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RESEARCH ARTICLE

STUDY OF CEMENT TREATED BASE AGREAGATE PROPERTIES FOR PAVEMENT STRUCTURE

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ABSTRACT

Balancing out materials with concrete is an appealing alternative to enable less reasonable materials to be utilized as base course or subbase. This is particularly the situation when great quality common materials are definitely not accessible or rare. Concrete TreatedAggregate Base (CTAB) is a non-conventional method used to improve aggregate's engineering properties due to the hardening of cement when moisture is present and extends during the period of curing times. Among the distinctive settled materials, bond bound materials build up a very high firmness and quality, and show great execution for asphalt serviceability and high toughness. Thus, the primary purpose of this study is investigation of cement treatedinfluence on the sand-gravel mixture by presenting a laboratory investigation aimed to characterize the behavior of CTAB at various cement portion (0,5,10,and15) % by weight of dry aggregate. Attemberg limits, California Bearing Ratio (CBR) test, unconfined compressive strength tests, and plate load test have been conducted on CTAB mixtures. Also, this research includes the design of pavement structure involving CTAB to enhance the economicbenefit from using CTAB. The strength of cement treated aggregate base represented by California bearing ratio (CBR) and compressive strength with percent higher than those to base by 46% and 58% respectively. The using of CTAB, binder and surface course present the best economical choice of pavement structure.Mixtures having cement satisfiedfewer than 10%% might be used as subbase materials instead of being used in pavement base.

INTRODUCTION

Total is a mechanical item term for sand, rock, and pulverized shake materials, in their normal or prepared express, that are utilized to give mass quality and protection in development applications.Cement treated aggregate is described as a mixture in which a relatively small amount of cement is used as a binder of coarse aggregates, and which needs a proper water content for both compaction and cement hydration. It used in road bases materials to improve its engineering properties due to the hardening of cement when moisture is present and extends the period of curing times.[1] Be that as it may, some expansion of a balancing out specialist, for example, bond, bitumen, lime or some non-customary operators can enhance the properties of sand-rock mixture (1). Among these distinctive balancing out materials, bond bound materials build up a very high solidness and quality, and show great execution for asphalt serviceability and high strength [1]. Therefore, studies about its physical properties, mechanical behavior, and durability are quite recent. Recovered Portland bond concrete is the most bounteous and accessible of the potential substitutes for regular total in urban zones, especially in Iraq.the mixtures are designed by adding (0%, 5%, 10%, and 15%) Portland cement.

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Although many authors have studiedthe possibility of using CTB in applications, there are a few researcheson the properties and mechanical behavior of mixturestreated with cement when used as road subbases orbase in paving roads because of the following reasons [4]:

- Improving the workability of road materials;
- Increasing the strength of the mixture;
- Enhancing the durability;
- Increasing the load spreading capacity.

The main objective of this research is to better understand the mechanical behavior of cement in order to evaluate whether they are feasibly useful as binder material in the base or subbase layer of road pavement. To carry out these objectives, laboratory tests such as compaction proctor test, CBR, plate loading test, unconfined compressive test, and tensile strength are achieved. Many mechanical properties are obtained such as mixtures density, plastic deformation, resilient modulus, unconfined compressive strength, flexural strength, and indirect tensile strength. Moreover, this paper reviews the parameters that influence the mechanical properties of cement treated aggregate such cement content, mixture dry density, and moisture content. The cement treaded base gives additional strength and support without increasing the total thickness of the pavement layers. Depending on project needs, CTB increases the construction speed, enhances the structural capacity of the pavement, or in some cases reduce the overall time project [(1)]. In addition, a stiffer base reduces deflections due to heavy traffic loads, thereby extending pavement life. Base thickness of CTB is reduced because of high bearing strength compared to unbound granular base thicknesses. [(1)] Moreover, CTAB can distribute loads over a wider area and reducing the stresses on the subgrade, it has a high load-carrying capacity, does not consolidate further under load and is resistant to freeze-thaw wetting-drying deterioration. [(1)] CTAB is a strong, frost- resistant base for a concrete pavement wearing surface. CTB Consists of native soils, gravels, or manufactured aggregates blended with prescribed quantities of cement and water. [(1)]

