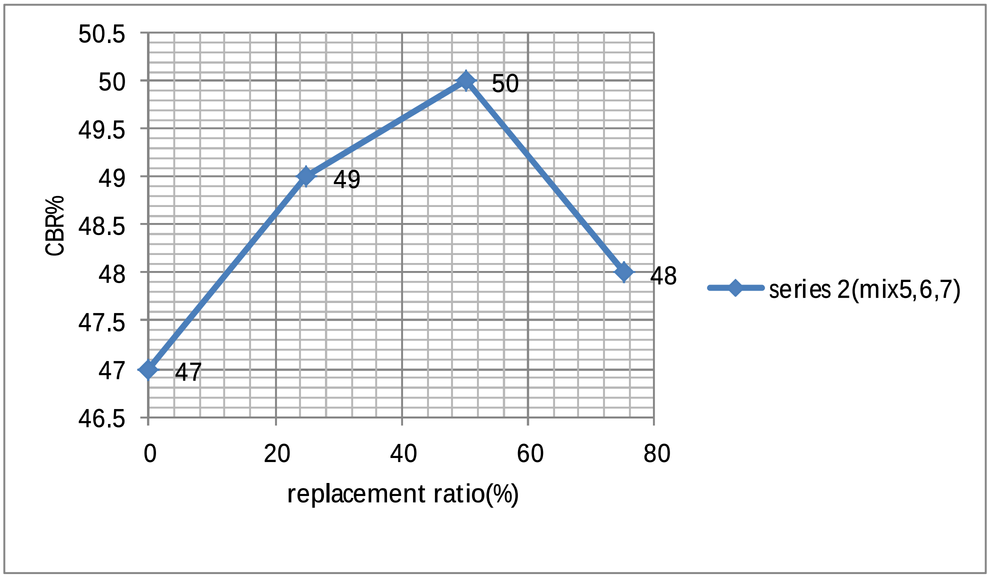


Figure (10) CBR % with subbase mixture made with recycled brick and ceramic (mix1,mix5,mix6,mix7).

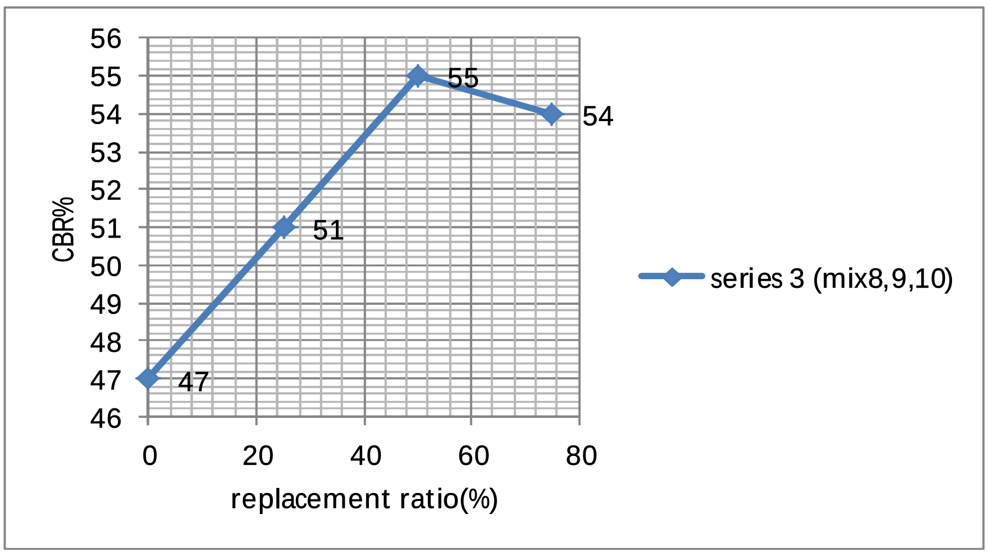


Figure (11) CBR(%) with subbase mixture made with recycled concrete and brick rubble (mix1,mix8,mix9,mix10).

