

Treatment of Over Size Ratios of Subbase Materials Used In Erbil Governorate Pavements, Kurdistan, Iraq

Faris Mohammed Jasim, Assistant Professor, Ph.D. ¹, Falah Hasan Ali, MSc, Civil Engineer ², and Mohammed Adam Mohammed, M.Sc., IT Engineer ³

¹ Civil Consultant Engineer, E-mail: faris.jasim@epu.edu.iq, EPU, EETC, Highway Engineering Department, Erbil, Iraq.

² Ministry of Construction & Housing, Department of Kirkuk Construction, Kirkuk, Iraq, E-mail: fala7h@gmail.com

³ KPC, Kurdistan Pipeline Company, Erbil, Iraq, E-mail: mohammedadamfaris@gmail.com

ABSTRACT

Coordination with the directorate of geological survey and mineral investigation in Erbil governorate to select the quarries and all subbase layer materials that used in both flexible, and rigid pavements, are taken from natural sources, according to their recommendation, the quarry locations are (Shamamek (E2), Qushtapa (E5), Ashty/Koya (E7), Salahadeen (E8) /Shaqlawa and Rawandouz (E9)) were chosen in this study in Erbil governorate.

The correction method was conducted for MDD that had oversize practical's on sieve (19 mm) less than 30%. Performing approach to obtain the correct and suitable procedure when retaining more than 30% of course aggregate for the types A or B. This study attempts to establish a useful practical treatment and recommends, based on the reality of actual work, to correct the modified density (according to ASTM, and AASHTO specifications, less than 30%), when it is more than 30%, Using the method of multiplying the modified density by coefficient (1.0125) for every 1% greater than 30% and up to 35%, no more.

Keywords: Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Corrected Dry Density (D_d), Ratio, sieve (19 mm).

1. INTRODUCTION

1.1 Overview

Pavement design has gradually evolved from art to science, empiricism still plays an important role even up to the present day. Prior to the early 1920s, the thickness of pavement was based purely on experience. The same thickness was used for a section of the highway even though widely different soils were encountered. As experience was gained throughout the years, various methods were developed by different agencies for determining the thickness of pavement required. (Yang H. Huang, 2004).

The unbound granular material consists of single particles of different sizes. The source can be natural, such as gravel, or produced, such as crushed rock. Waste products are not very common. Stresses in the unbound material will be distributed through the contacts between the single grains. Permanent deformation in the unbound material can be caused by compaction (volumetric) or shearing and the compaction can be intended or unintended. (Jan Englund, 2011).

1.2 Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)

Compaction requirements are measured in terms of dry density of subbase materials. The maximum dry density. And optimum moisture content (OMC) for compactive effort are basic properties to construct granular sub-base layers. These properties are determined by compaction curve, i.e., a moisture density curve or a proctor curve. This classification system identifies granular materials such as sand, gravel and stone fragments based upon gradation and Atterberg limits. Most state departments of transportation have sub-base specifications with granular material proportions (K. Wayne Lee, Milton T. Huston, Jeffery Davis & Sekhar Vajjhalla, 2001).

Omar Abbas AL-Azzawi et al. (2012) in Iraq reported that the results of monotonic tests revealed an increase of 71% and 107% in the carrying capacity when the relative density increased from 65% to 77% and from 65% to 88% respectively. The cyclic tests revealed a substantial increase in the number of cycles at any stress level as the relative density increases from 65% to 77% and from 65% to 88%.

Dr. Noori S. & Jabar M. Rasul (2014) for Erbil governorate in Iraq Studied that the 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 protect them from ingress of water, consequently prevent occurrence of permanent deformation.

Ratna Prasad and Darga Kumar (2015) in India explained the MDD decreases drastically from 10% to 15% and 25% to 30% in light compaction with increase of % fly ash from 0% to 30%. But from 0% to 10% and 25% to 30% fly ash, the MDD decreases slightly in modified compaction. The addition of % Fly ash in soil gravel mixture, OMC increases both in light and modified compaction and increases slightly from 0% to 10% and drastically increases from 10% to 25% and slightly increases from 25% to 30% in light compaction and modified compaction.

