Study of some geotechnical properties of white and colored kaolin clay in Iraq western desert

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Abstract. During this research the geotechnical properties of Kaolin rocks white and colored has been studies. An experimental program was undertaken to study the effect of the presence of iron oxides (Fe₂O₃) on the geotechnical properties for the white and colored kaolin rocks. White Kaolin clay give the geotechnical properties more than the colored kaolin. The iron oxide in colored kaolin destroyed the internal structure of the Kaolinitic mineral and decrease the crystallinity degree are decreasing and created porous because of influences of the oxidation. We can determine the (G dyne, K dyne, B, Ɣ) parameters from (Vp, Vs) and we can determine (Easta) from (E dyne). The effect of compressive strength for white and colored kaolin show during: modulus Ratio, toughness modules) so that colored kaolin is weaker than white kaolin, because of effect of iron oxides on structure.

Keywords: Kaolin, Geotechnical properties, Estatic, G dyne, iron dioxide

1. Introduction

White and colored Kaolin rocks located within Al–Gaara Formation, Dwaikhla mine are considered of great industrial and economical importance in our country being mainly entered in ceramics and white cement industries in addition to other industries, figure(1) illustrated the location of Dwaikhla mine at Al-Gaara Depression.(1)

The research was performed on these two types of rocks to clarify the extent to which the effect of iron dioxide existence (Fe₂O₃)% on their geotechnical properties (dynamic and Static) (2). and these samples are characterized by high degree of smoothness and refinement of their surfaces.

2. Results and discussion

The research has showed that colored kaolin rocks have low geotechnical properties as compared with white Kaolin rocks as a result of destroying of the interior structure of kaolin metal by iron oxide existed more than 2% in colored kaolin rocks and generating gaps as a result of oxidation, this research used cylindrical samples (for both types of rocks) and of standing edges of diameter 3cm, of various lengths close to the ratio of length/diameter.

The dynamic tests were performed using ultrasonic waves measuring device(OYO Corporation Sonic Viewer model 5217A) where the table(1) shows the test results of the white and the colored kaolin rocks samples and the values of their features of the colored rocks less than white kaolin rocks and this illustrated:-
A-The relation between the longitudinal velocities (VP) and the apical velocities (VS) for the white and the colored rocks reached (0.815), (0.989) respectively, table (2) this means that could assess (VS) directly from (VP) as illustrated in figure (3) (A, B) also could assess Poisson's percentage then calculating Edyn.

The difference of matching strength between the two types of rocks reflects the metal compound difference where colored Kaolin rocks are characterized by containing more than 2% of iron oxide Fe₂O₃ in white kaolin rocks not more than 2% at maximum, increasing the percentage of these oxides accompanied by deduction in crystallization and structure deformity of kaolin.

This effect appeared clearly in cubic compression coefficient B(Gpa) which is of high value in colored kaolin rocks as compared with white Kaolin rocks as a result of the interior structure of crashing kaolin metal in colored kaolin rocks as in table(3)

B-The percentage among the velocities (VP/VS) and poisons ratio of white and colored kaolin rocks reached (0.620) ,(0.996) respectively which referred to the possibility of calculation of poison percentage directly. Figure (3), and the results refers that the extend of the apical velocities(VS) in white kaolin rocks less than the extent of the longitudinal velocities(VP) of %46.2 and for the colored Kaolin rocks be%50, these percentages denote that using the apical velocities would select the engineering characteristic of rock.

