Subgrade Materials Quality Evaluation for Section-II (Jawa to Morgah City) of Rawalpindi Ring Road District Rawalpindi

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Subgrade Materials Quality Evaluation for Section-II (Jawa to Morgah City) of Rawalpindi Ring Road District Rawalpindi

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Dedicated to

My dear Parents, Uncle, family and

Honored Teachers

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ABSTRACT

Rawalpindi is a historic city and industrial, commercial and military hub for of the Potwar region. The current geopolitical importance of Pakistan and trade traffic growth in the region, the government of Punjab evoked Rawalpindi Ring Road project. The project was previously announced during early 90s being realigned from its previous route to Rawat towards Kohat road.

The study area is part of Kohat – Potwar Basin and comprises thick deposits of sub recent Potwar clay. The field studies were carried out in last week of February 2010. The study objective consists of evaluating soil's index and engineering properties as subgrade materials for section II (Jawa to Morgah city) of purposed Rawalpindi Ring Road in district Rawalpindi. During field investigation, nine tests pits were excavated as per project's specification along the purposed road alignment. In-situ compaction was determined by using sand-cone method (ASTM D 1556) which ranges from 81% 86%. The grain friction analysis reveals that the gravel varies from 1 to 54%, sand varies from 4 to 57% and silt/clays friction range from 33 to 92%. The Atterberg limits data reveals that the Liquid Limit varies from 23.1% to 30.5%, Plastic Limit 17.3% 22.8% and Group Index varies till 7. The soil in the study area was classified as A-4 using AASHTO M 145 soil classification. The Californian Bearing Ratio at 0.1" penetration ranges from 4% to 14%. Based upon AASHTO soil classification and NHA road specification, the soil of area is recommended for purposed road subgrade.

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Chapter No. 01

INTRODUCTION

1.1 Area

Geographically, Rawalpindi city lies in the northern Potwar plateau and is the fourth largest city of Pakistan hosting approximately 2.2 million persons. It lies between 33°28' & 33°48' N (latitude) and 72° 48' & 73° 22'E (longitude). The urban area of Rawalpindi spreads over 250 square kilometers on the south-western side to the national capital of Islamabad, Pakistan. Rawalpindi is a commercial, industrial and military hub of Potwar region.

Rawalpindi been capital of Pakistan before founding of Islamabad, gained rapid urbanization and commercial activities during past five decades which led need for better and faster road network in the area. In order to achieve this, the National Highways Authority (NHA) introduces the National Trade Corridor Improvement program (NTCIP) in 2006 (daily the Dawn September 2009). The program was focused to revamp the transport infrastructure for trade logistics to international standards, in order to improve regional connectivity between ECO countries. Earlier in late 90s', the provisional government of Punjab lunched a "Rawalpindi Ring Road" program in order to reduce traffic load on the urban road network of Rawalpindi city. The project's foreign consultants had purposed four-lined ring road between Koral chowk – Adyala – Pirwadahi chowk (figure 1.1). But the project was not implemented due to change in government (daily the Dawn September 2009). During past decade, the urban area of Rawalpindi city spread rapidly toward south and south-westward and its traffic became more congested due to narrow and ill maintained roads. The present federal and provisional governments after realizing importance of project had reinitialized it. They also approved modified project layout from Rawat (on N-5) –Dhamial – Dhama (on N-45) (figure 1.1) in order to divert all heavy traffic coming from south of country, outside Rawalpindi city. The present research focuses on the geotechnical investigations outcome on revised road alignment of Rawalpindi Ring Road, carried out by GEOENGINEERS Islamabad. During field investigation, soil index and engineering properties were determined using American Society for Testing & Materials (ASTM) based test procedures.

