Polytechnic Journal. 2022. 12(2)
ISSN: 2313-5727
http://journals.epu.edu.iq/index.php/polytechnic

RESEARCH ARTICLE

# Mechanical Properties of Sub-base Materials In Erbil Governorate Pavements, Kurdistan ,Iraq

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**Received:** 20 November 2021
**Accepted:** 11 June 2022
**Published:** 30 August 2022

**DOI**
10.25156/ptj.v12n2y2022.pp28-34

## ABSTRACT

Performing trials and error approach to obtain the correct and suitable procedure of sub-base materials that used in Erbil , when retaining more than 30% of course aggregate for the types A or B and consequently to possess practical procedure that to be more closed to site condition 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. 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%)..

**Key Words:** Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Corrected Dry Density (Dd).

## 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 s for determining the thickness of pavement required. P Unbound granular material consists of single particles of different sizes. The source can be natural, smooth , and river such as gravel, or produced, such as crushed rock (sand stone or lime stone) . Waste products are not very common. Stresses in the unbound material will be distributed through the contacts between the single grains. Deformation in the unbound material takes place in the contacts between the grains by crushing or sliding which will in turn move and rotate 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. Compaction of unbound material in a road structure has the purpose of increasing the bearing capacity of the material in order to avoid harmful deformation within the unbound layer but also within the whole road structure. (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, 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, Jeffiey Davis & Sekhar Vajjhalla, 2001). AL-Azzawi et al. (2012) 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%. Noori S. & Jabar M. Rasul (2014) for north region of 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% to15% 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) 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. Alaa Hassoon & Al-Obaedi (2014) 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) 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 .

## 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 | Shaqlawa | 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 | | |

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

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

**Figure (1) Moisture content and Dry Density Relationship**

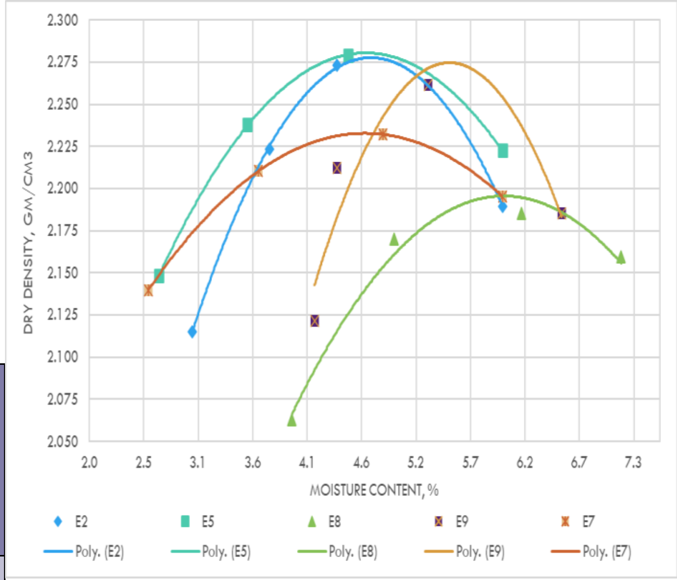



**Table (5) Results of Maximum Dry Density and OMC for All Samples**

| *Sample Code* | *MDD (g/cm3)* | *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/cm3)* | *Modified Dry Density (gm/cm3)* | *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 |

## 1.1 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 (Dd)**

| *Sample Code* | *MDD (g/cm3)* | *retained on sieve 19mm (%)* | *Passing on sieve 19mm (%)* | *Bulk Specific gravity (g/cm3)* | *corrected Dry Density (Dd) (gm/cm3)* |
|---|---|---|---|---|---|
| **E2** | 2.278 | 27 | 73 | 2.6 | 2.357 |
| **E7** | 2.234 | 29 | 71 | 2.6 | 2.329 |

