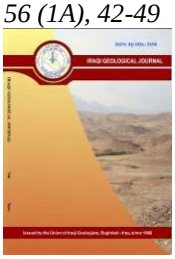
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Validity of the Injana Claystones as Fillers AL-Hajaj, Northern Salah-Alddin, Iraq

Munji H. Ali1, *, Mohammed R. Abood2, and Ghazi A. Zarraq3

[1] Department of Applied Geology, College of Science, Tikrit University, Tikrit, Iraq

* **Correspondence**: munji.h.mh@gmail.com

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Abstract

This study aims to evaluate the suitability of the Injana Formation clays for filling material in the Al-Hajaj area, Salah Aal-Din. The exposed rocks are Injana formation, in addition to the Quaternary Deposit. four stations were studied to determine their suitability as materials for dams. Geotechnical properties show that the type of clay is low plasticity clay and the chemical analyses show that the ratio of total dissolved salts ranges between 1.35-3.45 %, while the ratio of gypsum content ranges from 0.22-0.29. In the last, the geotechnical properties of Injana clays are accepted as filling materials for earth-fill dams when compare with National Center for Laboratories and Construction Sciences, 2003, Building Materials Specification, Sorb /R5. The aim of this study is to estimate the geotechnical properties of the clay rocks including petrophysical properties and Chemical properties and know the viability of clays for filling dams in the study area as filler material based on Iraq specification, 2003, Sorb/R5.

Keywords: Dams; Filler material; Physical properties; Chemical properties.

1. Introduction

The Injana Formation is considered one of the most widespread Formations in Iraq. The Formation in the study area consists of fragmentary successions of sandstone, siltstone, and claystone in varying proportions. The Injana Formation has been studied by many researchers from many different aspects due to the importance of the rocks of this Formation from the sedimentary and economic aspects.

Claystone rocks are the most prevalent in the sedimentary stratigraphic column, constituting about (45%-55%) of the sedimentary rock sequences Awadh, 2020). Therefore, they are used as filler materials in dams and in the core of the dam's rocks to prevent the occurrence of leakage in the body of the dam. Earthen dams consist mainly of loose materials such as clay, sand, gravel, rock crumbs, and mudstone (Fatohe et al., 1989), so most studies in this specialization have focused on dams and water reservoirs to retain water in heavy rains and the possibility of using it in times of drought as well as agricultural uses industrial, electric power generation, tourism, etc.

Clays are very important for different types of industry (Rmaidh and Awadh (2021); it uses for cement and bricks (Awadh, 2021). Due to the presence of large quantities of clay within the formation of Injana in the study area, in addition to its proximity to the proposed dams, such as the Makhoul dam, Wadi Al-Jarnaf Dam, and the Al-Hadhar Dam, which are earthen dams and require large quantities of

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clay, Therefore, it has become necessary to study the geotechnical characteristics of most of the existing clays to know their suitability for various engineering purposes.

The site research is located in the Hajaj area of Baiji District in Salah-Alddin, about 33 km from Tikrit city center, it is located within 38 S (Zone and band) and lies between 365615 E & 366076 E and 3857144 N & 3858255 N according to the Universal Transverse Mercator (UTM) system (Fig. 1). There are many studies dealt with filling material conducting metal, chemical, and physical soil analyses. Geotechnical assessment of the filling soil, from the left side of the Greater-Zab River to identify the sources and suitability of the soil in the study area for use in the building of the filling dam was concluded that some of them were valid, and others needed treatments. (Abboud, 2015) Suitability of Injana Clays for filling Materials in the Sharqad area. Laboratory assessment of filling materials required for the construction of the Khasa Jai, Kirkuk Dam and all models studied were found to be within specification (Al-Douri 2009) worked on the suitability of clay of the Injana Formation in Taq Taq area, Arbil, Iraq for filling materials all the study samples were suitable as filling materials. The current research aims to study the estimate the geotechnical properties of the clay rocks including (petrophysical properties and chemical properties) and know the viability of clays for filling Dams in the study area as filler material based on Iraq specification, Sorb/R5,2003.