C- The relation between the hardness coefficient(G-dyn) and the apical velocities(VS) reached to (0.620-0.999) in white and colored kaolin rocks respectively and (G-dyn) coefficient could be assessed directly from(VS) in this sample without resort to find values according to poisons or coefficient of dynamic figure(4)

D- As for the correlation strength between the longitudinal velocities and volumetric Stretch coefficient (K-dyn) in white and colored Kaolin rocks reached (0.77-0.94) respectively where as the differences in values referred to the difference in the two types densities of rocks as a result of oxidation process and this relation enabled us to assess(K) values directly of (VP) and also calculating cubic compression coefficient (B) via reverse the value, where(B) represented M2/kn, figure(4)

The crashing experiments were performed using the vertical compression device type (Amsler Wolpert) to calculate the compression resistance expressed according to the following equation:-

\[ C = c(0.778 + 0.222xD/L) \]  
\[ C = \text{the compression resistance of the sample when } l = D/L \]
\[ C = \text{The compression resistance of the sample when } l \neq D/L \]
\[ D = \text{The sample diameter, } L = \text{the sample length} \]

Table (3) illustrated results of these tests for white and colored Kaolin rocks resulted from applying potentials on the samples till deformity and crashing them and these results illustrated:-

1- Coefficient static flexibility values of white Kaolin rocks more percentage compared with colored Kaolin rocks(0.79669, Gpa 1.404Gpa) respectively and this illustrated that white Kaolin rocks of strong accumulated Coherent plate structure besides the existence of some fine gaps their effect appeared via the suitability of potential-separation of these rocks figure(6)(A,B) while the colored kaolin rocks of deteriorated considerably plate structure due to entering of (Fe₂O₃) ferric oxide inside the structure of kaolin and destroy it and creating a lot of gaps (figure 1), this also means that each of ( Edyn & Esta) will reach white kaolin rocks to (7), while reaching colored rocks to (15).
This high value indicates existing spaces within slate structure which affected by focusing stresses upon those samples. Accordingly the relation between the two coefficients (Edyn & Estat) of white kaolin rocks (0.6) which could be assessed the value of Estat from Edyn while the relation between them was weak in colored kaolin rocks.

B. The value of decreased resistance of white kaolin rocks is higher rate than colored kaolin rocks (Mpa. 3.54, Mpa 7.47) respectively. This explain that colored Kaolin rocks contain higher than rate 2% from ferric oxide which create the gaps as inevitable result of oxidation process in which crystallize degree will inserted in these rocks.

These values of compression resistance will be obvious through toughness coefficients which express the ability of the materials of absorb the energy during focusing stresses upon (6). It will be calculated according to the following equation:

$$M.T = \frac{2}{3} \times \frac{C.O}{EF} \quad (2)$$

As M.T := toughness coefficients Mn M/M³

Co := Vertical compression resistance Mpa

EF:= separation at collapse M/M

It was obvious that white kaolin rocks with toughness coefficients

(Mn M/M³ (0.045) while colored kaolin rocks reach to (Mn M/M³ (0.0312)). This reflects that the colored rocks will exposed to collapse in lithic phase more than white kaolin rocks as a result of strong slate phase and toughness of white kaolin rocks, besides the effect of compression resistance appears during the percentage of the coefficients (Modulus Ration) which represents a rate of (Estat / Co) (7).

The results showed that the value of coefficient rate of white kaolin rocks has less rates comparing with colored kaolin rocks which reach to (218) and (255) respectively. Then colored kaolin rocks will be according to engineering classification of sound rocks as in the figure (A.6) weaker ratio than white kaolin rocks and also according to classification of resistance of sound and preserved rocks because of weak structure of colored kaolin rocks and because of the effect of the existence of ferric oxide (Fe₂O₃) which works upon destroying slate structure of kaolin metal.

3. Conclusions

Most important conclusions of this research are :-

A. The value of dynamical characteristics of white aolin rocks is higher percentage than colored kaolin rocks because of deteriorated slate structure of colored kaolin rocks which shows inserting of ferric oxide (Fe₂O₃) in higher rate exceed (2%) in kaolin structure which started destroying that structure as shown in the figure – 1.

B. The relation between the apical and longitudinal velocities in both kinds were very strong and could be assessed (VS) immediately from (VP). Also the relation between velocities rates (VP/VS) and rate of poison (V) for both kinds very strong which could be assessed the poison percentage immediately.