1.3 California Bearing Ratio (CBR)

The CBR is an empirical test and widely applied in design of flexible pavement over the world. This method was developed during 1928-1929 by the California Highway Department. Use of CBR test results for design of roads, introduced in USA during 2nd World War and subsequently adopted as a standard method of design in other parts of the world (Roy, T.K., Chattopadhyay, B.C. & Roy, S.K., 2010).

Araya, Huurman, Houben and Molenaar (2011) in South Africa showed that the usefulness and characterization techniques of an intermediate testing – the repeated load CBR (less fundamental but better than the index tests) is demonstrated for approximation of mechanical behavior of unbound granular materials employed in developing countries. It was

shown that a good estimate of stress dependent equivalent modulus of the base granular can be obtained with the repeated load CBR with strain gauge testing.

Mr. Alaa Hassoon & Dr. Jalal Al-Obaedi (2014) in Iraq reported that the results obtained from maximum dry density test suggested that the waste materials could be compacted to reach reasonable density. The CBR test's results suggest that the CBR values obtained from recycled concrete is significantly higher than those CBR values obtained from the ordinary subbase. The Atterberg tests showed that the waste concrete material is satisfying Iraqi specifications for roads and bridges (SORB).

Abdul-Karim Hussein (2016) for Karbala province in Iraq explained the results of the Californian bearing ratio and Scraping ratio, for the samples taken from the study area have almost identical values because they have similar source rocks, it showed also that it is identical to the engineering specifications required.

R. Vinod Kumar & Pavithra.M, (2016) in India stated that the CBR test is frequently used in the assessment of granular materials in base, sub-base and subgrade layers of road and airfield pavements. The CBR test was originally developed by the California State Highway Department and was thereafter incorporated by the Army Corps of Engineers for the design of flexible pavements. It has become so globally popular that it is incorporated in many international standards ASTM 2000.

1.4 Standard Practice for Correction of Unit Weight:

3.1 This practice presents a procedure according to ASTM D 4718-2001, for calculating the unit weights and water contents of soils containing oversize particles when the data are known for the soil fraction with the oversize particles removed.

3.2 The practice also can be used to calculate the unit weights and water contents of soil fractions when the data are known for the total soil sample containing oversize particles. 1.3 This practice is based on tests performed on soils and soil-rock mixtures in which the portion considered oversize is that fraction of the material retained on the No. 4 sieve. Based on these tests, this practice is applicable to soils and soil-rock mixtures in which up to 40 % of the material is retained on the No. 4 sieve. The practice also is considered valid when the oversize fraction is that portion retained on some other sieve, such as the 3/4-in. sieve, but the limiting percentage of oversize particles for which the correction is valid may be lower. However, the practice is considered valid for materials having up to 30 % oversize particles when the oversize fraction is that portion retained on the 3/4-in. sieve

3.3 Calculate the corrected dry unit weight of the total material (combined finer and oversize fractions), as follows,

$$C\bar{\delta}D = 100 * \bar{\delta}_F * G_M * \bar{\delta}_W / (\bar{\delta}_F * P_C + G_M * \bar{\delta}_W * P_F) \dots\dots\dots(1)$$

where:

$C\bar{\delta}D$ = corrected unit dry weight of the total material (combined finer P_F , and P_C oversize fractions),

G_M = bulk specific gravity,

$\bar{\delta}_F$ = dry unit weight of the finer fraction,

and $\bar{\delta}_W$ = unit weight of water (62.42 lbf/ft³ or 9.802 kN/m³).