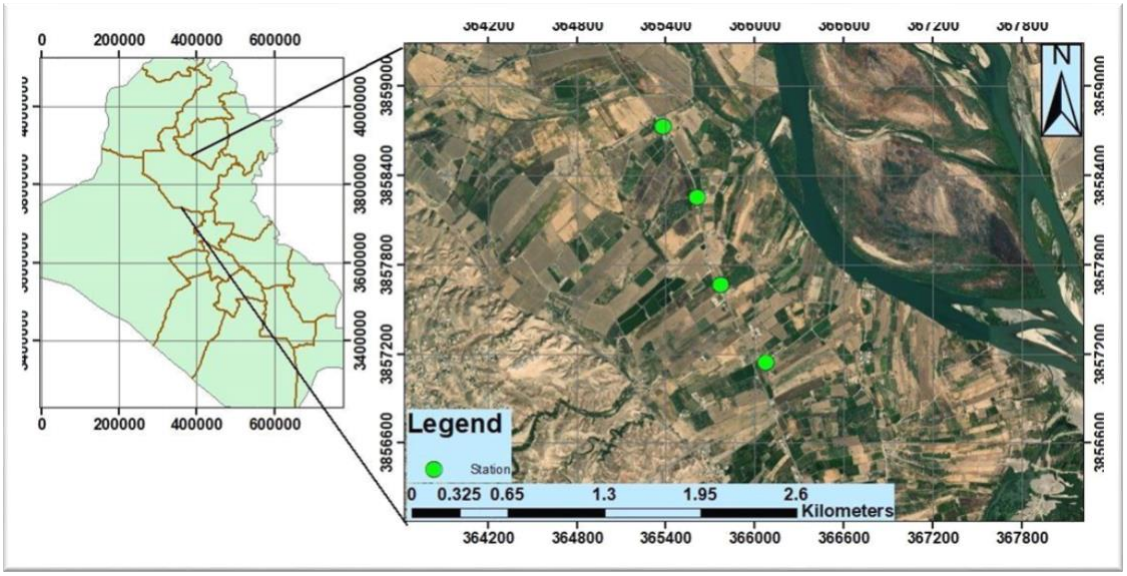


Fig 1. Location map of the study area

2. Geology of the Study Area

The reconstruction of exposed sedimentary succession in or near the study area is graded from middle Eocene to Recent, the following is a brief description of these Formations, from oldest to newest.

2.1. Fatha Formation

The section of this formation is in the Low Folded zone about 15 km north of Baiji District. The age of the formation is Middle Miocene the formation composed of anhydride, gypsum, limestone, and clay (Jassim and Goff, 2006). The formation was deposited in shallow coastal basins of high salinity; it is characterized by fossils consisting mainly of myelliids and estracudas found within the limestone layers (Buday, 1984).

2.2. Injana Formation

The section of this Formation is located in the Injana area of the Hamrin fold near the Baghdad-Kirkuk road (Fig. 2). It is distinguished by sandstone, siltstone, and mudstone sequences, and the thickness of which varies in sedimentary cycles up to 1 to 15 m (Jassim and Goff, 2006). In addition, these rocks have lenses of silt and sand of varying thicknesses. The age of the Formation is Upper Miocene. The thickness in the study area of the sandstone layers ranged between 3-6 m, while the thickness of the claystone layers ranged from 2- 5 m.

2.3. Quaternary Deposits

The thickness of the sediments of the Quaternary period in the study area ranges from 2- 4 m, and these sediments are divided into slope sediments which are rocky crumbs resulting from the processes of weathering and erosion of the exposed rocks in the area, and it is usually a mixture of gypsum, limestone, and sand-clay. Tectonically the study area falls within the Hamrin- Makhol block, in the Low Folded Zone according to the subdivision of (Jassim and Goff, 2006).

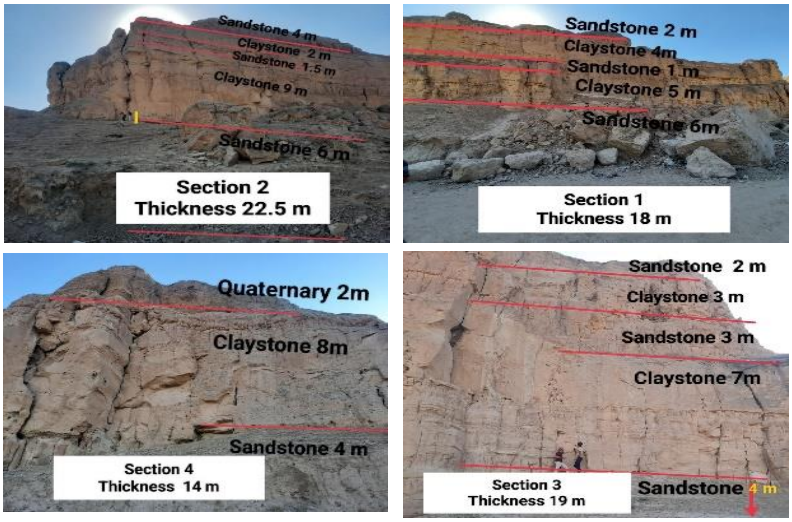


Fig 2. The sequences of the Injana Formation in the study area

3. Materials and Methods

The basic properties of the soil samples were determined for soil assessment and for use in filling materials analysis according to the ASTM laboratory testing standards as follows.