Historical Overview

Soil-bond was first utilized as a part of 1935 to enhance the roadbed for State Highway 41 close Johnsonville, South Carolina. Since that time, Portland bond has been utilized to balance out soils and totals for asphalt applications on a great many miles of roadway everywhere throughout the world. (2) After over 70 years, aggregate experience has exhibited that various types of soil-bond blends can be customized to particular asphalt applications. In any case, the essentials dependably continue as before. (2) Soil-cement is the simple product of Portland cement blended with soil and/or aggregate, and water and compacted for use in a pavement structure. There is no secret ingredient or proprietary formula that makes soil-cement work. Although sharing a similar chemical process, soil-cement differs from conventional Portland cement concrete in the consistency of the material, quantity of cement required, overall construction procedures, function and strength requirements.[(2)] Concrete treated total material thus is depicted as a blend in which a generally little measure of bond is utilized as a cover of coarse totals, and which needs a legitimate water content for both compaction and bond hydration. By and large, it as a street base material is delivered by utilizing coarse common or squashed totals and composed as a substantial traffic base or an overwhelming traffic wearing courseCement treated materials, which are a group of compacted blends with granular materials, Portland concrete and water, have been generally connected as street base/subbase asphalts. Since 1915, when an asphalt was built and compacted by utilizing a blend of shells, sand, and Portland concrete, the materials treated by bond shift from coarse-grained totals, reused totals to extremely fine-grained soils [17]. In practice, note that there are also other stabilizing agents to stabilize roadmaterials. They are lime, granulated blast furnace slag, pozzolanas, bitumen, and chemical stabilizers. The literature review ofprevious researches has indicated that coarse-grained materialswith low plasticity index are the most appropriate granulates forcement treatment where the cement treated granular materialshave been used as semirigid base course [4]. Concrete treated total material thus is depicted as a blend in which a moderately little measure of bond is utilized as a cover of coarse totals, and which needs an appropriate water content for both compaction and bond hydration. By and large, it as a street base material is created by utilizing coarse characteristic or squashed totals and composed as a substantial traffic base or an overwhelming traffic wearing course. The cement contentedwas the most important parameter controlling the design life (fatigue performance) of stabilized layers. It should be stressedthat layer thickness was also important on design life.

MATERIALS AND METHODS

Aggregate: The amount of totals is normally over 80% by mass in the blend. Subsequently, the properties as far as the materials of coarse totals are significant and must be accounted.[(1)] Limestone aggregate taken from the general Najaf sea quarries in research as granularlayer materialand should be free of roots, sod, and weeds. Fig. ?illustrates thataggregate grading curves within the specification limits forhighwaysand bridge in the Iraq.5 kg of base was used after confirmation of its properties by comparing the results of tests with the Iraqi specification of the road, the results were as shown in the table (1).

Table 1. Aggregate properties*

	average results of three sample	Specification limit[(13)]
Max. dry density (gm/cm^3) *	2.225	---
Optimum moisture (%)	5.7	---
CBR	48.5	Min. 35
Liquid limit (%)	25	Max. 25
Plasticlimit.		Max. 25
Plasticity index (%)	2	Max. 6
Gypsum (%)	6.92	Max. 10.75

* These tests have been conducted in Central laboratories in Consulting Bureau for faculty of college at university of kufa. contains an amount of19% liquid limit and 14% plasticlimit.

