GEOTECHNICAL PROPERTIES AND ITS SUITABILITY ASSESSMENT FOR AGGREGATES EXPOSED IN JAY DAM MOHMAND DISTRICT, KPK PROVINCE, PAKISTAN

BY

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(2020-2022)

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Philosophy in Geology

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CERTIFICATE

It is certified that **Mr. Talha Ishtiaq (Registration # 02112013001)** carried out the work contained in this dissertation under my supervision and accepted in its present form by Department of Earth Sciences as satisfying the requirement for the award of **M. Phil Degree in Geology**.

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DEDICATIONS

This research work is entirely dedicated to my ***devoted Parents*** *and* ***much-loved Wife****, whose support, words of encouragement and constant push for tenacity made this thesis work feasible. A special feeling of gratitude and special thanks to my friend* ***Mr. Zubair Ahmed*** *for being there for me throughout the entire research work.*

ABSTRACT

We analysed and looked at the aggregates from the proposed dam site in the Jay hamlet of Mohmand Agency, Khyber Pakhtunkhwa. The research location was arid and various samples were collected in order to find physio mechanical properties of rock on which the dam is constructed. In the dam site the exposed rocks were mostly Low grade metamorphic rocks which majorly consist of shangla blue schist of createaceous age.

The petrography results shows the abundance of Micas, garnets and quartz in schist. Furthermore, from the dam site, we took numerous samples of rocks. The samples were gathered at random from several locations close to the study area. We took the samples we had collected into the labs to run various tests on them. Sieve analysis, the Proctor Test, the Porosity Test, the Compressive Strength Test, the Slump Test, and the Los Angeles Abrasion Test are all part of the tests. Although the tests took a while, we were focused on gathering accurate data. We obtained the lab's desire data.

The test findings showed that the rocks exposed in the area had less porosity with high degree of hardness, indicating that the area was well suited for usage as an aggregate as a construction material.

ACKNOWLEDGEMENT

In the name of Allah, who is the most beneficent and merciful. Firstly, I am thankful to Almighty Allah who granted me the potential to learn, conduct this research, and put all the pieces fit together.

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Last but not the least I would like to thank my whole family for their continuous support, prayers, love and understanding when undertaking my research and writing my report. Without the support of my loved ones, I would not be able to carry out this thesis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

NCWI	Normalised Cumulative Weighted Index
TIN	Triangulated Irregular Network
3D	Three-dimensional
MM	Mixed matrix
PD	Pressure-driven
VOCs	Volatile Organic Compounds
ERS	Electrical Resistivity Surveys
GPR	Ground Penetration Radar
FWRDP	FATA Water Resources Development Project
FATA	Federally Administrated Tribal Area
CCA	Culturable Command Area
MMT	Main Mantle Thrust

Chapter 1

1.1 INTRODUCTION

Large-scale civil engineering projects demand a grasp of the local geology. The regional geology dictates the placement and nature of each of the following structures: building foundations, roadways, railroads, and dams. Determine the root reasons of slope failure and potential preventive measures (Attewell, P. B., & Farmer, I. W. 1976). What role does a geologist play in the feasibility analysis and site selection of a significant civil engineering project?

There have been several methods used in the past to find potential sites for dam, including GIS, AHP which incorporated polygon intersection, overlay and normalised cumulative weighted index (NCWI), GIS spatial analysis for a valley by analysing its geometrical properties, shape and bathometric properties, a geo spatial information system for small hydropower, and the hydropower site identification process automation using a GIS-based computer programme. In order to locate reservoirs, two models—a weighted linear combination and a Boolean model—were used, and they were compared. A thorough geological analysis of the area where a dam construction is being contemplated is required. (Mohammed, J. 2014-2015)

It is necessary to take into account characteristics such rock kinds, geological structures, weathering, cracks, and fissures (Sissakian, V. K., Adamo, N., & Al-Ansari, N. 2020). The material upon which the dam is built must be able to support the weight of the building without failing. The geology must also be water-resistant in order for the dam to be built there (Burwell, E. B., & Moneymaker, B. C. 1950). Water is one of the fundamental elements of all human endeavours and is necessary for existence. Water has been distributed unevenly, which has been made worse by climate change on a worldwide scale. Multi-purpose dams make it easier for people to live by providing water for drinking, irrigation, hydropower, and lowering the risk of flooding. The most favourable location for hydro projects has the least adverse effects on the environment. Therefore, a site suitability analysis that takes into account geographical elements like lakes, geological dangers, and downstream circumstances is essential for the construction of the dam (Githinji, T. W. 2013).

A dam is constructed over a river, and the river's width should be as small as feasible or the river valley should be narrow to lower the cost of the dam, which is mostly used to store water. If the foundation on which the dam is built is porous or permeable, the entire idea of building the dam will be rendered meaningless. Such a location causes quite a significant amount of water to flow into the rock beneath the foundation, decreasing the dam's capacity.

A dam's failure can result from a variety of causes, such as:

- Earthquakes An abrupt drop in water level
- Inadequate wave protection on the reservoir side of the dam
- Inadequate spillway capacity, causing water to flow across the whole dam surface, leading to erosion.

The primary goal of geological research for any project involving civil engineering

- Examining the local area's geological structure.
- Examining the earth's surface.
- Examining the earth's subsurface.
- The state of the groundwater in that specific area.
- The area's seismic situation and a review of seismic data from the previous 60 years.

- The local lithology.

1.2 Evaluation of Dam sites

Some factors, such as 2D and 3D surface area, maximum volume, elevation of the dam base, dam surface elevation, dam height, dam breadth, catchment area, and contour proximity, can be used to analyze and examine the profile of potential dam sites. For the purpose of creating contours with a 25 m difference, the digital elevation model is used. The 3D surface area and volume were calculated using the contours and a triangulated irregular network (TIN). 3D The ArcGIS analyst tool, which is used to find the cross-section, is another example of graphical representation in usage (height and breadth). To determine the catchment area, hydrological methods are employed. The profile of a dam site can be accurately predicted by each of these factors. (Shao, Z et al., 2020)

1.3 Methods and Materials

Geological and geotechnical studies provide information and data that are utilized for foundation analysis and treatment, soil characterization, rock mass quality assessment, stability analyses for the design of surface and subsurface excavations, and their support. The expense or planning of geological and geotechnical investigations for any project depends on the complexity of the geology, as well as the size and sensitivity of the project structures. Additionally, the prefeasibility, feasibility, design, and construction stages of the project are always tied to the specifics and cost of the research. (Akroyd et al., 2016)

In the prefeasibility stage, the results of the reconnaissance survey and previously published geology and topographic information are deemed sufficient for assessing the initial viability of the project site. To create geotechnical models at the project structure components, more research—including surface, subsurface, and laboratory testing—is needed in the feasibility stage. In order to rule out any deficiencies in the interpreted conditions, geotechnical models that had already been constructed during the feasibility stage are checked and fine-tuned during the design and construction stages. As a result, further surface and subsurface research is carried out alongside in-situ and laboratory testing. (Barton et al., 1974)

For DHP, geological and geotechnical investigations have been carried out at various phases in accordance with the project's goals. Geological conditions were estimated during the feasibility stage using the data that was available, such as satellite pictures, remote sensing data, regional geological maps, and topographic maps. Geological mapping, subsurface drilling, the excavation of test pits and adits, in-situ testing, and geophysical surveys were used to enhance this data. When the project's location, size, and loading were decided, the detailed design phase began. At this point, additional geological and geotechnical investigations were planned and carried out, including drilling, test pits, adits, in-situ testing, and geophysical surveys, to enhance and supplement the geotechnical model for the dam site that had already been constructed.

The samples of rock and soil are chosen for laboratory testing to determine the engineering properties such as interactions of volume-weight (unit weight, specific gravity, density, and intact rock's porosity), water absorption and hardness of intact rock, and reactivity and durability for aggregate (Ahmed, M. 2000). Uniaxial compression, point load, Poisson ratio, elastic modulus, tensile strength, and sonic velocities of entire rock are a few examples of index tests. In-situ experiments, such as the plate load test and the direct shear test, were also conducted to ascertain the engineering characteristics of rock mass and soils.