- Grain size analysis content is determined following (ASTM, D 422-63., (2004).
- Soil plasticity indexes are determined by liquid limit and plastic limit tester following (ASTM, D 4318-00., (2004).
- Chemical properties are determined following (B.S.1377-3, 1990).

3.1. Physical Properties

3.1.1. Grain size analysis

The grain size analysis is important in knowing the type of the soil through the size of its grains it is divided into two types according to the size of its granules (coarse grains) include gravel and sand, as for the second type (fine grains) include clay and silt. Tablet 1 shows grain size designation for various soils. Table 2 shows the sizes of the sieves used in the size analysis of the soil.

Table 1. Grain size designation for various soils

Type of clay	Opening mm	U.S. Standard
Gravel	>4.75	4
Coarse sand	>2.0	10
Medium sand	>0.425	40
Fine sand	>0.075	200
Fines (silt, clay)	<0.075	Pan

Table 2. The sizes of the sieves used in the size analysis of the soil

Classification system	Size of Gravel mm	Size of Sand mm	Clay & Silt mm
Unified	4.75 – 75	0.075- 4.75	Clay &silt are Identified by their plasticity characteristics
AASHTO	2.0 – 75	0.05 - 2.0	0.002 – 0.05 <0.002
MIT	2.0 – 100	0.06 - 2.0	0.002 – 0.06 <0.002
ASTM	2.0 – 100	0.075 - 2.0	0.005 – 0.075 <0.005
USDA	2.0 – 75	0.050 - 2.0	0.002 – 0.05 <0.002

The grain analysis was carried out in two stages, it's the sieve analysis to separate the fine particles whose diameters are greater than 0.075 mm, and the wet analysis was used to separate the fine particles whose diameters are less than 0.075 mm According to the principle of sedimentation velocity using Stock's law, the test was carried out according to Standard (Gilbert and Gedeon, 2004) and American Standard (Iraq specification (Sorb/rs)) and the results of sieve analysis are shown in Table 3 and Fig 3.