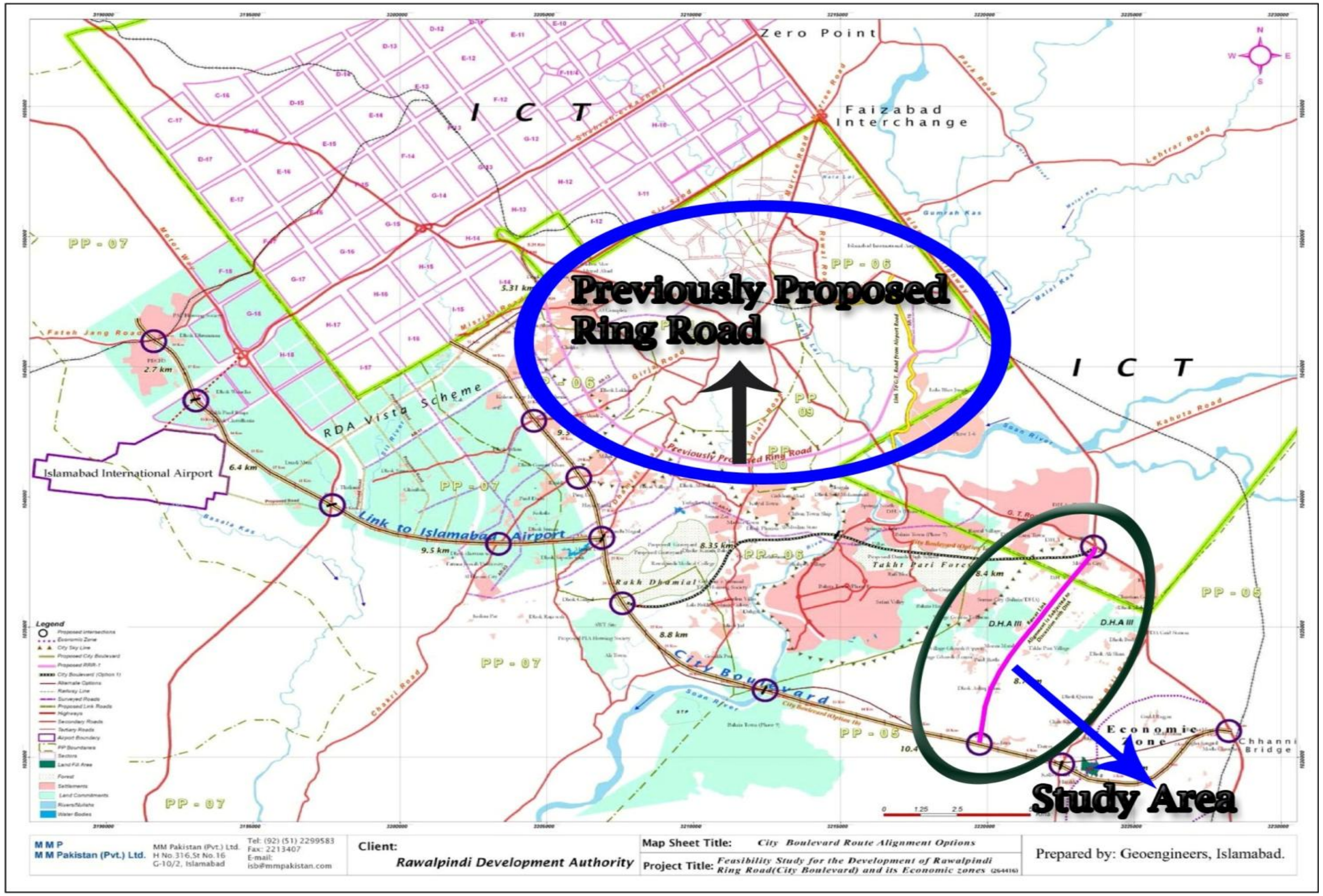

Figure1.1: Location map for Rawalpindi Ring road

1.2 Research Theme

The main purpose of this investigation was to evaluate the purposed road embankment materials quality along the proposed road alignment of section II for Rawalpindi Ring Road. The guidelines indexed as in American Association for State & Highway Transportation Officials (AASHTO) and by NHA, were used for determination of different soil properties. Accordingly, a test pit was excavated of one meter deep after removing top surface soil cover (O – horizon) at every kilometer or if any change in surface lithology were observed for in-situ dry density determination by sand-cone method (ASTM D 1556 – 00/ AASHTO T 191–93). Approximately, 10kg soil sample was also collected from these pits for their index and engineering properties determination in engineering laboratory, which includes;

a. Determination of soil grain friction (ASTM C136 – 05 &, C117 –.04 / AASHTO T 127–91 & T 11–91),

b. Determination of the Atterberg Limits (ASTM D 4318 – 00 / AASHTO T 89–93 & T 90–92),

c. Determination of moisture density relation of soil using modified effect (ASTM D 1557 – 02 / AASHTO T 180–93 D) &

d. Determination of Californian Bearing Ratio (ASTM D 1883 – 99 / AASHTO T 193–92).

Based upon field observation and interpretation of laboratory test results, the engineering analysis was give for the purposed road embankment.

1.3 Location & Accessibility

The study area lies south-east of Rawalpindi city at 72°48' & 73°22' E (longitude) and 33°28' & 33°48'N (latitude). The purposed Rawalpindi Ring Road section II begins at Jawa village and end at Morgah city. It is accessible from Grand Truck Road (N-5) via Rawat through Chhanni Bridge.