2. Materials Samples Selection:

Coordination with the directorate of geological survey and mineral investigation in Erbil governorate to select the quarries. In the first step of this work was an assessment for all quarries who had permission, the quarries had a different type of Sub-base layer material gradation (A & B) and the access to the quarries was very easy. Table (1) shows selection quarries in Erbil city and its surroundings were chosen for this study. Performing trials and error approach to obtain the correct and suitable procedure when more than 30% of course aggregate by weight of material retained on the sieve 3/4-inch (19.0-mm) for the types A or B and consequently to possess a practical procedure that to be more closed to site condition and increase the effort of compaction inside the field or increasing factor of safety. Materials were characterized by standard laboratory tests to verify particle morphology, size distribution, and compaction performance characteristics. These tests included:

1. Sieve Analysis Test according to ASTM (C-136) and SORB (2003).
2. Plasticity Index (PI) Test according to ASTM (D-4318).
3. Los Angeles Abrasion Test according to ASTM (C-131).
4. Soundness Test according to ASTM (C-88).
5. Maximum Dry Density (MDD) Test according to ASTM (D-1557).
6. California Bearing Ratio (CBR) Test according to ASTM (D-1883).
7. Correction of Maximum Dry Density (MDD) according to AASHTO (T224) & ASTM (D-4718).

Table (1) Location of quarries

Sample Code	Locations		
	Districts	Sub-Districts	village
E2	Erbil	Shamamek	Jadida
E5	Dashty Hawler	Qushtapa	Shekhan
E7	Koya	Ashty	Kharaba 53
E8	Shaqlawaw	Salahadeen	Qalaman
E9	Rawandouz	Rawandouz	

3. RESULTS AND DISCUSION

Two fundamental goals drove the collection of the data and the subsequent data analysis. Those goals were to develop a base of knowledge about the correction of MDD if it was equal or less than 30% passing in sieve 19mm and make trial and error approach to find the best method that will be affected to field compaction value if the passing in sieve 19mm more than 30%. The results of gradation, plasticity index (PI), Los Angeles abrasion, soundness, maximum dry density (MDD), optimum moisture content (OMC), and California bearing ratio (CBR) tests through table (2) to table (6).

Table (2) Results of Sieve analysis tests and types

Sample Code	Passing in Sieve, %								Type
	3"	2"	1"	3/8"	#4	#8	#50	#200	
	75mm	50mm	25mm	9.5mm	4.75mm	2.36mm	0.3mm	0.075mm	
E2	100	100	82	56	38	33	17	6.9	A
E5	100	100	87	56	40	35	19	8.9	B
E7	100	100	88	58	37	32	18	10.7	B
E8	100	100	85	60	43	37	20	8.6	B
E9	100	99	86	59	40	36	19	9.8	B

Table (3) Atterberg Limit Test Results

Sample Code	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)
E2	19.6	13.90	5.70
E5	19	13.6	5.4
E7	20.28	14.75	5.53
E8	Non-LL		
E9	Non-LL		

Table (4) Results of Los Angles Abrasion & Soundness Tests

Sample Code	E2	E5	E7	E8	E9
Los Angles Abrasion (%)	16	18	18	19	20
Soundness (%)	13	13	12	14	13