Portland cement

Scientists played out a writing survey to archive the advancement of ebb and flow details for choosing concrete substance for balancing out total base materials.(5) (6)In this examination, Portland bond Type II was utilized as a treatment material for the granular blends in view of more noteworthy sulfate protection and direct warmth of hydration contrasted with another sort of portland concrete while the cost is frequently the same. Hence, high soil sulfate substance brings about swell, hurl issues, and can affect cementations and stabilization mechanisms.[(1)] The Portland cement was used after comparing the chemical and physical properties with the Specification limit (AASHTO M 85 -74), as shown in Table (2); the Portland cement of Kufa factory used in all the tests. [(12)]

Table 2. Cement properties

Tests	Sample	Specification limit
Chemical tests		
Sio2 *	20.3	
So3	1.89	No more than 2.5%
Insoluble residue	0.77	Not than 1.5%
Cost on ignition	0.59	No than 4%
Physical tests		
Initial settling time (min.)	137	Not less than 45 min
Last settling time' (hrs.)	240	Not more than 10h
Compressive strength @3day(Mpa)	17.1	Not less than 15 (Mpa)
Compressive strength @7day(Mpa)	28.0	Not less than23 (Mpa)
Fineness (cm2/gm.) by Blaine method	2769	Not less than 2500
Recommendation:- the samples are confirmed to I.Q.S. (5)		

'water'

Water utilized as a part of blending or curing might be spotless and free of oil, salt, corrosive, soluble base, sugar, vegetable, or different pernicious substances harmful to the completed item. Water might be tried as per the necessities of AASHTO T 26. Water known to be of consumable quality might be utilized without testing [(6)].

Experimental work

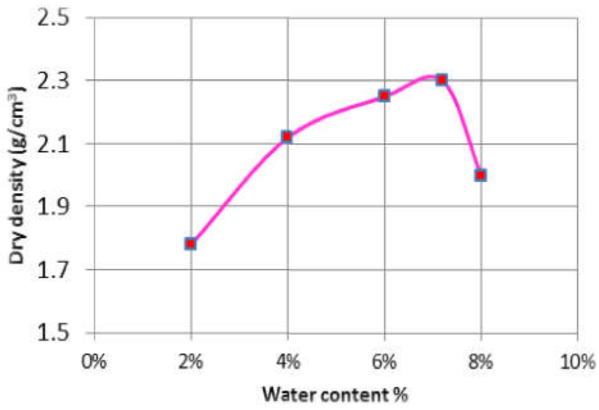
This examination shows a research facility examination pointed characterizethe behavior of cement with natural aggregate. Tensile strength is a very important geotechnical parameter to predict the cracking behavior of pavements, earth dams, and earth structures using stabilized soils. The physical properties of the used natural aggregate are summarized in Tab. (1). The natural aggregateshave highest density value, while treatedaggregate has highest water absorption value. Indeed, the highamount of adhered mortar attached to base particle leadsto a decrease in particle density and an increase in the waterabsorption.

Compaction test

The specimens shall be compacted and tested for density and moisture content in accordance with ASTM D 558CTB samples shall be taken from each sublet and used to create laboratory test specimens representing the various sublet,. Using the density results for each sublet comprising a lot, an average density for the lot shall be determined, which will serve as the basis for acceptance of the lot with regard to density. [(6)] Within each sublet in the field, one (1) in-place density test shall be performed in accordance with ASTM D 1556, ASTM D 2167, or ASTM D 6938. The location of the test shall be randomly selected in accordance with the procedures contained in ASTM D 3665. The in-place density results for each sublet comprising the lot shall then be averaged and compared with the corresponding average lot density. [(6)]
Dry density of the compacted soil is one of the main factors that influence the strength of the CTAB. In adding, water is essential to achieve maximum density to aid in hydration of the cement. Mixing design shall be in according to (AASHTO T134), regardless of the type of mixer used method employed, shall be continued until the cement and water are evenly distributed throughout the aggregate to prevent the formed of cement balls when water is add, and a mixture of uniform appearance is obtains. [(12)] Aggregate and cement be portioned by weight, Where the amount of aggregate was 5kg and four percentage of cement (0%, 5%, 10%, and 15%) of aggregate weight was checked. After that determine moisture-density relationship by construct (moisture-density) curve and determine ideal dampness substance and greatest dry thickness According to (AASHTO T134-70) [(12)] , mixing 5kg of base aggregate with cement and water of (2%, 4%, 6%, and 8%) from base dry weight and continued confusion that has been getting a homogeneous mixture. as show in Figure (1) ,the amount of water required to give optimum moisture content was (7.2%) which get from compaction test.