1.3.1 Concrete Aggregates

For a concrete dam to be built, as well as any accompanying structures, suitable aggregates must be available in adequate quantities. Sand, gravel, and cobbles are typically mined from natural sources to create aggregates. They could, however, be crushed from suitable rock if it were more practical to do so (Bérubé, M. A., & Fournier, B. 1993). The aggregates for minor dams can be purchased from currently active commercial sources. If the aggregates come from rock quarries or borrow pits, plans should be undertaken to landscape the areas and otherwise restore them to reduce any negative environmental effects. Their negative impacts would be reduced if aggregates were obtainable from the reservoir area, especially lower minimal water surface. Nevertheless, before completion of the dam, any early storing in the reservoir, may prevent the use of aggregate sources in the reservoir. (Barton et al., 1974)

1.3.2 Water for Construction

This element, aside from water quality, is comparatively insignificant for major rivers. Obtaining sufficient water for construction in small streams and offstream reservoirs may be difficult. Water rights should be secured for the contractor so that he has access to enough water for his purposes throughout construction, including washing aggregates, cooling, and batching concrete. Information on prospective sources and yields should be acquired if tapping ground water is necessary. Additionally, it is a good idea to learn the locations and yields of adjacent existing wells, any restrictions on the use of groundwater, and any licences that could be required. (Akroyd, T et al., 2016)

1.4 Literature Review

Planning, site selection, and appraisal for significant engineering structures like dams, weirs, and power plants all heavily rely on geology (Bell F.G. 2009). An expert geological and geotechnical study plan is always created in an effort to characterize the site characteristics reasonably, if not precisely (Hunt 2005). The investigations consist of both field work and lab testing, with the former including both surface and subsurface work.

Surface investigations consist of geological, geomorphological, engineering, and rock discontinuity surveys to record the properties of discontinuities. To characterize the geological characteristics of the site, such as distribution of different types of soils and bedrock and comprehensive picture of the geology in a region, an engineering geology map should be created (Lisle 2004; Bell 2007).

The primary geologic risks, bedrock geology, seepage locations, water presence, structural geology, location and direction of discontinuities, geomorphology features, and surficial geology are all covered in this map (Lisle 2004). Planning future subsurface investigations to interpret the subsurface profile can be done using this map (Bell 2007).

Because this information serves as the foundation for the characterization and rock masses classification, the interpretation of rock structures, and the development of three-dimensional (3D) geological models, conducting discontinuity surveys at accessible rock outcrops is always preferred during geological mapping. For use in regional engineering, 1:10 000 scale geological maps are created. Maps are made at a scale of 1:5000 for tunnels, borrow areas, minor reservoirs, and large dam sites. The scales utilized for the trenches, open pits, and excavations range from 1:500 to 1:100. Plotting should be done at sizes of 1:5000 or 1:10000 for soils and 1:20000 or

1:30000 for other lithological units, particularly bedrock. (Copen, M. D., Legas, J., Lindholm, E. A., Tarbox, G. S., & Reed, F. D. (1976).

Borehole drilling, pitting, sampling, and aditing are examples of direct methods for subsurface exploration. Indirect methods, which are primarily applications of geophysical techniques, include seismic refracting surveys, electrical resistivity surveys (ERS), ground penetration radar (GPR), and others (Anon, O. H. 1979). The goal of both exploration techniques is to gather as much subsurface data as possible in order to assess a site's feasibility and stability for a certain engineering construction. Subsurface drilling is a frequent and widespread method of conducting subsurface research (Hunt 2005). According to conventional wisdom, the drill must reach the deepest substratum that could be impacted by loads, seepage, and structural deformation (Palmström & Singh 2001).

The area and geological conditions, as well as the depth and quantity of boreholes, are just a few of the variables. In order to save time and money, further boreholes may be replaced with geophysical methods of investigation if the region is uniform and the distance between two boreholes is between 20 and 40 meters. The smallest total number of boreholes recommended for dams under 40 meters in height is 3 to 4 on either side of the valley, and 2 to 3 on the suitably sloping and crossing valley floor. Most boreholes must be at least half as tall as the dam, and very few must be at least the height of the dam. . (El-Naqa, A. 1994)

In addition to drilling boreholes, routine test pit excavation is done to see how the soil looks near the surface and to collect samples for later laboratory testing. Adits are often pricy affairs that can be done as part of huge projects or when the geological conditions are too complicated to be understood through borehole drilling and geological mapping. (Anon, Q. 1977)

Feasibility-level geotechnical assessment have been widely studied for various dams world-wide like Anamur dam site of Turkey (zsan, A., & Karpuz, C. E. L. A. L. 1996), Obruk dam site at Corum, Turkey (Kocbay, A., & Kilic, R. 2006),. blast-fill dam on the Burlykiya River (Korchevskii, V. F., & Petrov, G. N. 1977), Bakhtiary Dam located at southwest of Iran (Haftani, M., Gheshmipour, A. A., Mehinrad, A., & Binazadeh, K. 2014 and Zolfaghari, A., Bidar, A. S., Javan, M. M., Haftani, M., & Mehinrad, A. 2015), geotechnical study of Diamer Basha Dam, Pakistan (Ali, W., Mohammad, N., & Tahir, M. 2014), Simly Dam Pakistan (Ghoraba, S. M. 2015), Assessment of mafic rocks at Tarbela Dam (Ahmad, T., & Sajid, M. 2022) and many more.

Research work on Mohmand Dam located in Mohmand district (previously Mohmand agency) is also available in literature. (Babar, M. S., Israr, J., Zhang, G., & Ali, U. 2022) (Imran, M., Sanaullah, M., Ahmad, U., & Ahmed, L. 2023). But to the best of my knowledge, studies on small dams of this districts either not published or not even carried out.

1.5 The Study Area

Mohmand Tribal district has Mohmand and Warsak Dam along with other five small dams, namely: Jay Dam, Pindiali Small Dam, Motoshah Small Dam, Abdul Shakoor Small Dam and Khurshid Dam. (Murad khan, the frontier post - 2023). The projected Jay Dam's location is 7 kilometres to the southeast of Jay Kalay Village, the Mohmand Agency's administrative centre. 71° 28' 3.07" East and 34° 15' 33.09" North are the planned locations for the dam. The planned dam axis is located on Gandao Khwar. A watershed area of 202 square kilometres surrounds the Gandao Khwar. (Dam, K., & Mohmand, D. 2018)

The stream is not perennial, according to site observations made over the past three months and enquiries from the neighborhood. Runoff and possible floods will occur in the Khwar as a result of rainfall events in March–April and July–August. With the formation of the Jay dam, flood water may be held and used for irrigation in the command area. It will also rehydrate the underlying aquifer to counteract the negative effects of excessive groundwater consumption in addition to storing water for crops. The study area is characterised by a rough, mountainous topography with moderate to high relief. It is common for main streams to form a "U," which denotes an established valley.

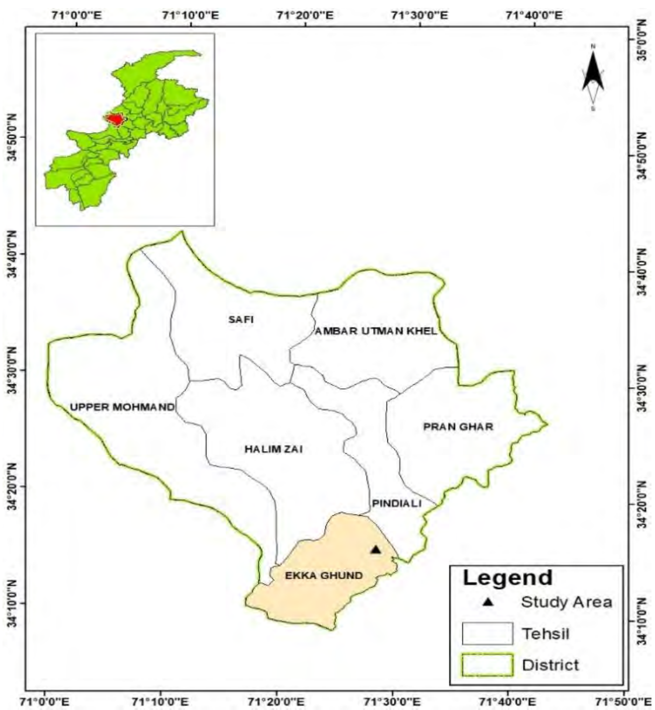


Figure 1.1: *Area of Study*

Based on the easily accessible hard rock on the abutments and foundation, a concrete gravity dam crossing Gandao Khwar has been proposed for the Jay Dam project. The spillway, under sluice, and non-overflow section make up the top 115.3 meters of the dam's construction. The dam can be up to 15 meters tall from bottom to top. The reservoir has a 49.47 ha-m capacity. 36 lit/sec is the intended discharge rate for the irrigation channel (1.28 cusecs). More than 38 years of continued operation are anticipated for the dam.