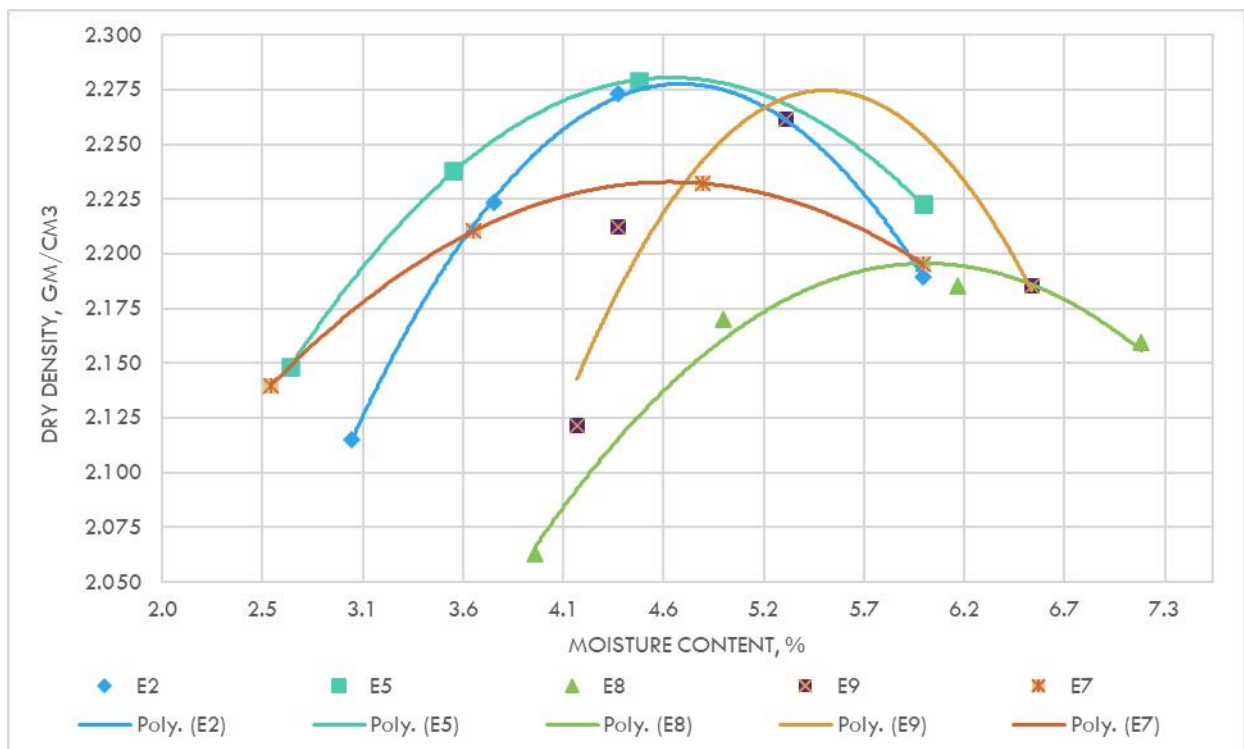


Figure (1) Moisture content and Dry Density Relationship

Table (5) Results of Maximum Dry Density and OMC for All Samples

Sample Code	MDD (g/cm ³)	OMC (%)
E2	2.278	4.7
E5	2.281	4.6
E7	2.234	4.6
E8	2.196	6
E9	2.275	5.5

Table (6) All Samples Computed Results of CBR

Sample Code	Maximum Dry Density (gm/cm ³)	Modified Dry Density (gm/cm ³)	CBR Modified (%)
E2	2.278	2.164	46
E5	2.281	2.167	66
E7	2.234	2.122	54
E8	2.196	2.086	49.2
E9	2.275	2.161	59.6

3.1 Correction Methods for Maximum Dry Density

The procedures of correction for MDD conducted according to AASHTO (T-224) procedures when the retained on the sieve (19mm) it is equal or less than 30%. Table (7) shows that the retained on the sieve (19mm) for all samples.

Table (7) Retained on Sieve 19mm for All Samples

Sample Code	E2	E5	E7	E8	E9
% Retained on Sieve 19mm	27	31	29	32	34

3.1.1 Retained on Sieve (19mm) ≤ 30%

Samples (E2 and E7) have retained on sieve 19mm less than 30% and need to conduct the correction procedures for MDD. Table (8) shows the results of corrected dry density (D_d) that had oversize particles ≤ 30% and figure (2) shows the different values of MDD before and after corrected for both samples.