C. The relation between hardness coefficients (G) and apical velocities (VS) for both kinds showed that it is very strong which we can assess (G) immediately from (VS) without need for calculation of poisons percentage or dynamic flexibility coefficient. Also calculation of coefficient of volumetric expansion (K) from longitudinal velocities (VP) because of strong emulation
between the two coefficients in both kinds of rocks, then calculation of cubic compression coefficient \( (B) \) through reverse of the quantity only.

4. Static flexibility coefficients value of white kaolin rocks \((1.54)\) characterized that had the higher percentage than colored kaolin rocks \((0.79)\) Gpa because of deteriorated slate structure of colored kaolin rocks. This state will be obvious through the percentage of \((E_{dynam} \text{ and } E_{static})\) which seems to be very high in colored kaolin rocks\((15.30)\), while it is little in white kaolin rocks \((6.99)\). also the relation between \((E_{dynam} \text{ and } E_{static})\) in white kaolin rocks is moderate and weak in colored kaolin rocks.

5. Regarding the value of compression resistance, it will be \((\text{MPa} \ 7.06)\) in white kaolin rocks, while it reaches to \((\text{MPa} \ 3.54)\) in colored kaolin rocks because of destroyed internal structure of such rocks. Its effect is showed in toughness coefficient which reaches in white kaolin rocks to \((Mn/M^3 \ 0.044)\) and \((Mn/M^3 \ 0.0301)\) in colored kaolin rocks which is exposed to failure and collapse in slate phase more percentage than in white kaolin rocks.

6. Engineering classification of rocks showed that the white Kaolin rocks has coefficient percentage of \((213)\), while colored Kaolin rocks may reach \((256)\). In other words that the characteristics of white Kaolin rocks better than colored Kaolin rocks because of deteriorated slate structure which was resulted from entering of \((\text{Fe}_2\text{O}_3)\) ferric oxide more than \((2\%)\) in these kinds of rocks.

4. References

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Table (1) values of dynamic properties of rock samples

| Sample s No. | Rock type | P (MPa) | Edyn (GPA) | K (GPA) | G (GPA) | B (GPA A) | Vs (M/sec) | Vp (M/sec) | Vp/Vs |
|------------|---------|--------|------------|--------|---------|-----------|-----------|-----------|-------|
| 1          | White kaolin | 2288. 3 | 7.2112    | 8.5544 | 4.1123  | 0.2       | 1.2563   | 1164.4  | 2270. |
| 2          |         | 2327. 8 | 8.8667    | 7.835  | 3.9956  | 0.3       | 1.1147   | 1315.7  | 2389. |
| 3          |         | 2145. 8 | 3.2767    | 2.585  | 1.7998  | 0.3       | 1.2456   | 1155.6  | 2287. |