The supervision of the dwelling and the designs of the subprojects would be handled by FWRDP design consultants. The consultants will assess the subprojects in accordance with the selection criteria. As a result, a feasibility study would be created for the subprojects that met the criteria for selection. The FATA Secretariat, the project's promoter and client, entered into a formal agreement with a joint venture headed by BAK Consulting Engineers, AGES Consultants, and Rehman Habib Consultants in October 2016 to provide design and oversight services for the project.

In order to properly assess the earthquake safety of dams, valid seismic criteria must be used. These suggestions are meant to assist the engineer and project manager in choosing the seismic evaluation parameters for dam projects in accordance with the demands imposed by the project location and its related seismic hazard, the design chosen, and the risk created by the finished construction. The use of sound design, premium materials, efficient construction control processes, and ongoing surveillance and monitoring of the performance of the finished structure, albeit they won't be a replacement for an appropriate seismic evaluation, will. (Dam, K., & Mohmand, D. 2018)

Table 1: *Important characteristics of the Jay Dam project*

Catchment Area	202 square kilometers
Dam Kind	Concrete Gravity Dam
Dam Crest Length	115.3 m
Height of Dam	15 m
Spillway width	72 m
Dam Life	Above 38 Years
Total Cost of Project: Rs.	307.984 Million
Construction Duration	20 Months

1.6 Construction Planning & Development

The following are the primary elements of the irrigation project at Jay Dam:

1. Geotechnical analysis
2. Foundation construction
3. Main Dam Embankment
4. Spillway, downstream of which is Stilling Basin
5. Structure of Intake and Outlet
6. Irrigation system

Figure 1.2: *Jay Dam site*

1.7 General Statement:

On the Jay Dam site, several samples and aggregates were gathered. These samples were subjected to a number of tests in Peshawar, close to the Chamkanai building site. These experiments were conducted in order to ascertain the physiomechanical characteristics of the rock samples. These tests' outcomes will be compared to the findings of regular testing.

1.8 Aims and Objectives:

Early in the design process, the construction issues that the contractor might run into when building the dam and related elements should be taken into account. The lack of space for the contractor's construction plant, equipment, and storage of materials close to the dam is one of the main issues, especially in small canyons. Concrete costs can be significantly decreased by situating the concrete factory to minimize handling of the concrete, aggregates, and cement.

To determine whether the location is appropriate for the construction of a dam or not is the primary goal of this research study. Various samples were taken from the dam site, and they will go through a series of tests to determine their physio-mechanical characteristics. Tests are run to determine the soil type, density, porosity, and other factors. In order to identify the likelihood that natural disasters like floods, earthquakes, and other potential effects on dams would occur, regional geology will also be researched to identify significant geological formations like folds and faults around dam locations. The Culturable Command Area (CCA), which is an area of land that may be used for agriculture and is around 100 ha in size, will be irrigated by the Jay Dam's low-height dam and irrigation pipes.

Table2: *List of tests performed during the study*

S.NO	**Test Name**
1	Porosity test
2	Sieve Analysis
3	Proctor
4	Compressive Strength test
5	Slump test
6	Los Angeles Abrasion test

Chapter 2

2.1 Regional Geology

Due to extensive tectonic activity over a long period of time, the strata in the study region are highly faulted and folded. The Main Mantle Thrust (MMT) and the Kohistan Fault are located, respectively, in the southeast and north of Mohmand district. Quartz veins are the same colour as the host rock. These can be as long as 9m and have widths ranging from 0.15 to 1.5 m. The quartz veins include manganese and chlorite, however the quality of each vein differs. There are many different types of rocks found together in a very disturbed environment (ANJUM, M. N., Ali, N., Rehman, Z. U., Ghayas, M., & Ahmad, W. 2018).

The rocks of the countryside are composed of slates, phyllites, various schists, amphibolites, marble and crystalline limestone. Granite, microgranites, diorites and pegmatites are found in the region's northern and eastern sections. This region of the meta-sedimentary terrain may denote the northern limb of a large eroded fold that is connected to the Mullagori structure, according to the lithology of the region. The various rock kinds are serpentines, pyrozenites, and peridotites. (Kazmi et al.,1997).

Slates and phyllites frequently contain dolerite intrusions. Epidote is frequently dispersed in the area in a variety of ways. Numerous quartz veins include green and yellowish-green epidote, which the locals mistake for emerald. The solid and thick-bedded yellowish brown and greenish white limestone contains thin argillaceous material partings in some locations.

While coarse variety is not rare, a significant portion of the limestone is of the fine to medium-grained form. The other varieties of limestone include white to light grey with noticeable dark-gray regions and dark grey with tiny reddish flecks. The marble and limestone that are greenish and yellowish in colour seem to have been compulsorily inserted by the ultramafic body. In the ultramafic body, peridotite and serpentinite are the most prevalent rocks. Serpentines range in colour from light to dark green, are rigid and compact, and may become talcosic. Peridotite is typically serpentinized, hard, and whitish-green in appearance. Light to dark green schists are exposed over a larger area of the Pipal region and are in close contact with the ultramafic body. The schists have thin to thick bedding and are compact and broken. Limonite crystals range in size from small to nearly one-inch cubes, and are evenly distributed throughout the green schist. (Saif, S. I. 1971)