Table (8) Results of corrected Dry Density (D_d)

Sample Code	MDD (g/cm ³)	retained on sieve 19mm (%)	Passing on sieve 19mm (%)	Bulk Specific gravity (g/cm ³)	corrected Dry Density (D_d) (gm/cm ³)
E2	2.278	27	73	2.6	2.357
E7	2.234	29	71	2.6	2.329

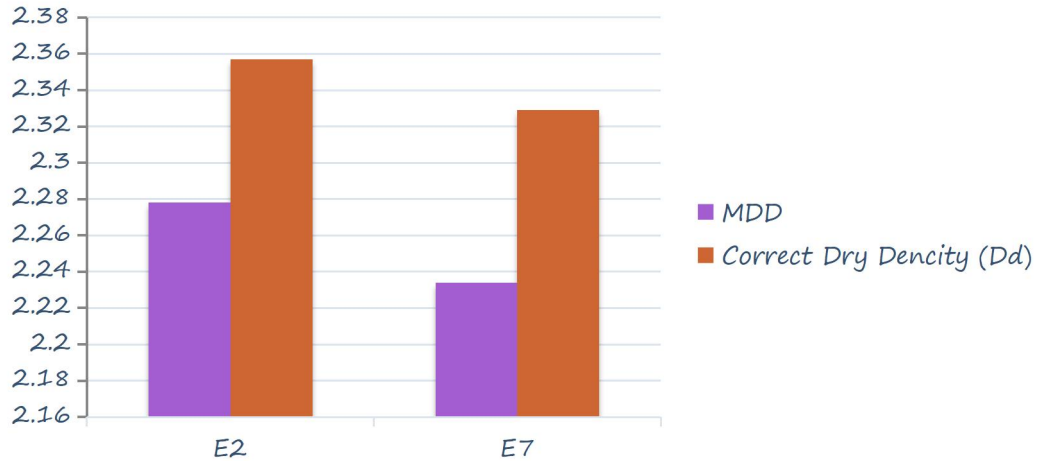


Figure (2) Different Value of MDD before and After Correction

Corrected value of MDD is higher than the original value and it was affected to the field compaction value will increase the effort of compaction inside field or increasing factor of safety.

3.1.2 Retained on Sieve (19mm) > 30%

According to AASHTO T-224 and ASTM D-4718 if the retained on the sieve (19mm) more than 30% no correction procedure is required for MDD. At first, the corrected dry density (Dd) was calculated for actual retained on sieve 19mm then assumed that the retained (30%) on sieve 19mm, and tried to find the actual results of samples (E5, E8, and E9). Table (9) shows the results of Dd for all samples that had values more than 30% retained on sieve 19mm. Figure (3) shows the different values of MDD before and after corrected for each sample.

Table (9) Results of D_d for Samples had over size particles > 30%

Sample Code	Actual retained on the sieve (19mm)	Assume the retained on the sieve (19mm)	Corrected Dry Density (D _d) (gm/cm ³)		% of increase (1-Assumed/actual)
			Actual Retained	Assumed 30% returned	
E5	31 %	30 %	2.371	2.368	0.1
E8	32 %	30 %	2.311	2.303	0.3
E9	34 %	30 %	2.376	2.364	0.5