Gradation test

At the point when tried as per ASTM C 136, the total should comply with the degrees appeared in Table 1. A total mix that meets the necessities of Table (3) might be chosen by the Contractor and utilized as a part of the last blend outline. The last total mix might be very much evaluated from coarse to fine inside the points of confinement assigned in the table and should not differ from as far as possible on one strainer to as far as possible on neighboring sifters, or the other way around. The segment of definite total mix passing the No. 40 (425 µm) sifter might have a fluid cutoff of not more than 25 and a versatility file of not more than 6 when tried as per ASTM D 4318. (6). All aggregate samples required for testing shall be furnished by the Contractor at the expense of the Contractor. Sampling shall be performed by the Contractor in accordance with ASTM D 75. [(6)]



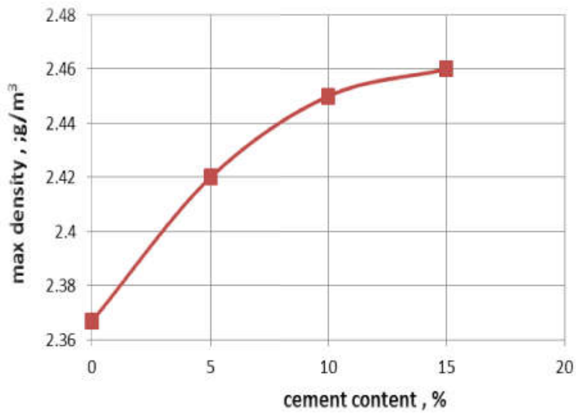


Figure 1. Compaction test resultant

Tab. (3). Aggregate Degreeto CTAB Material[(6)]

Sieve Size	Percentage by Weight Passing Sieves	
	Gradation A	Gradation B
1.5 in (37.5 mm)	100	100
No. 4 (4.75 mm)	45 – 100	55 - 100
No. 10 (1.80 mm)	37 – 80	45 - 100
No. 40 (450 mm)	15 – 50	25 - 80
No. 80 (210 mm)	0 – 25	10 - 35

Plastic Index, Liquid and Plastic Limit tests

For cohesive soils So as to derive the plasticity index a soil, its liquid and plastic limit must got.

Plasticity index (PI) = Liquid limit (LL) - Plastic limit (PL)

It represent wetnesscontented range over which soil is a plastic state.

Liquid limit

Taking 250 g of dry base passing through sieve No. 40 mixed with 50 cm^3 of water to become a homogeneous mix, put the sample in the balance device and brush thickness of 3 mm so that the horizontal surface of the sample. An incision in the middle length of 13 mm, and the balance returned to the machine and the machine spins at a rate of two per second and calculated the number of strikes and took a sample of the form which calculated the water content was its account. As far as possible is characterized as the dampness content at which the dirt being referred to turns out to be excessively dry, making it impossible to be in a plastic condition. As far as possible test, as characterized by (BS 1377), includes taking a 15 g soil test, blending it with water, and moving it into a 3 mm measurement string. (The moving procedure will decrease the dampness substance of the example.) This procedure is done more than once for various examples until the point that the fact is achieved when the example just folds when moved into a 3mm distance across string. The dampness substance of the example being referred to can be taken as the plastic furthest reaches of that dirt.