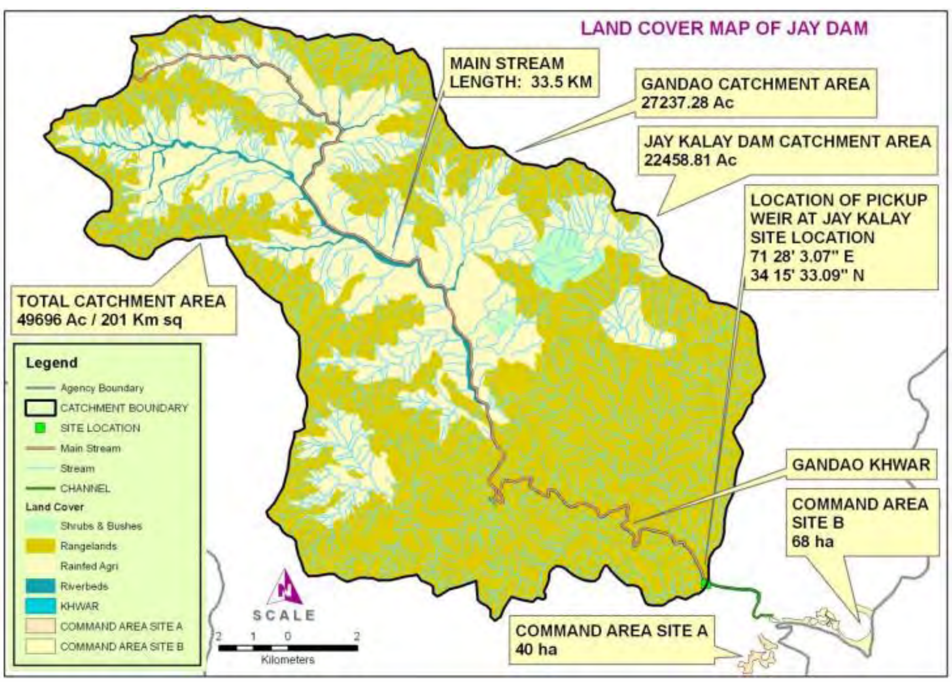


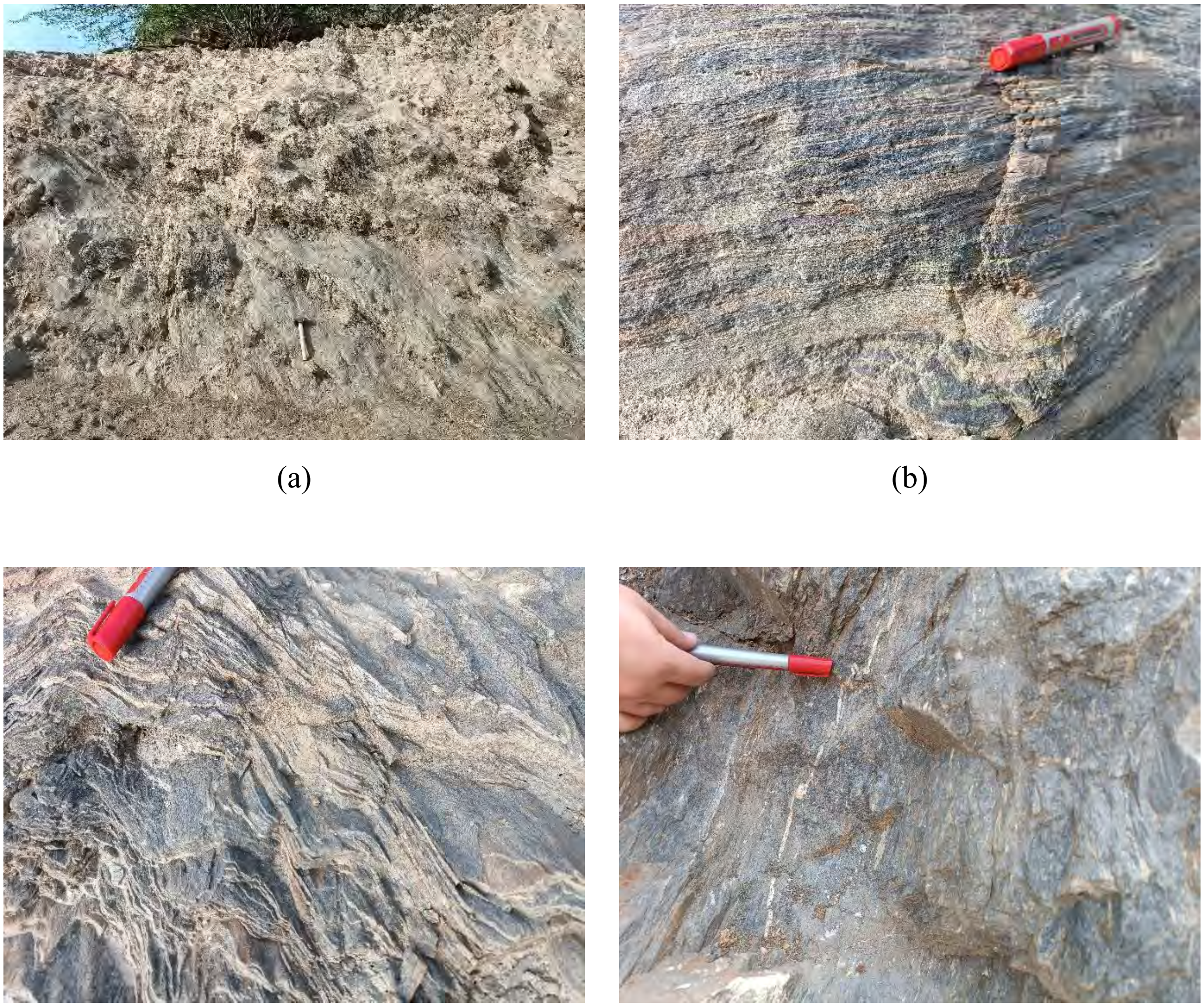
Figure 2.1: *Tectonic map of the Jay Dam*

(Ref: Prepared by FATA Secretariat, for the Asian Development Bank 2014)

2.2 Dam Site Geology:

In the stream area and its surrounds, the majority of the exposed mafic and ultramafic rocks are made up of several rock types, including gabbros, peridotite, greenstones/pillow lavas, serpentinite and dunite. These rocks occasionally show up as smaller bodies and lenses in the research area. The tiniest bodies can vary in size from a few millimetres to tens of metres wide and hundreds of metres long. In the Khwar/main stream and the surrounding area, greenstones/pillow lavas, gabbros, peridotite, serpentinite and dunite make up the majority of the exposed mafic and ultramafic rocks. Near the dam site, there are sporadic lenses and smaller bodies of these rocks. There are occasional lenses and smaller bodies of these rocks close to the dam site. The smaller bodies can be hundreds of metres long at their longest and can range in size from a few millimetres to tens of metres wide. (Shah, S. I. 1977).

There are exposed schistose foliated rocks with a medium hardness termed argillite on both banks of the creek. Most of the exposed garnet-bearing schist and argillite rocks are found in the reservoir. They are low to medium in hardness, medium to coarse in texture, and occasionally quite tightly packed. Grey to black is the range of their colours. Compared to the right banks of the reservoir, the rocks on the left bank have more mild to severe fractures. Loose argillite rock fragments and sand-filled boulders that blanket the streambed make up the overburden at the dam site. Schist is largely evident on the left and right abutments of the dam site. Muskovite, a fine-grained flaky mineral, dominates the rock, with traces of quartz, graphite, and biotite.



(a) (b)

(c) (d)

Figure 2.2: *Showing metamorphosed different rocks units exploded at the vicinity of Dam*

2.3 Reservoir:

Just upstream of the proposed dam axis, between the proposed dam axis and the confluence of the region's mainline, are the reservoir regions. There is space for water storage because the stream is large. On both banks of the creek, foliated, rather hard rocks, such argillite, are exposed. In the reservoir region, both banks of the streams have exposed medium-hard, schistose rocks. The right and left abutments contain the majority of the exposed garnet-bearing schist and argillite rocks of the dam. These are low to medium hard, medium to coarse grained, and very badly broken. They are also quite closely attached. They come in a variety of colours, from grey to black, and are sometimes shared. The stream bed close to the dam has been covered by overstretch. There are argillite materials present as well as sandy gravel/boulders with loose rock fragments. Overburden encountered is often about 3 meters thick. Up to 30 meters of bore holes have been bored in the nullah bed.

2.4 Soils:

The sample used for classification must be accurate and collected using a proper acknowledged or standard process. It must also be representative of the strata. It is crucial to precisely pinpoint the source of the content. The origin description could be a station number and offset, a grid system, a geologic stratum, a pedologic horizon, a boring number and depth and/or sample number, or a geographical description with relation to a permanent monument. (Carter, M et al,. 2007).

The methods discussed in the preceding subsections can be used to classify, identify, and describe materials that are not natural soils. The following substances should not be classified as primary USCS soils because they are not regarded to constitute soils:

Poorly cemented or partially lithified materials:

- Shale
- Claystone
- Siltstone
- Sandstone
- Decomposed Granite

The Project area is composed of sedimentary, igneous, and metamorphic rocks. Conglomerates, sandstone, limestone, and shale make up the majority of sedimentary strata on Earth. These geological features could lead to soil erosion and sedimentation. Among the metamorphic rocks found nearby are schist, slate, and marble. There are also sizable thick areas of pure clay. Although there is also some wind-blown soil, streams and rivers deposit the vast bulk of the soils as a result of the local weathering of bedrock. The area has a variety of landforms, including gullied land, rough broken terrain, gravel fans, plains, and piedmont. Lowlands are calcareous in nature, while level parts are loamy. The levels of phosphorus and organic materials are quite low.

Chapter 3

3.1 Petrography

The mineralogy and the textural relationships within a rock are best described with the help of petrographic studies. These include observation of important field features as well as detailed microscopic examination of rocks. Detailed analyses of minerals and their textural relationship by microscopic study of thin sections are critical to understanding the origin of rock. In contrast to the rocks of Dam site area, the petrographic and mineralogical details of most of the other rocks in the region have been studied in reasonable detail.