4
| Color kaolino | 4 | 5 | 6 | 7 | 8 | 9 |
|--------------|---|---|---|---|---|---|
| 2137.        | 2.5654 | 2.3245 | 1.1345 | 0.2 | 5 | 3.7823 | 844.3 | 5 | 1295. | 1.534 |
| 2165.        | 2.7764 | 1.8232 | 1.043 | 0.2 | 5 | 4.8766 | 644.9 | 5 | 1185. | 1.688 |
| 2246         | 4.4432 | 2.3854 | 2.6451 | 0.2 | 5 | 2.4332 | 854.14 | 3 | 1685. | 1.938 |
| 2240         | 4.455 | 4.145 | 1.591 | 0.2 | 5 | 2.4180 | 868.16 | 6 | 1690. | 1.936 |
| 2320         | 5.295 | 8.088 | 2.616 | 0.2 | 5 | 1.2363 | 932.14 | 6 | 1787. | 1.917 |
| 2122         | 6.180 | 6.358 | 2.310 | 0.2 | 5 | 1.5726 | 1034.1 | 6 | 2108. | 2.021 |
| 2382         | 4.934 | 4.523 | 1.870 | 0.2 | 5 | 2.2278 | 885.9 | 6 | 1711. | 1.932 |
| 2241         | 4.643 | 4.509 | 1.752 | 0.2 | 5 | 1.2174 | 682.2 | 6 | 1747. | 1.980 |
| 2309         | 9.940 | 7.463 | 3.889 | 0.2 | 5 | 1.6779 | 1296.1 | 6 | 2340. | 1.805 |
| 2331         | 8.534 | 8.305 | 3.206 | 0.2 | 5 | 1.2046 | 1172.8 | 6 | 2323. | 1.982 |
| 2324         | 9.055 | 8.256 | 3.442 | 0.2 | 5 | 1.2112 | 1214.5 | 6 | 2350. | 1.935 |
| 2254         | 9.517 | 8.854 | 3.652 | 0.2 | 5 | 1.2419 | 1272.5 | 6 | 2395. | 1.881 |
| 2289         | 9.674 | 8.310 | 3.703 | 0.2 | 5 | 1.2032 | 1271.4 | 6 | 2405. | 1.891 |
| 2257         | 4.705 | 3.844 | 1.815 | 0.2 | 5 | 2.6017 | 896.17 | 6 | 1665. | 1.858 |
| 2102         | 3.698 | 2.245 | 1.219 | 0.2 | 5 | 4.4541 | 761.47 | 5 | 1365. | 1.781 |
| 2139         | 2.887 | 2.735 | 1.690 | 0.2 | 5 | 3.6556 | 713.75 | 5 | 1399. | 1.960 |
| 2030         | 3.963 | 3.886 | 1.500 | 0.2 | 5 | 2.5735 | 855.96 | 5 | 1700. | 1.986 |
| 2237         | 6.10  | 5.62  | 2.350 | 0.2 | 5 | 2.303  | 987.8 | 5 | 1896. | 1.9 |
| 2127         | 5.776 | 3.366 | 2.378 | 0.2 | 5 | 2.9708 | 1057.2 | 5 | 1735. | 1.658 |
| 2154         | 6.503 | 3.289 | 2.475 | 0.2 | 5 | 3.0403 | 1071.4 | 5 | 2058. | 1.921 |
| 2072         | 4.646 | 2.903 | 1.884 | 0.2 | 5 | 3.4482 | 953.23 | 5 | 1615. | 1.695 |
| 2069         | 4.205 | 3.321 | 1.631 | 0.2 | 5 | 3.0106 | 887.43 | 5 | 1629. | 1.835 |
| 2075         | 3.783 | 3.864 | 1.452 | 0.2 | 5 | 2.5873 | 835.39 | 5 | 1670. | 2.1 |
| 2115         | 4.051 | 3.112 | 1.578 | 0.2 | 5 | 3.2135 | 862.67 | 5 | 1570. | 1.828 |
| 2008         | 6.446 | 6.433 | 2.417 | 0.2 | 5 | 1.5543 | 1096.4 | 5 | 2192. | 1.999 |
| 2025         | 5.408 | 5.397 | 2.027 | 0.2 | 5 | 1.8525 | 1000.0 | 5 | 2000. | 2 |
| 2080         | 5.11  | 3.94  | 1.980 | 0.2 | 5 | 2.7090 | 970.47 | 5 | 811.0 | 1.196 |
| Color kaolino | 22 | 23 | 24 | 25 | 26 | 27 |
| kaolino      | 21 | 22 | 23 | 24 | 25 | 26 |
| 2237         | 6.10 | 5.62 | 2.35 | 0.2 | 5 | 2.303 |
| 2127         | 5.776 | 3.366 | 2.378 | 0.2 | 5 | 2.9708 |
| 2154         | 6.503 | 3.289 | 2.475 | 0.2 | 5 | 3.0403 |
| 2072         | 4.646 | 2.903 | 1.884 | 0.2 | 5 | 3.4482 |
| 2069         | 4.205 | 3.321 | 1.631 | 0.2 | 5 | 3.0106 |
| 2075         | 3.783 | 3.864 | 1.452 | 0.2 | 5 | 2.5873 |
| 2115         | 4.051 | 3.112 | 1.578 | 0.2 | 5 | 3.2135 |
| 2008         | 6.446 | 6.433 | 2.417 | 0.2 | 5 | 1.5543 |
| 2025         | 5.408 | 5.397 | 2.027 | 0.2 | 5 | 1.8525 |
| 2080         | 5.11  | 3.94  | 1.98  | 0.2 | 5 | 2.7090 |
Table (2) shows values of some dynamic factors for white Kaolin and colored Kaolin.