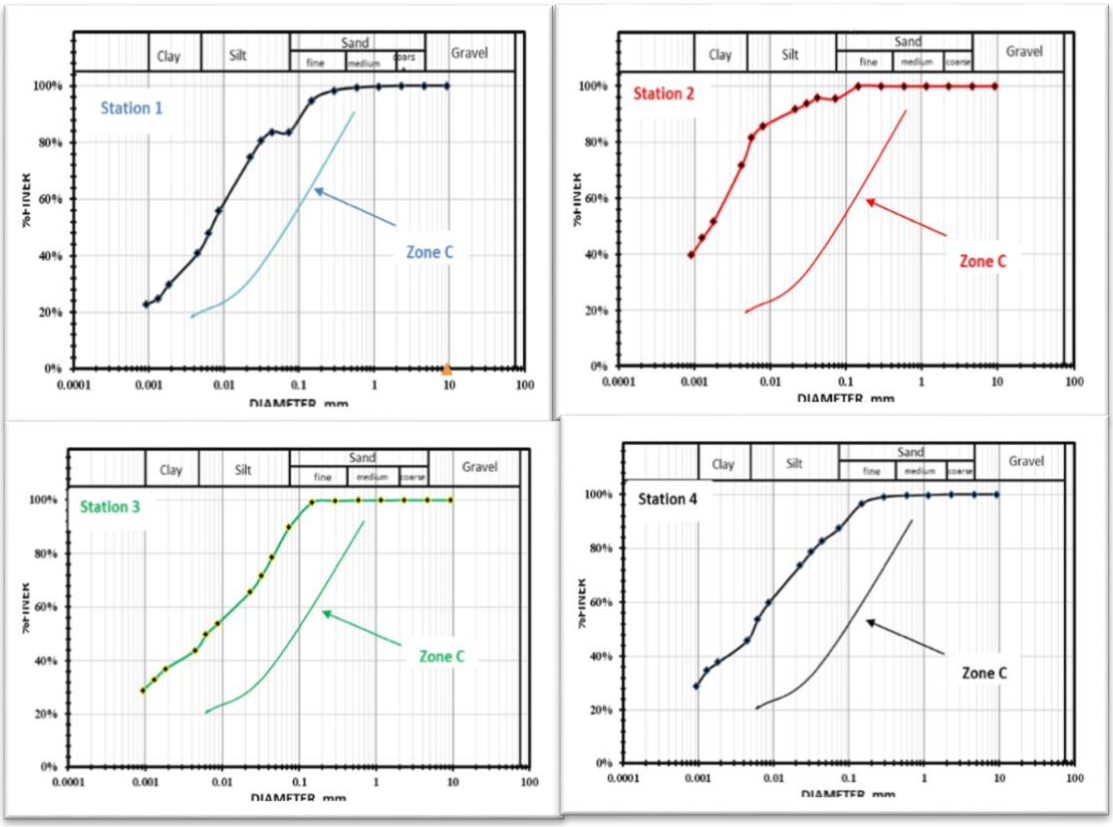


Fig 3. Chart of the grain size analysis of the clay samples

3.1.2. Atterberg limits

It is the water content of the soil in which the soil moves from one state to another (Hussein,1991). The liquid limit and plastic limit were determined in Al-Ahmad Laboratory for Engineering Tests according to specification ASTM, D 4318-00, (2004). Atterberg limits are used to classify soil and knowing its engineering properties. The results are shown in Table 3.

Table 3. The results of grain size analysis and Atterberg limits in the study area

Station No.	Clay %	Silt %	Sand %	Liquid limit L.L %	Plastic limit P.L %	Plasticity index P.I %
1	43	51	6	43	15	28
2	77	19	4	45.5	16	29.5
3	46	44	10	42	14	28
4	48	39	13	44	15.2	28.8

The soil of the study area was classified according to Unified Soil Classification as in Table 4 because the soil is soft in the study area.

Table 4. Unified soil classification (Al-Khafaji,1992)

Liquid limit	Unified Soil Classification Criteria	Group symbol	Group Name
Less than 50 %	LLR<0.75	OL	Organic Silt or clay
	LLR>0.75 and PI <4 or Plots below A-line	ML	In Organic silt
	LLR>0.75 and PI>7 and Plots above A-line	CL	Lean clay
	LLR>0.75 and LL and PI in shaded area	CL-ML	Silty clay
More than 50 %	LLR<0.75	OH	Organic Silt or clay
	LLR>0.75 and PI plots below A-line	MH	Elastic Silt
	LLR>0.75 and PI in plots on or above A-line	CH	Fat clay
Peat	Highly Organic Soil, normally more than 20 % by weight is organic, primary organic matter, dark in color, and organic odor	Pt	Peat

Depending on sieve analysis and Atterberg limit that was dropped on the plasticity diagram As in Fig. 4, the soil was classified according to the Unified Soil Classification in Table 5.

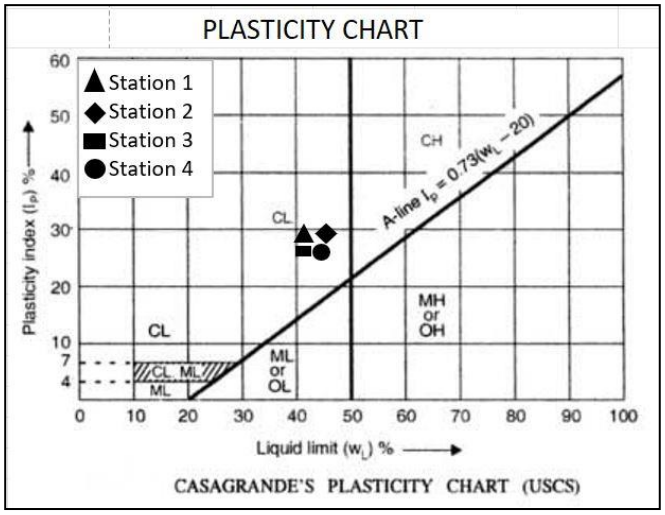


Fig 4. The classification of the study area soil samples by unified soil classification

Table 5. The Classification of the soil of the study area based on the standard classification of soil

Station no.	Soil symbol	Soil classification
1	CL	Low plasticity clay
2	CL	Low plasticity clay
3	CL	Low plasticity clay
4	CL	Low plasticity clay

3.2. Chemical Properties

Soil chemical analyzes play a major role in knowing the suitability of soil for engineering purposes and its engineering problems for example, when the proportion of gypsum in the soil is greater than the permissible limit, in this case, the problem of dissolving the soil from exposure to water occurs, and this is what happened and is happening in most areas of Salah al-Din. To determine the validity of the clays of the Injana formation as filler materials from a chemical point of view, the gypsum content, and the total dissolved salts (TDS) must be within the allowed ranges in the standard specifications.