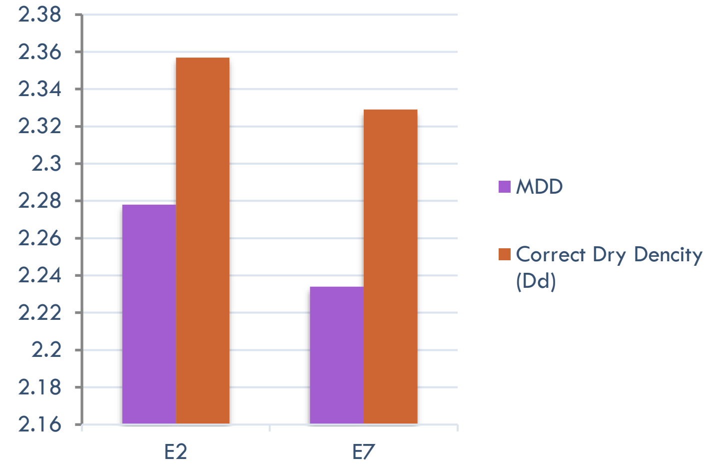



**Figure (3) Different Value of MDD before and After Correction**

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 (4) shows the different values of MDD before and after corrected for each sample.

**Table (9) Results of Dd 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 (Dd) (gm/cm3)* | | *% 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 (4) Different Value of MDD before and After Corrected

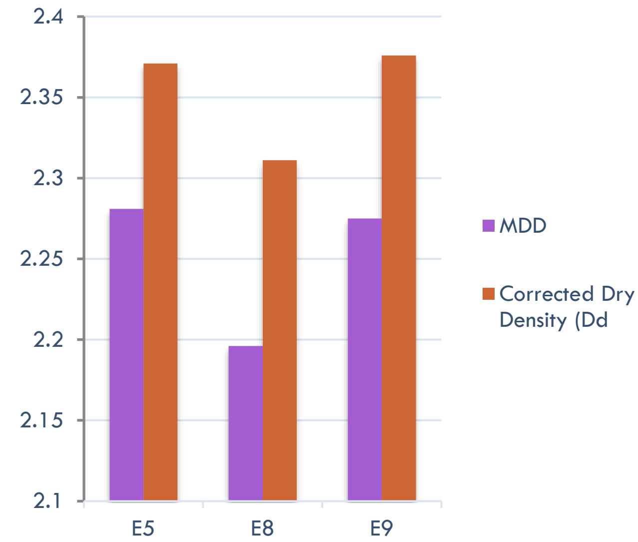
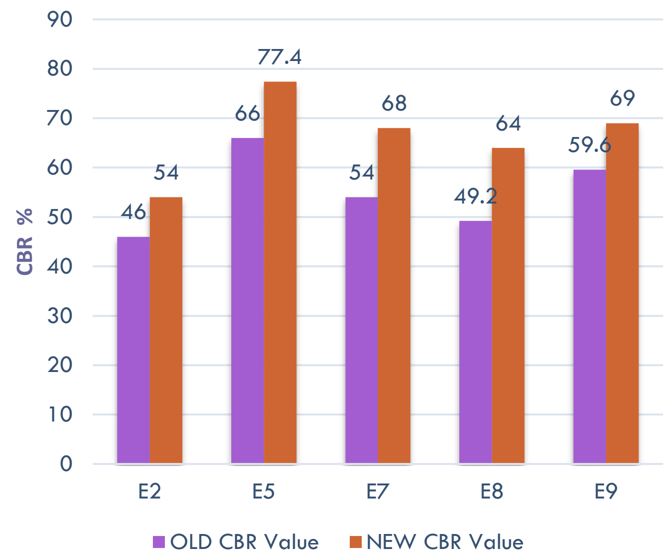



Figure (5) Different Value of CBR before and After Corrected




AASHTO & ASTM had advised to late the oversize up to ≤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 (5) are showed the different values of CBR for each sample before and after the corrected of MDD.

**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 |

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.

## 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.

Therefore, When oversize practical's retaining on sieve 19mm more than 30% of course 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.

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