The mechanical properties of a given rock volume are dependent on its geological composition. Being able to predict these mechanical properties based on mineralogical parameters could prove useful in engineering and construction settings. On the basis of detailed field and petrographic observations, the rocks of the Dam site area can be characterize as Schist.

3.2 Schist

Schist is foliated low-medium grade metamorphic rock. It is formed by metamorphosis of mudstone and shale or some form of igneous rock. It usually has better crystallisation of mica minerals. They are biotite, chlorite and muscovite so this called schistosity texture. There are many types of this rock so they may be named for mineral comprising the rock. i.e Mica schist, green schist , garnet schist etc.

The classification depend on their mineral content. There are some types a group of metamorphic limestones, marbles, calc-shists and cipolins, with crystalline dolomites and It has contain silicate minerals such as mica, tremolite, diopside, scapolite, quartz and feldspar. After a crystallization sequence its separate group is rich in quartz ith variable amounts of white and black mica, garnet, feldspar, zoisite and hornblende. These were once sandstones and arenaceous rocks.

The graphitic schists may represent sediments once containing coaly matter or plant remains. There are also schistose ironstones (hematite-schists). Origin of the schist include calc-schists, the foliated serpentines, which are once ultramafic masses rich in olivine. The white mica-schists, porphyroids and banded halleflintas, which have been derived from acid tuffs, quartz-porphyries and rhyolites. The most of the mica-schists are altered clays and shales so it is into the normal sedimentary rocks through various types of phyllite and mica-slates. They are among the most common metamorphic rocks.

A special subgroup consists of the andalusite-, staurolite-, kyanite-, and sillimanite-schists, together with the cordierite-gneisses. They usually appear in the vicinity of gneissose granites and have presumably been affected by contact alteration.

During metamorphism, rocks which had been firstly sedimentary, igneous or metamorphic are converted into schists and gneisses. If the composition of the rocks was firstly similar, they may be very tough to differentiate from one another if the metamorphism has been excellent. A quartz-porphyry, for example, and a quality grained feldspathic sandstone, may additionally both be transformed into a gray or crimson mica-schist. Usually, but, its miles feasible to differentiate among sedimentary and igneous schists and gneisses. If, for example, the complete district occupied by using these rocks has strains of bedding, clastic structure, or conformability, then it could be a sign that the original rock become sedimentary.

In different instances intrusive junctions, chilled edges, touch alteration or porphyritic structure might also prove that in its original condition a metamorphic gneiss became an igneous rock. The closing enchantment is often to the chemistry, for there are certain rock kinds which occur simplest as sediments, at the same time as others are determined only among igneous masses, and but advanced the metamorphism can be, it hardly ever modifies the chemical composition of the mass very substantially. Such rocks as limestones, dolomites, quartzites and aluminous shales have very specific chemical characteristics which distinguish them even when completely recrystallized.

Figure 3.1: *Site Photographs: Medium grade Schist rock.*

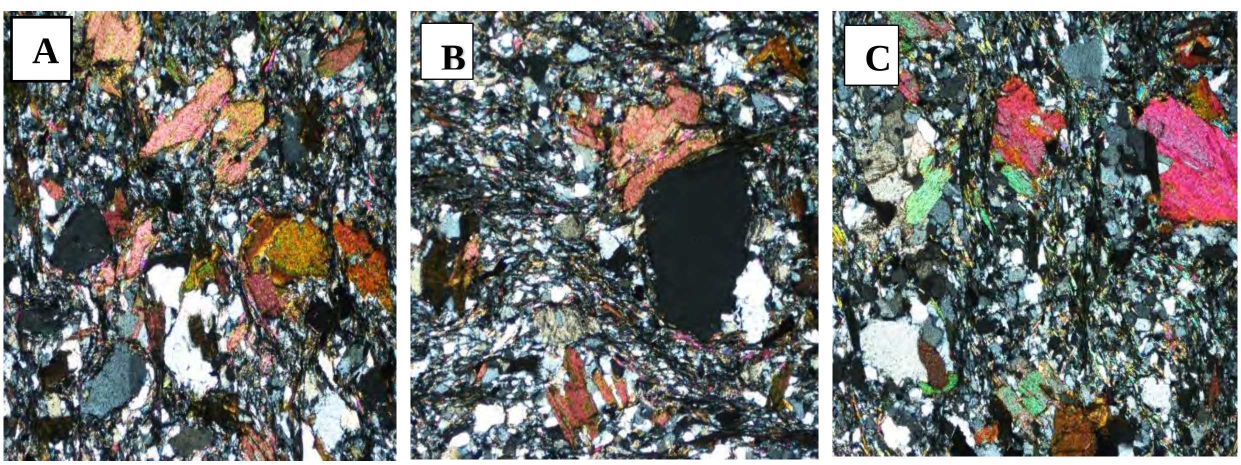


Figure 3.2: *Photomicrographs (XPL): (A) A very slight greenish tint can be seen in this muscovite against the quartz. (B) The middle photograph shows the same view under XP and the garnets are seen to be isotropic (C) Micas*

Figure 3.3: *Site Photographs: Quartz vein embedded in schist.*

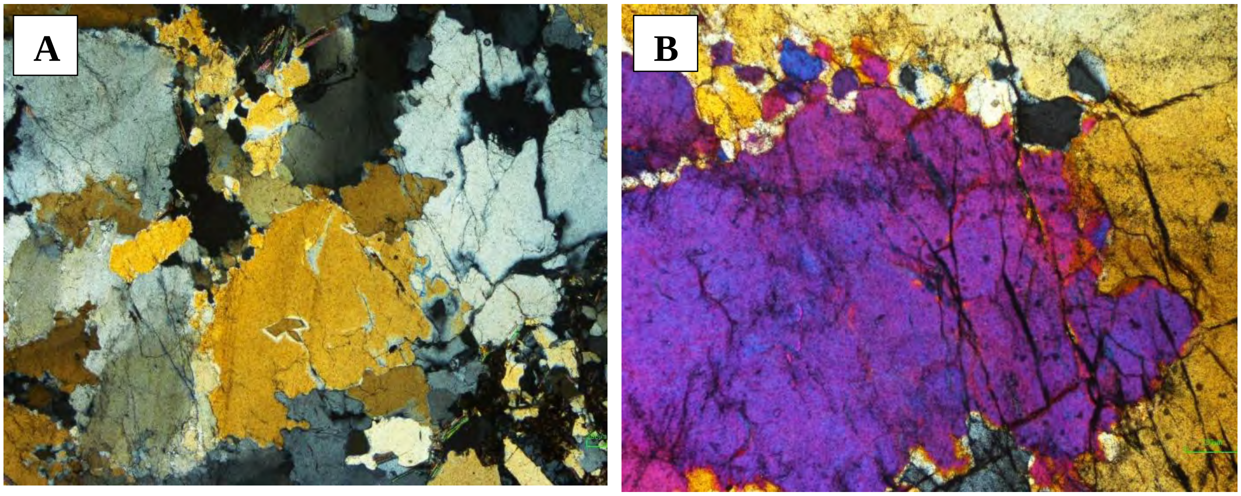


Figure 3.4: *Photomicrographs (XPL): (A) individual crystals of quartz can be seen but, within these, the extinction is not uniform and this shadowy extinction is fairly common in deformed rocks. (B) Quartz crystals along with micas.*