Chapter No. 02

GEOLOGY

2.1 Tectonic framework of the study area

The arc, oroclines and syntaxes characterize geology of Pakistan as there is no part of the world where mountain belts bend so often and so severely. On the present plate tectonic setting, Pakistan lies on the northwestern corner of the Indian lithospheric plate representing part of the Tertiary convergence between the Indian and Asian plates. The deformation style and structure on the edges of these plates mimic their past and present inter-relationships. The tectonic setting of the Indo-Pakistan is an integral part of the global tectonics. It is related to the formation and break-up of the super-continent Pangaea, the rotation of the different continents relative to each other and opening and closing of major present day and Paleo-oceans, such as the Tethys, Pacific, Atlantic and Iapatus. These events led to rifting, shear movements, uplifts and volcanic activities.

During the late Paleozoic, most of the continental masses were joined to form one great super-continent called Pangaea. During the late Paleozoic era, Pangaea began to break up into two supercontinents; Laurasia continent in the north and Gondwana continent in the south. A new ocean "Tethys" was created between these drifting continents. During the late Mesozoic era, the Gondwana continent was fragmented as further sea-floor spreading complicated the paleography of the Indian Ocean. The tectonic history of the area becomes less clear due to lack of overlapping of the older tectonics by younger one.

Separation of the India plate from Africa and Madagascar probably started during late Mesozoic. During early Tertiary, the Indian plate drifted rapidly towards north-eastward. But by mid Tertiary, its speed reduced as it changes its course towards north-westward led to formation of Kohistan-Ladkha island arc and raise of Karakorum-Hindu Kush granitic belt (Patriat & Achache, 1984).

The continued under thrusting of the Indian plate since Cretaceous as it crowded northward into the Asian plate narrowed part of the Tethys Sea between the landmasses until it was destroyed. The Himalayas show the perfect continent to continent collision after having gone through the earlier stages of subduction, magnetism and collision. The building of the highest mountain chain is also related to the opening up of the Indian Ocean as the Indian plate was displaced from the north to northeast at different movement rates from the post-Jurassic to recent times.

In the case of the continental collision, intensely compressed and metamorphosed ultramafic rocks and basalts commonly define a suture zone where two plates collided such zones are all that is left at the surface of the a former oceanic zone that separated the two continents before collision. In the Indian Himalayas, northern collision zone has been identified as Indus-Tsangpo suture (ITS), Main central Thrust (MCT), Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT). The collision zones in the northern Pakistan have been subdivided as the Main Karakoram Thrust (MKT), Main Mantle Thrust (MMT), Main Boundary Thrust (MBT) and Salt Range Thrust (SRT).

2.2 General Geology of Pakistan

Pakistan has established as one of the most fascinating position of the globe. The northern part comprises of the collision mountain belt that are Himalaya, Karakoram and Hindukush Range (figure 2.1). Thrust sheets, Extensive nappes with Barrovian metamorphism, large granitic batholiths and sutures marked by mélanges, Ophiolites and high pressure metamorphic rock characterize these ranges (figure 2.2). Some of the mountains rising at rate of over 5mm/year and exposed granitic plutons only a few million years old. The opening of the western part of the Indian Ocean and the 4,000 km northward drift of India and its collision with Eurasian are unique events.

The exposed rock sequence includes Precambrian metamorphic (Hazara Slates) and plutonic rocks, Paleozoic, Mesozoic and Paleogene pericratonic shelf deposits, which form the platform cover and the marginal fold belt, and an extensive and exceptionally thick pile of Neogene molasse (Siwaliks) that fill the foredeep. Famous for their rich and exotic vertebrate fauna, the Siwaliks are the product of the intense denudation that accompanied the uplift of the Karakoram and the Himalayas, which may have removed half of the elevated crustal mass in these rapidly rising mountains. Part of this debris was deposited on the ancient Siwalik flood plains, but by far the greater amount was carried to the sea to form the second largest submarine fan in the world, the Indus fan. Pakistan has been geologically well-known for several decades for its great mountains, extensive glaciers, devastating earthquakes, exotic and prolific Neogene vertebrate fauna, chromite -bearing Ophiolites, and Precambrian and