California bearing ratiotest

CBR tests are performed on untreated compressed blendedmixesof aggregate as a quantity of granulated soilstrength. The mixtures are compacted in the test mold of15.24 cm diameter and 12.7 cm height; moreover, 4.54 kg surchargeweight was applied.Figure (1) illustrates effect of increasing cement portion on CBR results which indicates improvement in course strength and resistance to applied load from that found in natural aggregate.

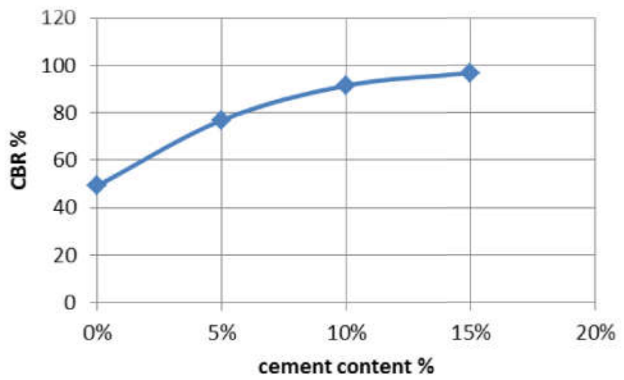


Figure 1. CBR Test results

Plate loading test

The test-show fundamentally comprises of a square iron box of 0.5 • 0.5 • 0.5 m measurements. The total is spread in five layers of 10.0 cm thickness in the model and compacted physically by round and hollow solid hummer weighted around 10 kg under OMC of every blend. At that point, sand cone test is done on the surface of the final compacted total layer to check the relative thickness and ensure that it more noteworthy than 95% as indicated by the benchmarks of thruways Iraqi Code. The surface of compacted totals is leveled; at that point, the stacking round steel plate of 16 cm distance across and 2.5 cm thickness is focused. A contact weight of 0.5 N/mm2 on black-top surface layer is considered. Utilizing the BISAR-straight versatile program, the vertical pressure compasses to the base coarse considering 5.0 cm black-top wearing coarse and 5.0 cm black-top fastener coarse declines to 0.35 N/mm2. The deflection under the vertical pressure permitted to reach nearly the greatest incentive after 30 min for each cycle. From that point onward, the aggregate load is discharged, and the material is permitted sufficient time to bounce back. This cycle is rehashed three times.In order to crystallize CTAB mixture's elasticity –plasticity behavior , stress- strain relationship has been considered as shown in Figure (2) which obvious ascending in strength properties with increasing cement content in the mixture, while deterioration in elasticity characteristic appears due to stiffness of cement mortar.in spite of these fact still 10% from cement portion satisfied in CTAB.

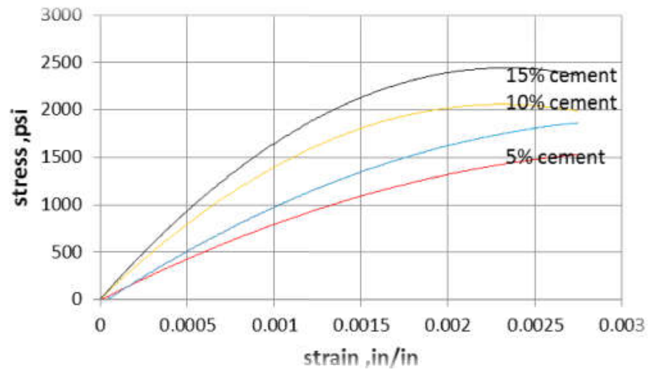


Figure 2. Stress – strain results

Resilient modulustest

The resilient modulus obtained from the plate loading test isbased on the elastic theory. When a rigid plate is put on thesurface of the subgrade soil, the resilient modulus is as follows[21]:

$$\mathrm{Mr} = \frac{\pi(1-\mu^2)p \cdot a}{2w}$$

Mr : the resilient modulus (Mpa);
p : the uniform applied pressure (Mpa);
a : the radius of circular plate (mm);
w: the deflection corresponding to the third load on the rigidplate test (mm); and
µ is the Poisson’s ratio of the aggregate.