Figure 3.5: *Site Photographs: Schist*

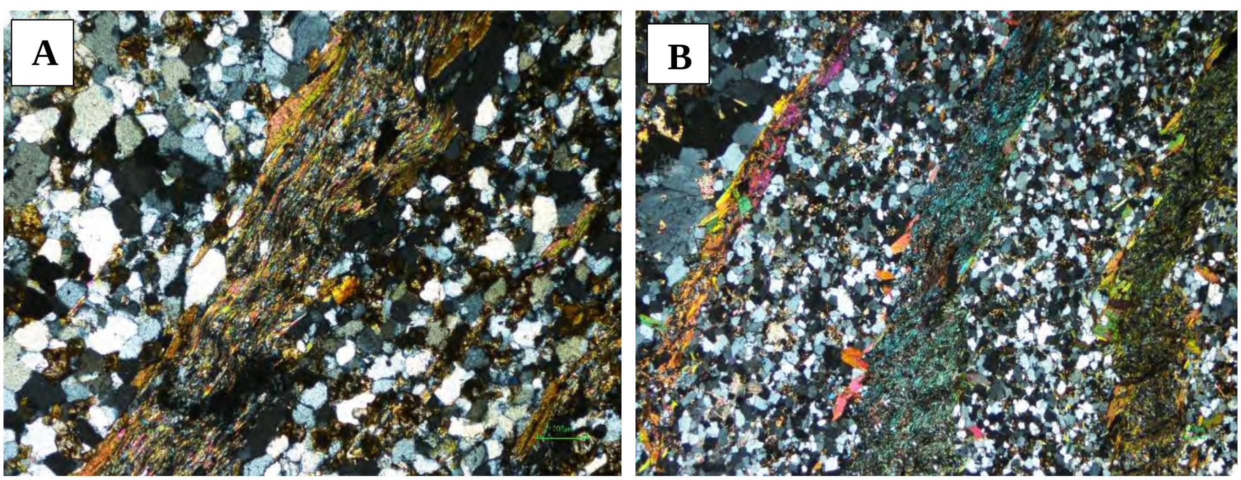


Figure 3.6: *Photomicrographs (XPL): (A) Garnet and muscovite-biotite layers in a garnet micaschist. (B) Layers showing variety of micas in schist.*

Chapter 4

4.1 Geotechnical Properties and Test Methodology

The procedures and test interpretations for the following laboratory tests should be consistent across laboratories because they are standard. Getting representative samples for laboratory testing is a big challenge. The equipment in the laboratory frequently determines sample size, which is an important factor. Here is a list of laboratory examinations:

1) Porosity test
2) Sieve Analysis
3) Proctor test
4) Compressive Strength test
5) Slump test
6) Los Angeles Abrasion test.

4.2 Porosity Test

The porosity of the soil is defined as the distance between soil particles that contain minerals. Because of how tightly or loosely the soil grains are packed, porosity varies greatly from one type of soil to another. (Marinos, P et al., 2001)

By figuring out how much water is needed to fill each individual pore, you may estimate the volume of the spaces between the particles in a soil sample and gauge its porosity.

Here is a technique for determining the porosity of soil.

4.2.1 Calculating Porosity Experimentally by Saturation

1) Take a sample of the soil you want to analyse and gently remove it. Handling the sample coarsely risked destroying the soil's structural integrity.

2) To calculate the soil's volume, transfer the soil sample to a graduated beaker. Exactly note down this volume.

3) Fill a graduated cylinder with a significant amount of water. Use more water at first than you think you'll need. Make a note of this volume exactly.

4) The soil sample should be well-watered. Get the water as near as you can to the exact top of the soil in the beaker without going over it.

5) In the graduated cylinder, deduct the amount of water you used up from the initial amount. That demonstrates how much water was required to completely saturate the soil.

6) The amount of water consumed has the same volume as the pore volume Vp.

7) Porosity = Total Pore Volume 100%

8) You may find "Total Volume" by adding Vs and Vp. So, using a scientific calculator, perform the following calculations to arrive at the following number:

Porosity = Pore Volume Sample + Pore Volume × 100%

The calculation's formula is as follows.

$$Pt = VpVs + Vp \times 100\%$$

Table 3: *Results of porosity for the collected samples*

Samples No	***Depth (m)***		***Porosity (%)***	***Average Porosity (%)***	***Remarks***
	From	***To***			
1	*7.84*	*7.98*	*8.01*	*7.11*	*Maximum average value of porosity was determined at left abutment*
2	*13.42*	*13.66*	*6.22*		
3	*3.98*	*4.22*	*4.90*	*6.02*	*Moderate Value*
4	*7.86*	*8.18*	*7.14*		
5	*1.12*	*1.36*	*3.98*	*3.98*	*Minimum value of porosity was determined at right abutment*

Higher porosity means as the sample has a lot of pores, rocks with a high porosity are not suitable for use in construction. Here, however, the porosity is quite low, indicating that the dam region is not porous and is therefore ideal for building.

4.3 Sieve Analysis

Due to this, preferred technique is sieving analysis for determining size of particle. Sieving analysis is the best widely used quality-control method in the powder process control business due to its ease of use, effectiveness, and minimal cost. However, users should be informed about standards and tolerances of test sieve, the proper technique of sieving, and sieve cleaning and care processes in order to carry out reliable sieving analysis. (Rigopoulos, I. et al., 2014)

4.3.1 Apparatus

1) Balance (with accuracy to 0.01g)
2) Stack of test sieves
3) Rubber pestle and mortar (for crushing the test material if lumped or conglomerated)
4) Oven
5) Sieve shaker

The balance utilized should be sensitive to 0.1% of total weight of sample brought.

Figure 4.1: *Sieves*

4.3.2 Procedure

1) Take a 500g sample which is oven-dried as first step.
2) Crush the lumps but not the particles using a pestle and mortar, if the particles are conglomerated.
3) Calculate the mass - weight (g) of sample accurately.
4) Get a pile of test sieves ready. The sieves are set up in ascending size order, by keeping the smallest aperture size at the top. A receiver is used under each sieve to gather samples.
5) Weigh each pan and sieves separately.
6) On top of the sieve stack, place the samples from Step 3, cover with the lid, secured by clamps, and adjust the timer between 10 to 15 minutes, and then turn on the sieve shaker.
7) Put an end to the sieve shaker and evaluate the soil or other materials that were retained in every sieve.

When the whole process is completed, users can evaluate the outcomes. Compare the initial sample weight to the final sample weight by keeping the track of initial sample and the sample obtained on the sieves after experiment. If the end sample's weight deviates from the initial weight by more than 2% then analysis and sample should be thrown out. Technically, losses of sample can cause the analysis to be inaccurate and flawed.

4.3.3 Data and Calculation

Figuring out the particle size distribution of the coarse aggregate. The total weight of the coarse aggregate is 920 grams.

Table 4: *Test results of sieve analysis*

Sieve size	Retained weight of the aggregate (g)	% of total weight retained (g)	Cumulative % of the total weight retained (g)	% of aggregate passing through sieve
20mm	160	16	16	84
10mm	730	73	84	4
5mm	30	3	100	0
Pan	0	0	0	0

The table above displays the outcomes of various aggregate types put through various sieves. The bulk of aggregates pass through 20mm sieves due to their open pores, according to the table, while aggregates scarcely pass through 5mm sieves due to their small passing holes.

4.4 Proctor Test

The Proctor compaction test is a geotechnical laboratory test procedure used to assess the soil's compaction properties and determine the ideal water content at which soil can reach its maximum dry density. The Modified Proctor Test, which was later modified from the original Standard Proctor Test, was given that name. The compaction energy is the main difference between the two trials.

For the Proctor compaction test, a dry soil sample is mixed with water and compacted in three layers in a cylindrical mould with an internal diameter of 4 inches and a height of 4.584 inches. A typical Proctor mould has a volume of 1/30 ft3. Each layer is struck 25 times with a 5.5 lb hammer that is dropped freely from a height of 12 in. Energy output from the hammer is 12,400 ft lb/ft3.

For projects requiring tremendous weights, such as runways capable of supporting heavy aeroplane loads, a modified Proctor compaction test was developed. The hammer in this test weighs 10 lbs and drops effortlessly from an 18-inch height. In the typical Proctor mould, the dirt is compacted in five layers with 25 blows applied to each layer. The updated Proctor test has a compaction energy of 56,000ft.lb/ft3, which is roughly 4.5 times that of the original Proctor test.

4.4.1 Apparatus

1) Metal cylindrical mold with a base plate and collar that separate by two inches, an internal diameter of either 4" (10.16 cm) or 6" (15.24 cm), and an internal effective height of 4.6" (11.7 cm) (5.08 cm).
2) With sensitivity ranges of between 0.1 and 1 grammes, there is Sensitive Balance.
3) Oven with thermostatic control (105°C to 110°C)
4) Containers for moisture
5) Steel straight edge.
6) No. 4 sieve
7) Graduated cylinder.
8) Tray & scoop.
9) Mixing tools like spoon, trowel, spatula.