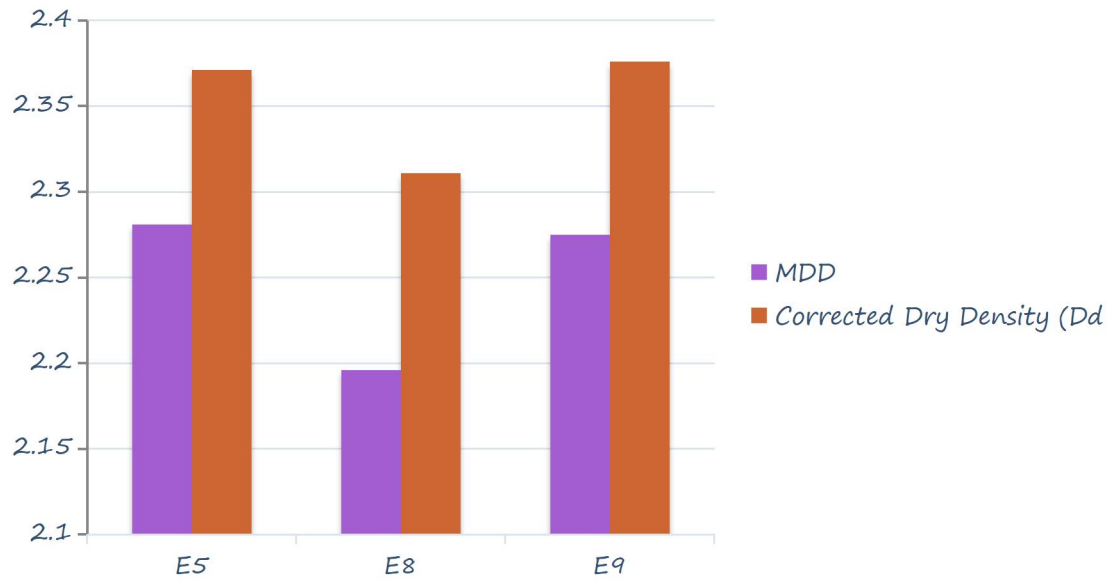


Figure (3) Different Value of MDD before and After Corrected

AASHTO & ASTM had advised to late the oversize up to $\leq 30\%$ but according to actual site condition, it must take all percentage as it like 34% for sample E9 that to be MDD equal to (2.376 g/cm³). This value of corrected dry density will be very close to site condition materials with the full thickness of the subbase layer.

3.2 California Bearing Ratio (CBR) New Value

The new value of CBR is conducted according to the correction results of MDD. Table (10) and figure (4) are showed the different values of CBR for each sample before and after the corrected of MDD. After compared both values, the new values of CBR are increased and that affected the strength of sub-base layer materials. It is true that this method of correction leads to the achievement of great results of CBR values for all samples which are actually "represent the real behavior of the material in the field, But in contrast, the layer using the sub-base materials on increasing the compaction effort depending on the" high MDD value developed after correction procedure.

Table (10) Results of CBR for corrected Dry Density

Sample Code	CBR Modified (%)	New CBR (%) After corrected of MDD
E2	46	54
E5	66	77.4
E7	54	68
E8	49.2	64
E9	59.6	69



Figure (4) Different Value of CBR before and After Corrected

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the laboratory testing program carried out in this study, the main conclusions of the research are presented below:

1. Correction method was done for MDD that had oversize practical's on sieve 19 mm less than 30%, then found the corrected value of MDD is higher than the original value and it is affected to field compaction value (will increase the effort of compaction inside the field or increasing factor of safety).
2. When the oversize practical's on sieve 19 mm more than 30%, it was assumed that all material retained on sieve 19 mm is 30% and for the second time was actual retained (>30%) and finally take an actual retained value of corrected values of MDD because the percentage of increase value for sample (E9) was (0.5%) from the standard value of AASHTO & ASTM as not more than 30%.
3. The method of correction leads to the achievement of great results of CBR values for all samples which are actually "represent the real behavior of the material in the field, but in contrast, the layer using the sub-base materials on increasing the compaction effort depending on the" high MDD value developed after correction procedure.
4. In general, the correction technique resulted in an increase in CBR%, depends on the percentage of the retaining materials and the specific density of the aggregate, so that the percentage of increase in CBR% reached to the all quarries more than 15% and for E2 (more than 17%), E7 (more than 25%), and E8 (more than 30%).
5. The research, after applying the correction process to all quarry materials samples, will have an economic return as it requires additional compaction operations, thus ensuring granular layers (bases, subbase and selected subgrade) with higher specifications and better quality in terms of field density under the asphalt layers, which leads to better performance, longer durability and less maintenance costs.