Figure (3) demonstrates slightly effect of 5% cement content on resilient modulus results where is asuitable value recorded when adding 10% and 15%

Permanent deformationtest

The issue with bond treated materials however is that they are weak in nature and are delicate to over-burdening. Since over-burdening dependably happens, one needs to consider when outlining asphalts with a concrete treated base. Come up short spare asphalts however must be planned when suitable exchange capacities, e.g. weakness connections .To use current mechanistic– exact techniques for asphalt plan, material properties of the asphalt framework (asphalt layer, base, subbase, and subgrade) are expected to break down its reaction to traffic-type stacking. Information of material properties takes into consideration the forecast of stresses and strains created in the asphalt framework. For flexible asphalt plan, the expectation of disappointment depends on deciding the plastic twisting in base layer. The plastic distortion for mixed base total blends can be gotten from the plate test after the third stacking cycle.

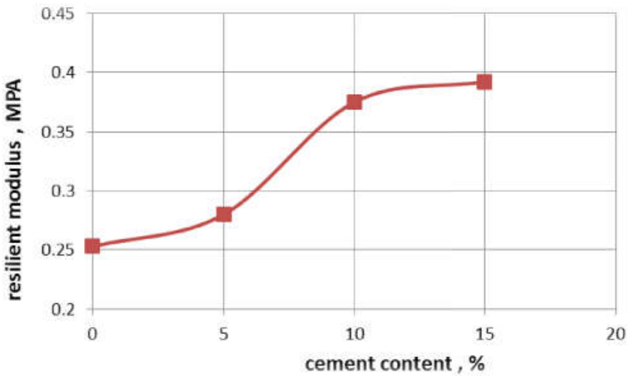


Figure 3. Resilient modulus results

Unconfined compressive strengthtest

Free compression testing was lead in accordance with ASTM D1633. [4]Omit the requirement for immersing cured examples in water for 4 hr. prior to testing.[9] Compressive strength is typically used since it can be determined in a short period of time (7 days) and because of the simplicity of the test. For cement treated mixtures, compressive strength tests (ASTM C 39) are conducted where the preliminary cementcontent by weight or by volume was selected. The unconfinedcompressive strength (UCS) values for aggregate mixtures areobtained by testing cylindrical specimens of dimensions 150diameters with 300 mm height (length/diameter ratios of about 2.00) using steel molds. The cast specimens are kept in ambienttemperature for 24 h; after that, the samples are wrapped indouble layers of wet burlap where placed in moist environmentfor curing. The average unconfined compressive strength of thecement treated specimens after 7-days moisturecuring time is obtained. According to ASTM D 1633, produces a 7-day compressive strength meeting the following requirements: [6]

Ctb situation	7-day compressive strength	
	Minimum value	Maximum value
Under pcc pavement	500 psi (3.447 MPa)	1,000 psi (6.895 MPa)
Under hma pavement	750 psi (5.170 MPa)	1,000 psi (6.895 MPa)