Figure 4.2: *Cylinder metal molds used in test*

4.4.2 Procedure

In order to perform the Proctor compaction test, soil samples are compressed using a standard mould and a predefined amount of compaction energy. In the standard Proctor test, three separate soil layers are compacted using a 4-inch-diameter mold using 25 blows from a 5.5-pound hammer that fall 12 inches.

Before being divided into 4 to 6 samples for the Proctor test, the soil is air dried. Depending on the kind of soil, water is added in increments of 3% to 5% or more to each sample to change its water content. The dirt is then put into a Proctor compaction mold and crushed in three levels, receiving 25 blows from a standard hammer for each layer. The surface of the prior layers is scratched before each new layer is added, to achieve an even distribution of the compaction effects.

For each Proctor compaction test, the sample is taken out and dried before the water content and dry density are calculated. A curvature for density or the dry unit weight as a water content function is displayed based on the full set of results. The ideal water content to get the highest dry density can be found in the table given below.

Table 5: *Showing Maximum dry density and moisture content*

	Proctor Test						
Lab No	**USM/ML/036**						
Description Sample	0	Mould volume Cm^3		2130.0			
Location:	0	Mould Wt. gms		4434.0			
Maximum Dry Density ASHTO T-134							
Container No.		1	2	3	4	0	
Wt. of Container	**Gms**	50.5	52.5	55.8	45.4	24	
Wt. of wet soil + container	**gms**	300.50	360.40	210.55	270.6	100.4	
Wt. of dry soil + container	**gms**	350.4	390.5	430.4	475.8	160.2	
Wt. of water	**gms**	18.7	19.2	29.7	39.9	16.6	
Wt. of dry soil	**gms**	180.66	160	210	240	110.5	
Moisture content	**%**	4.5%	5.7%	7.8%	10.2%	10.4%	
M.D.D:1.56 gm/cc							
O.M.C: 10.2%							

4.5 Compressive Strength Test of Concrete

This test is thought to be the most common one carried out on the building material since it provides a thorough overview of all the qualities of concrete. A concrete work may be accepted or refused based on this test. Numerous factors, such as mix design, quality control, and the calibre of the raw materials used, affect the compressive strength of concrete.

1. The test sample may be a cube or a cylinder, with the most typical sizes being 15 cm x 15 cm and 30 cm, respectively, depending on the code employed. For instance, ASTM C39 specifies a common test procedure for specifying the compressive strength of concrete cylinders. (ASTM, D. 2000).
2. To minimize voids, concrete is carefully poured into the mould and compacted.
3. After 24 hours, molds are removed and test specimens are then submerged in water to cure.
4. Specimens are checked by the compression testing machine after the designated curing period (3, 7, 28, 56, or 91 days).
5. Gradual loading continues until specimen failure.
6. To calculate the compressive strength of concrete, divide the failure load by the specimen's cross-sectional area.

4.5.1 Apparatus

Molds, a tool for testing compression, a trowel, a mixer, and steel bar which is 16 mm diameter and 60 cm long.

Figure 4.3: *CS Cylinder*

4.5.2 Sample Preparation

The concrete patches applied on the job site or those made with the same mixture are utilized as samples.

Specimen size: 3 cylinders [15 cm x 30 cm] or 3 cubes [15 cm x 15cm x 15 cm]

A minimum of three samples should be tested at each age. The average of the concrete's specimens is used to calculate its strength.

4.5.3 Concrete Mixing

1. First, use a laboratory batch mixer or a hand mixer to fully blend the cement and satisfactory aggregate.

2. The coarse aggregate must be added next, and it should be mixed in well. Add water and continue mixing the concrete until it appears to have the correct consistency and homogeneity.

4.5.4 Pouring Concrete into moulds

1) Clean the molds thoroughly and oil it to avoid sticking of concrete to them and making cleaning more difficult later.
2) The molds should be filled with successive layers of concrete. A wall that is approximately 5 cm thick separates each tier. A tamping rod is used to firmly press each layer down (35 strokes).
3) Use a trowel to smooth the top surface.

4.5.5 Curing

After being kept in moist air for twenty four hours, test specimens are detached from the moulds and immersed in fresh water for the designated amount of time to cure.

4.5.6 Procedure

1) Remove the specimen from the water and wipe off any extra moisture after the allotted length of time has passed.
2) Measure the specimen's dimensions before applying any load on it.
3) Position the sample in the proper spot inside the testing device. You should be aware that the weight will be applied to the face perpendicular to the casting direction.
4) Position the specimen so that it is centred on the machine's base plate.
5) Make sure the machine's moving part touches the top of the specimen.

6) Until the specimen breaks, gradually apply the stress at a rate of 140 kg/cm2/minute.

7) Seventh, note the maximum load.

Compressive strength of Concrete Formula

One can calculate the compressive strength of a sample by dividing the maximum force it can withstand by the cross-sectional area of a set of cubes.

Concrete's Compressive strength = Max load carried by top surface area of Specimen

Specimen surface area: = 150 x 150 = 22500 mm^2 = 225 cm^2

The Max compression load is 450KN

1KN = 1000N : 450Kn = 450×100 = 450000N

Compressive strength of Concrete = Max load carried by top surface area of Specimen

Compressive Strength of Concrete = 450000 /22500 = 20N/mm^2 = 203Kg/cm^2

Similar calculation is carried out for the specimen at different ages as stated below:

Table 6: *Test comparison of compressive strength of concrete*

Details	**Specimens**		
	Specimen 1 @ 7 days	**Specimen 2 @ 14 days**	**Specimen 3 @ 28 days**
Max load that Specimen bear	310KN	408KN	445KN
Compressive Strength in N/mm²	310000/22500 = 13.7N/mm²	408000/2250 =18.13N/mm²	448000/2250 = 19.9N/mm²
As M20 grade concrete mix which bear a max load upto 20N/mm²			
Minimum Strength to be achieved at different days	65% @7 days	90% @14 days	99% @28 days
Percentage of Concrete gain (test results)	(13.7x100)/20 = 68.5%>65%	(18.13x100)/20 = 90.6%>90%	(19.9x100)/20 = 99.1%>99%

A good quality concrete must not show less than the minimum Compressive strength at relevant days. Hence concrete is safe to use.

4.6 Slump Test

It acts as a metric for the stiffness or homogeneity of concrete. To ascertain the consistency of concrete, perform a slump test. We can determine the stiffness or amount of water added to a mixture by its consistency. The concrete mixture's uniformity needs to be rigid enough to meet the standards for the final product's quality.

4.6.1 Concrete Slump Test

A property of freshly-poured concrete is determined using the concrete slump test. It is an empirical test that determines how easily new concrete can be produced. It evaluates consistency between batches with more specificity. The test is well-liked, due to the straightforward gear and straightforward process.

4.6.2 Principle of Slump Test

It is possible to predict what will happen to a compacted, inverted cone of concrete when gravity takes effect by using the results of the slump test. It gauges the concrete's consistency or moisture content.

4.6.3 Apparatus

1) Scale for measurement,
2) Slump cone,
3) Steel temping rod.

Figure 4.4: *Slump cone*

4.6.4 Procedure

1) A 300 mm (12 in) tall cone-shaped frustum serves as the mould for the slump test. 200 mm (8 in) is the diameter of the base, and 100 mm is the diameter of the top hole (4 in).
2) With three layers of concrete, the container is filled, its workability will be evaluated, and the base is set on a level surface.
3) A steel rod with a standard 16 mm (5/8 in) diameter and a rounded end is used to heat each layer 25 times.
4) The top surface is struck off (levelled with the mould top aperture) once the mould has been entirely covered with concrete using a rolling motion of steel temping rod and screening.
5) The cone is gently and carefully raised vertically once the concrete has been filled and levelled. At this point, unsupported concrete will sag.