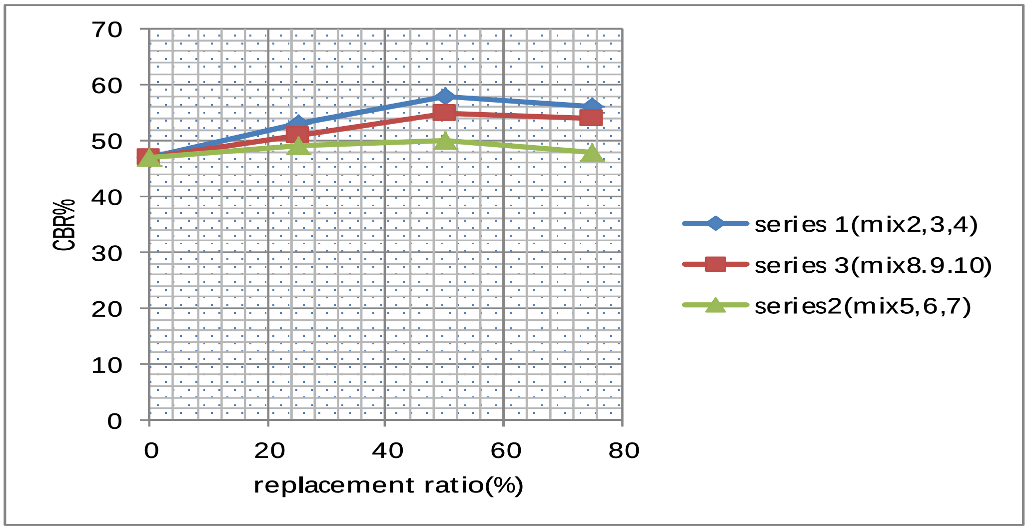


Figure (12) CBR % with all subbase mixtures.

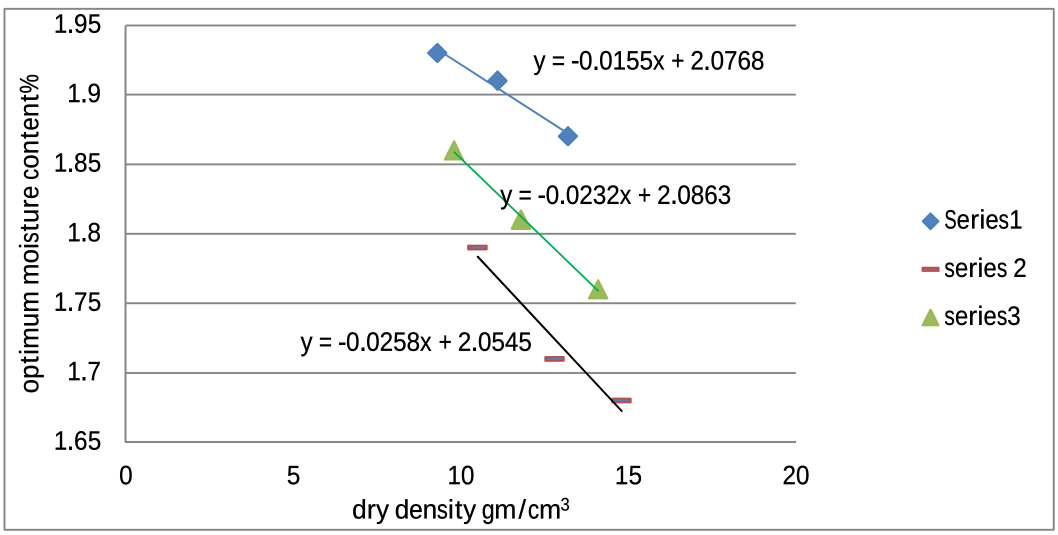


Figure (13) Optimum moisture content – dry density Relationships for all series.