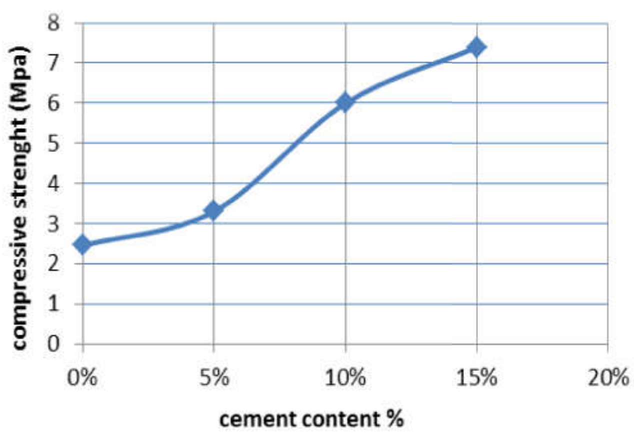


Figure 13. Compressive strength test resultant

Fatigue crackingtest

Weakness breaking is thought to be a standout amongst the most essential kinds of misery influencing the execution of adaptable asphalts on major thruways. This examination investigations the consequences of a research facility investigation of the static and weariness reaction of a run of the mill bond treated base (CTAB) to assesses its mechanical parameters i.e. flexural quality, flexural solidness and ductile strains. A similar four distinctive arrangement of concrete substance were assessed in the blend of 0%, 5%, 10%, and 15%. Two noteworthy sorts of testing were led with the end goal of this examination, i.e. Flexural Fatigue Tests (dynamic stacking) which were done with strain control mode. From the tests, the flexural solidness was gotten from most extreme elastic strains on the base of the examples. The results of the paper are as outlined as take after: First, 0% and 5% CTAB was discovered to be delegated altered material while 10% and 15% CTAB are ordered as balanced out materials. Second, weakness breaking marvel can be seen in balanced out materials (5% CTAB) while different sorts of pain may influence the conduct of unmodified materials (0% CTAB). Third, 10% solidified material is seen to be the most reasonable material to perform under weariness stacking conditions. Fourth, a progression of proposals are introduced for additionally explore i.e. the Flexural Fatigue Test be led at an appropriate (lower) strain an incentive rather than the 400 µe greatness utilized as a part of this exploration. Development of modulus of elasticity depending on the strength development. Modulus of elasticity Equation model of ACI as shown in this equation:

$$\mathbf{E(t) = 0.000285 * w^{1.5} * f_c(t)^{.75}}$$

Where : E(t) is modulus of elasticity in Mpa at time t,
w is mixture maximum density in Kg/m3, and
f_c (t) is compressive strength in Mpa at time t

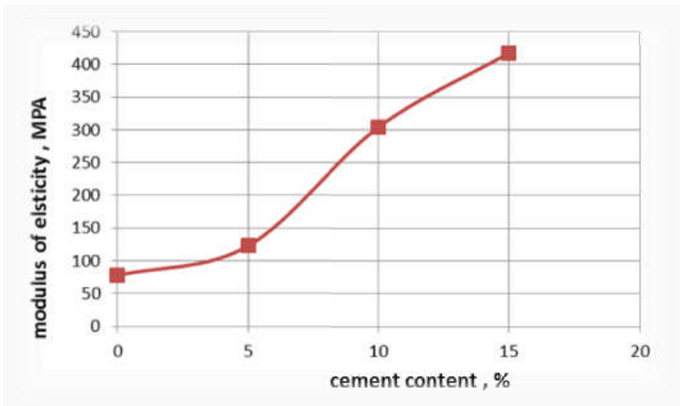


Figure 4. The modulus of elasticity

“Tensile strength”test

The ductile strength of cement treated recycled aggregate is constantly considered as a significant material parameter for outlining asphalt structures. The reason is on the grounds that the base of the treated aggregate layer suffers the tensile stress. In general, flexural beam tests and indirect tensile tests have been employedto evaluate the tensile strength of treated aggregate.

Experimental results

The proportioning design method of cement treated base aggregateCTBA mixture thatconnected in the most recent decades is speculative. Along these lines, the issue of outlining this blend is the absence of a viable technique that permits foreseeing its mechanical properties from blend parameters like the blend creation and the attributes of parts [4]. This paper in this investigations the influence of blend factors on the mechanical properties of CTBA. The goal is to demonstrate the likelihood for building up a compelling way to deal with anticipate the mechanical properties on premise of blend parameters. Choosing the scope of the preparatory bond content by weight or by volume, which is for the most part dictated by the material sort, is investigated by many studies as for exampleArulrajah et al. [12] as shown in Table 6.