Therefore, when oversized practical's retaining on sieve 19mm more than 30% of coarse aggregate for types A or B and consequently to possess a practical procedure that to be more closed to site condition, therefore recommends the use of the correction equation of MDD to a ratio not exceeding 35 %, which represents the reality of the material in the site.

5. REFERENCES

- AASHTO T-224. "Standard Method of Test for Correction for Coarse Particles in The Soil Compaction Test | AASHTO Bookstore". Bookstore. transportation.org. N.p., 2010.
- Abdul Karim Hussein. "Engineering Evaluation and The Most Important Applications of Sub-Base Deposits for Selected Quarries in the Governorate of Karbala" Iraqi academic scientific Journal Vol.24. No.2 (2016): 320-332.
- Alaa Hassoon and Jalal Al-Obaedi. " The Use of Recycled Concrete as A Subbase Layer for Highways" Al-Qadisiya Journal for Engineering Sciences, Vol.7. No.3 (2014): 273-277
- Araya, Alemgena A. et al. "Characterizing Mechanical Behavior of Unbound Granular Materials for Pavements". TRB 2011 Annual Meeting (2011): 403-415.
- ASTM C131 / C131M - 14 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in The Los Angeles Machine". Astm.org. N.p., 2014.
- ASTM C136 / C136M - 14 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates". Astm.org. N.p., 2014.
- ASTM C88 - 13 Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate". Astm.org. N.p., 2013.
- ASTM D1557 - 12E1 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 Ft-Lbf/Ft³ (2,700 Kn-M/M³))". Astm.org. N.p., 2012.
- ASTM D1883 - 16 Standard Test Method for California Bearing Ratio (CBR) Of Laboratory-Compacted Soils". Astm.org. N.p., 2016.
- ASTM D4318 - 10E1 Standard Test Methods for Liquid Limit, Plastic Limit, And Plasticity Index of Soils". Astm.org. N.p., 2010.
- ASTM. "ASTM D4718 / D4718M - 15 Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles". Astm.org. N.p., 2015.
- Englund, Jan. "Analyses of Resilient Behaviour Of Unbound Materials for The Purpose of Predicting Permanent Deformation Behaviour." N.p., 2011.
- Huang, Yang H. Pavement Design and Analysis. Upper Saddle River, NJ: Pearson/Prentice Hall, 2004.
- Lee, K. Wayne, and et al. Structural Analysis of New England Subbase Materials and Structures. [Storrs, CT]: New England Transportation Consortium, 2001.
- Omar AL-Azzawi, Namir AL-Saoudi, and Falah H. Rahil. "Deformation Characteristics of Base and Subbase Layers under Monotonic & Cyclic Loading". Eng. &Tech. Journal, Vol.31, Part (A), No.16, 2013: 3052-3060

- Noori S. Ali and Jabar M. Rasul, " A Study on Stabilization of Base Course Material with Portland Cement". Eng. & Tech. Journal, Vol.32, Part (A), No.5, 2014: 1129-1140.
- Prasad R, Ratna, and Darga Kumar N. "Effect of Fly Ash on CBR Results Of Granular Sub Base Subjected To Modified Compaction". International Journal of Engineering Trends and Technology 29.1 (2015): 35-40.
- R. Vinod Kumar and Pavithra M. "Experimental Study on Design of Flexible Pavement Using CBR Method". International Journal of Engineering Research 5.1 (2016): 63-68.
- Roy, T.K., Chattopadhyay, B.C. & Roy, and S.K. "California Bearing Ratio, Evaluation and Estimation: A Study on Comparisons ". Indian Geotechnical Conference (2010): 19-22.
- SORB, Standard Specifications for Roads and Bridges", Section R/6(Selected Granular Materials-Sub-base layer Course), Revised Edition (2003). Republic of Iraq, Ministry of Housing and Construction, State Corporation of Roads and Bridge