|       | VS  | VP  | VP/VS | G   | K   |
|-------|-----|-----|-------|-----|-----|
| VS    | 0.5 | 0.5 | 0.33  | 0.96| 0.93|
| VP    | 1   | 0.5 | 0.5   | 0.93| 0.94|
| VP/VS | 1   | 0.8 | 0.25  | 0.5 | 0.47|
|       | 1   |     | 0.3   |     | 0.5 |
| G     |     |     |       | 1   | 0.95|
| K     |     |     |       |     | 1   |

Table (3) shows values of the static properties of the samples.

| rock    | samples | Esta | Edyn/Estat | CO  | M.I | M.R |
|---------|---------|------|------------|-----|-----|-----|
| L1/A    | 1.485   | 5.0025 | 4.324      | 0.0093 | 336.43 |
| L1/B    | 5.259   | 1.797  | 0.463      | 0.0001 | 726.02 |
| L1/C    | 0.748   | 1.040  | 4.969      | 0.0233 | 103.99 |
| L2/A    | 0.247   | 9.516  | 3.556      | 0.0402 | 69.630 |
| L2/D    | 1.259   | 2.0473 | 4.084      | 0.0093 | 300.44 |
| L2/F    | 1.195   | 2.8853 | 5.267      | 0.0186 | 225.31 |
| L3/C    | 0.774   | 5.77   | 11.99      | 0.0914 | 64.537 |
| L3/D    | 0.452   | 11.701 | 11.31      | 0.1502 | 39.901 |
| L3/E    | 0.783   | 7.8853 | 6.212      | 0.0410 | 126.16 |
| U1/A    | 0.541   | 9.103  | 12.59      | 0.1309 | 42.951 |
| U1/C    | 0.355   | 9.096  | 3.230      | 0.0170 | 109.98 |
| U1/D    | 0.916   | 8.059  | 5.273      | 0.0177 | 170.7 |
| U1/E    | 0.366   | 7.232  | 6.503      | 0.0603 | 56.402 |
| U2/B    | 1.706   | 5.3132 | 4.563      | 0.0074 | 373.4 |
| U2/D    | 6.947   | 1.3925 | 16.42      | 0.0024 | 666.27 |
| U3/A    | 2.457   | 1.9537 | 13.32      | 0.0492 | 180.75 |
| U3/B    | 1.455   | 2.1201 | 9.724      | 0.0542 | 150.7 |
| U3/C    | 1.502   | 1.9218 | 7.423      | 0.0346 | 202.41 |
| U3/F    | 0.963   | 4.1139 | 8.983      | 0.0707 | 107.22 |
| AVE     | 1.54    | 6.9900 | 7.07       | 0.044  | 213.27 |
| C1/B    | 0.498   | 1.5820 | 4.275      | 0.0462 | 116.64 |
| C1/E    | 0.155   | 4.7460 | 4.769      | 0.0601 | 32.661 |
| C2/A    | 0.592   | 7.7573 | 3.57       | 0.0305 | 167.75 |
| C2/C    | 0.324   | 1.3880 | 3.602      | 0.0226 | 87.187 |
| C2/D    | 2.435   | 1.5899 | 3.296      | 0.0022 | 738.82 |
| C2/F    | 0.225   | 8.0380 | 3.556      | 0.0435 | 63.164 |
| C3/A    | 0.253   | 2.4770 | 2.702      | 0.029  | 90.915 |
| C3/B    | 1.896   | 2.8664 | 2.506      | 0.0070 | 753.93 |
| AVE     | 0.796   | 1.5306 | 3.534      | 0.0301 | 256.28 |