3.2.1. Gypsum content ($CaSO_4.2H_2O$)

Determine in percent based on the method listed in B.S.1377-3 (1990). The percentage of gypsum in the study area varied between 0.22- 0.29. The main cause of gypsum accumulation in the soil is its deposition from groundwater and surface curd water because of high evaporation; gypsum is formed as a result of the ascending of groundwater, Mosaic property, into the upper terra and the associated high evaporation of gypsum (Boyadgiev,1974). The gypsum in the study area can be formed by weathering of the Fatha Formation rocks. Table 6 shows the results of gypsum content in the study area.

3.2.2. Total Dissolved Salts (TDS)

It is the weight ratio of water-soluble salts to the weight of the soil. The degree to which salts dissolve varies depending on their nature, chlorides are generally easier to dissolve than carbonates and sulfate. The Total dissolved salts are affected by temperature, pH values, and the amount of dissolved CO_2 gas as well as evaporation and moisture. Table 6 shows the results of total dissolved salts in the study area.

Table 6. The results of the chemical properties in the study area.

Station No.	Gypsum %	Total Dissolved Salts Mg\l
1	0.22	1.35
2	0.26	2.40
3	0.24	3.45
4	0.29	1.70

4. Results and Discussion

The results of the tests of the research stations based on Iraqi specifications National Laboratory and Construction Research Centre, 2003 to determine the validity of the Injana formation as filler material are shown that the type of clay is low plasticity clay (CL), and the chemical analyses show that the ratio of total dissolved salts ranges between 1.35-3.45 %, while the ratio of gypsum content ranges from 0.22-0.29.

After comparing the results of the physical and chemical tests with the specifications (National Laboratory and Construction Research Centre, 2003) for determining the viability of the Injana formation as filler material; All stations proved to be conforming to specifications and were valid in all respects.

4.1. Assessment of the Viability of Clays for Filling Materials

Fill dams are one of the most common types of dams in the world because of their advantages, which include the use of local natural raw materials, ease of design and construction, the use of little equipment in construction, the requirements of foundations being less rigid than those of concrete dams, as the weight of the construction is dispersed by the wide base of these dams, its suitability for different types of foundation, and the effects of water pressure are greater than those of other types. In terms of economic cost, they are less expensive than other types of dams (United States Society on Dams,2007) (Stephens, 2010). Reports most soils that can be used in the construction of fill dams provided they contain no dissolved matter and no organic matter Soils and mud with a liquid limit greater than 80% should be avoided (Gilbert and Gedeon, 2004). Some impervious soils that tend to retain moisture over long periods are unsuitable as fill, this type of soil is problematic, especially in areas where rainfall is expected during the construction of the dam. If a soil type can be selected, it is preferable to well-graded soils rather than single-grained soils, because soils of the former are cohesive, resistant to erosion and liquefaction, and require little adhesion. To determine the clays of sample bores representing the study area for use as a starting material in the construction of dams, the results of soil analysis must be compared with Table 7.

Table 7. Physical and chemical specifications for filler soil by (Iraqi specifications National Center for Laboratories and Construction Sciences, (2003), Building Materials Specification, Sorb / 5)

Physical and chemical specifications for filler soil	Allowed Ranges
Plasticity Index	(10-20) %
Grain Size Analysis	Matches the curve C
Gypsum Content	No more than 3 %
TDS	No more than 4.4 %
Liquid limit	No more than 55 %

In the final evaluation of clays samples based on Iraqi specifications National Center for Laboratories and Construction Sciences, (2003), Building Materials Specification, Sorb /R5 all the samples in the study area were found to meet the specification, Above, as shown in Table 8.

Table 8. viability of clays for filling Materials in the study area as dictation material based by (National Center for Laboratories and Construction Sciences, (2003), Building Materials Specification, Sorb /R5)

Station No	Plasticity index %	Liquid limit %	Grain. S.A %	T.D.S %	Gypsum %	Final Assessment
1	+	+	+	+	+	Successful
2	+	+	+	+	+	Successful
3	+	+	+	+	+	Successful
4	+	+	+	+	+	Successful

6. Conclusions

- Geotechnical tests of clay of Injana Formation show that the type of soil is low plasticity clay CL and the results of the size analysis data also included different rates of clay, sand, and silt, the ratio of sand ranged 4%-13%, and the ratio of silt 19%-51%, and the ratio of clay 43%-77%.

- In the chemical analysis of the clay, it was noted that the models studied had very little gypsum ranging from 0.22 to 0.29 and fall within the ranges required as materials to fill dams. They also contain a percent of the dissolved salt group ranging from 1.35%-to 3.45% where all models meet standard specifications.

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