mortar will be delicate and dangerous under wet conditions. This could bring about detachment of coarse particles which thus may bring about raveling [4]. According to laboratory tests have been conducted on aggregate –cement mixture with different cement percentages to stabilize base materials ,it found the best cement percent for this purpose is10% by weight of dry weight of aggregate. Despite the fact that 15% of the cement gives greater strength, but the difference between the power given by 10% of the cement do not vary much from the power given by the cement percent of 15%, and the addition of large amounts of cement caused cracks in the road and therefore ingress of moisture to the layers of the main road and the disintegration elements of the basic which reduces the strength and durability of the road and thus affect the performance of the road structural and age to it, so you must use the proportion of cement, which give us the strength and durability at a reasonable cost and negligible cracks.

Table 5. Thicknesses of pavement structure without CTB

Layer	Material	Layer Coefficient	Drainage Coefficient	Thickness, cm
1	surface	0.44	1	4
2	binder	0.41	1	5
3	Base coarse	0.36	1	10
4	CTB	0.23	1.1	27

Table 6. Thicknesses of pavement structure with CTB

Layer	Material	Layer Coefficient	Drainage Coefficient	Thickness,(cm)
1	surface	0.44	1	4
2	binder	0.41	1	5
3	Base coarse	0.36	1	10
4	Subbase	0.123	1.1	50

Total Available SN= 5.6 is greater than design SN

Table 7. Thicknesses of pavement structure without base

Layer	Material	Layer Coefficient	Drainage Coefficient	Thickness, cm
1	surface	0.44	1	4
2	binder	0.41	1	5
3	CTB	0.23	1.1	40

Material cost

Table 8. Pavement coarse prices

Material	Cost
Subbase	20000 id/ m3
Cement	140000 id/ m3
Base	15000 id/ m3
Binder	10000 id/ m3
Surface	10000 id/ m3

The design is acceptable.
Now, we have two choices:
1- Adding cement to the subbase layer:
2-Adding cement to base and subbase layer:

According to base aggregate classification in this research, thecement is chosen to be added by 10% by the mass.Coarse aggregates applied for treated granular layer shouldhave some basic requirements such as a continuous grading, acoarse aggregate size and a good aggregate strength. The valueof PI is likewise considered to decide if the material is reasonable for concrete treatment. On the off chance that the PI is high, the

Design and economic study

This study includes the design of flexible pavement and study the comparison between typical pavement and pavement with cement treated base in one of its layers in terms of thickness and cost.

The design is acceptable.
Now, we have two choices:
1- Adding cement to the subbase layer:
2-Adding cement to base and subbase layer:

For 1 m^3 from pavement section the total cost is as follolws

Pavement layers	Cost , ID	total thickness ,m
Surface Binder Base Subbase	55000	69
Surface Binder Base CTB	48000	46
Surface Binder CTB	39000	49

Economic Study

For road pavement the thickness of pavement structure have large effect on the total cost of the road ,so in this part we will estimate the total cost for pavement with four layer(surface, binder, base coarse ,CTB) and pavement with three layer (surface, binder, CTB) and compare it's cost with the cost of the typical pavement (without cement).

Conclusion

The important conclusions can be drown from this study as following:

- The strength of cement treated base represented by California bearing ratio (CBR) and compressive strength with percent higher than subbase by 46% and 58% respectively.
- The cement treated base is efficient alternative of the subbase material in flexible pavement.
- The CTB can be used in base course within pavement structure in addition to surface and binder course.
- The using of CTB, binder and surface course presents the best economical choice of pavement structure.

Recommendations

For future studies, therecommendations which can be presented as follows:

- The evaluation of CTB materials performance by resilient modulus, flexural strength and permanent deformation.
- Analysis of stresses and strains within pavement structures containing CTB and comparison of this analysis with this of pavement structures which not contain CTB materials.

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