6) Slump is the term used to describe the reduction in height in the centre of slumped concrete.
7) Scale is used to show the reduction in height of concrete to that of mould. The slump is assessed by positioning the cone next to the slumped concrete and placing the steel temping rod over the cone so that it would also come over the area of depressed concrete. (often approximated to the closest 5 mm (1/4 in)).

4.6.5 Precautions in Slump Test

What to anticipate from an inverted, compacted cone of concrete under the influence of gravity can be determined by the results of the slump test. The concrete's consistency or moisture content is measured.

4.6.6 Types of Concrete Slump

Concrete that is slumped can show a variety of shapes, and the slump is referred to by the concrete's profile.

1) Collapse Slump
2) Shear Slump
3) True Slump

Collapse Slump

The concrete completely collapses during a collapse slump. The slump test should not be used if the slump collapses because this indicates that the mixture is either extremely workable or too wet.

Shear Slump

A shear slump occurs, causing the top portion of the concrete to rip off and fall sideways. OR If one-half of the cone slips down an inclined plane, the slump is known as a shear slump. If a shear or collapse slump is reached, a new sample should be taken, and the test should be repeated. If the shear slump persists, which can happen with harsh combinations, it is a sign that there is a lack of mix cohesiveness.

True Slump

The concrete just slows down and, to some extent, holds its shape in a true slump. In many tests, this slump is the only one that is used. Since combinations with a stiff consistency have no slump, there is no difference in the quite dry range between mixtures with variable workability. Since a true slump in a slender mix with a predisposition to harshness can definitely turn into a shear slump type or even collapse, and since radically disparate slump values can be recorded in independent samples from the same mix, the slump test is inaccurate for lean mixtures. Several different types of compacting factors are obtained and used, depending on whether the concrete is suitable for construction or not. Larger projects, which represent the hardest concrete, need greater compacting factors. Concrete is inappropriate for heavily used construction projects like tunnels and bridges due to its poorer compacting properties. (ASTM, D. 2000)

Table 7: *Workability, Slump and Compacting Factor of concrete with 19 or 38 mm (3/4 or 11/2 in) maximum size of aggregate*

Degree of workability	Slump		Compacting Factor	Use for which concrete is suitable
	Mm	In		
Very low	0-25	0-1	0.78	Very dry mixes; used in making of road. Roads vibrated by machines that are power operated.
Low	25-50	1-2	0.85	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by machines that are hand operated.
Medium	50-100	2-4	0.92	Medium workability mixes; manually compacted flat slabs using aggregates that are crushed. Normal reinforced concrete manually compacted and heavily reinforced sections with vibrations.
High	100-175	4-7	0.95	High workability concrete; for sections with congested reinforcement. Not normally suitable for vibration

4.7 Los Angeles Abrasion Test (ASTM C 131, AASHTO DESIGNATION: T-96)

In a spinning steel drum filled with a predetermined quantity of steel spheres, the Los Angeles test determines the amount of deterioration of mineral aggregates of typical gradings caused by a mixture of processes including grinding, abrasion or attrition and impact. A popular test procedure for determining aggregate abrasion and toughness properties is the Los Angeles (L.A.) abrasion test. Because the constituent aggregate in HMA must be able to withstand crushing, disintegration and deterioration in order to make a high-quality HMA, aggregate abrasion properties are crucial. ASTM, D. (2000)

4.7.1 Apparatus

1) Steel Spherical Balls
2) The device must be a cylinder that is closed at both ends and made of steel. To introduce the sample, a hole must be made in the cylinder.

The aggregate used in highway paving must to be durable and resistant to abrasion from internal forces, traffic buffing, and compaction machinery. The aggregate for the roads must be resilient enough to withstand abrasion. In labs, resistance to abrasion is measured through loss angles abrasion testing.

Figure 4.5: *Abrasion machine*

4.7.2 Principle of the Test

By striking the aggregate while being mixed with it and rotating in a drum for a predetermined number of revolutions, regular steel balls are employed to produce an abrasive effect. Calculating the percentage wear brought on by rubbing against steel balls yields the abrasion value. Use the aggregate sample portion that was kept on the 1.70 mm (No. 12) filter to prepare the sample, and then put it in a big rotating drum with a shelf plate affixed to the exterior wall.

4.7.3 Procedure

The prepared sample is set into the abrasion testing apparatus. After that, a predetermined quantity of steel spheres are added to the machine, and the drum rotates for 500 revolutions at a speed of 30 to 33 revolutions per minute (RPM). Following that, the material is separated into two groups:

that which goes through a 1.70 mm (No. 12) filter and that which is retained on the sieve. The sample is baked to dry it out.

By computing the difference between the retained material's (larger particles') weight and the initial sample weight, you may determine the percentage loss via abrasion. The "percent loss" refers to the weight difference, which is conveyed as a percentage of the starting weight. (ASTM, D. 2000)

Table 8: *Los Angeles Abrasion Test Results*

LOS ANGELES ABRASION TEST (ASTM C-131 ST ASASHTO T 96)							
LOCATION					Al-Mehreen Enterprises (MCL Asphalt Plant Peshawar)		
REQUEST NO					Situation Base Course Class B		
GRADING	1 ½”-1”	1”-3/4”	¾” – ½”	½”-3/8”	3/8”-1/4”	¼”-No.4	No.4-No.8
Designation	A				C		
Weight of test sample	1250 ± 25	1250 ± 25	1250 ± 25	1250 ± 25	1250 ± 25	1250 ± 25	
Designation			B				
Weight of test sample			1250 ± 25	2500±10			
TOTAL WEIGHT OF TEST SAMPLE 5000 ± 10C							
E) Revolution (33 / 33 rpm) No.					1	2	
F) Designation					A	B	
G) Total weight of test sample					5000	5000	
H) Total weight of tested sample retained on 1.7 mm seive					4431	4521	
I) Loss by abrasion					11.38 %	9.58%	
					Avg	10.48	

By calculating the amount that has been abraded and comparing it to the initial weight, the percentage is determined. When used for construction, a high percentage ensures the material's fragility because it means more material is being abraded. Materials with low abrasion are always thought to be the best for big projects because of their hardness.

Chapter 5

5.1 Results and Discussion

Several soil and rock samples were taken from the Jay Dam region, and these samples underwent a number of Geophysical tests. The samples underwent testing to determine their fitness for dam construction, and the results were compared to industry standards. The results of several standard tests, including Porosity, Proctor, Slump Test, Compressive Strength Test, and Los Angles Abrasion, for the analysed rocks and soil sample fall within the acceptable limits of standard standards for typical rocks and soil used in dam construction.

To distinguish samples based on their size, we conducted a sieve analysis test, in which the sample aggregate was run through various sieves of varying diameter. The results are shown in the table above. Proctor tests were conducted to determine the soil's capacity for compaction, particularly the ideal water contact at which the soil can attain its maximum dry density.

1) ASTM D698 - 12 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft3 (600 KN-m/m3))
2) ASTM D1557 - 12 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 KN-m/m3)).

Due to their severely fragmented form, the Unconfined Compressive Strength (UCS) values indicate that these rocks are extremely strong. Its application is thus constrained in high-performance projects. However, using it in heavier projects as well may be viable with the right preventative and reinforcement measures.

A slump test was also carried out to gauge the concrete's stiffness or consistency. How much water is utilized in the mixture is indicated by the stiffness. The outcome may be one of three possible types using concrete as a defense. It could be real slump, collapse slump, or shear slump.

The most recent test we conducted was the LA (Los Angeles Abrasion) test. By using various apparatus, we conduct this test to determine the material's brittleness or hardness. Calculating the percentage of degraded or abraded aggregate and comparing it to the required level of quality leads to the conclusion that weaker concrete was used. The more aggregate that has been abraded, the higher the percentage will be. The hard aggregate will exhibit a lower percent loss due to its resistance to rapid abrasion from the rotation of steel balls. The test we conducted yielded a percentage of almost 10%, indicating that the aggregate was too tough to be abraded so it could be used on a construction site.

We can infer that the majority of the materials were suitable for construction by comparing all of the tests with the necessary requirements. The primary indicators that the rocks in the Jay area are ideal for dam construction for irrigation reasons are their high degree of hardness and low porosity.

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