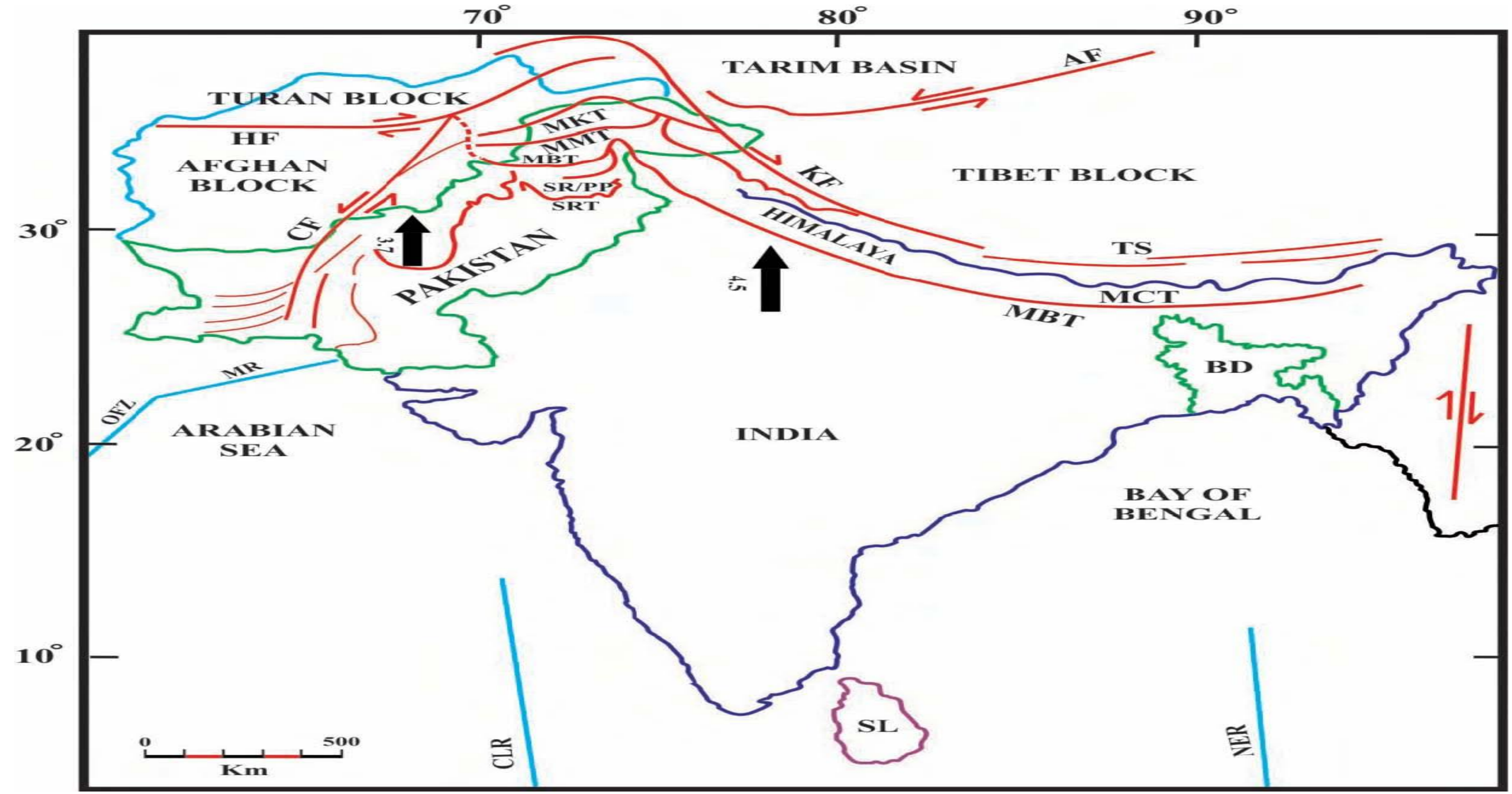

Figure 2.1: Tectonic sketch map showing the Himalayan collision zone and motion of India relative to Asia (in cm/year, (Jacob and Quittmeyer 1979). AF Alltyn Tagh Fault, BD Bangladesh, CF Chaman Fault, CLR Chagos-Laccadive Ridge (Reunion Hotspot), HF Herat Fault, KF Karakoram Fault, MBT Main Boundary Thrust, MCT Main Central Thrust, MKT Main Karakoram Thrust, MMT Main Mantle Thrust, MR Murray Ridge (Kerguelen hotspot track), NER Ninety-East Ridge, OFZ Owen fracture zone, SL Sri Lanka, SR/PP Salt Range/Potwar Plateau, SRT Salt Range Thrust, TS Tsangpo suture. *(Modified after Davis and Lillie (1994)).*

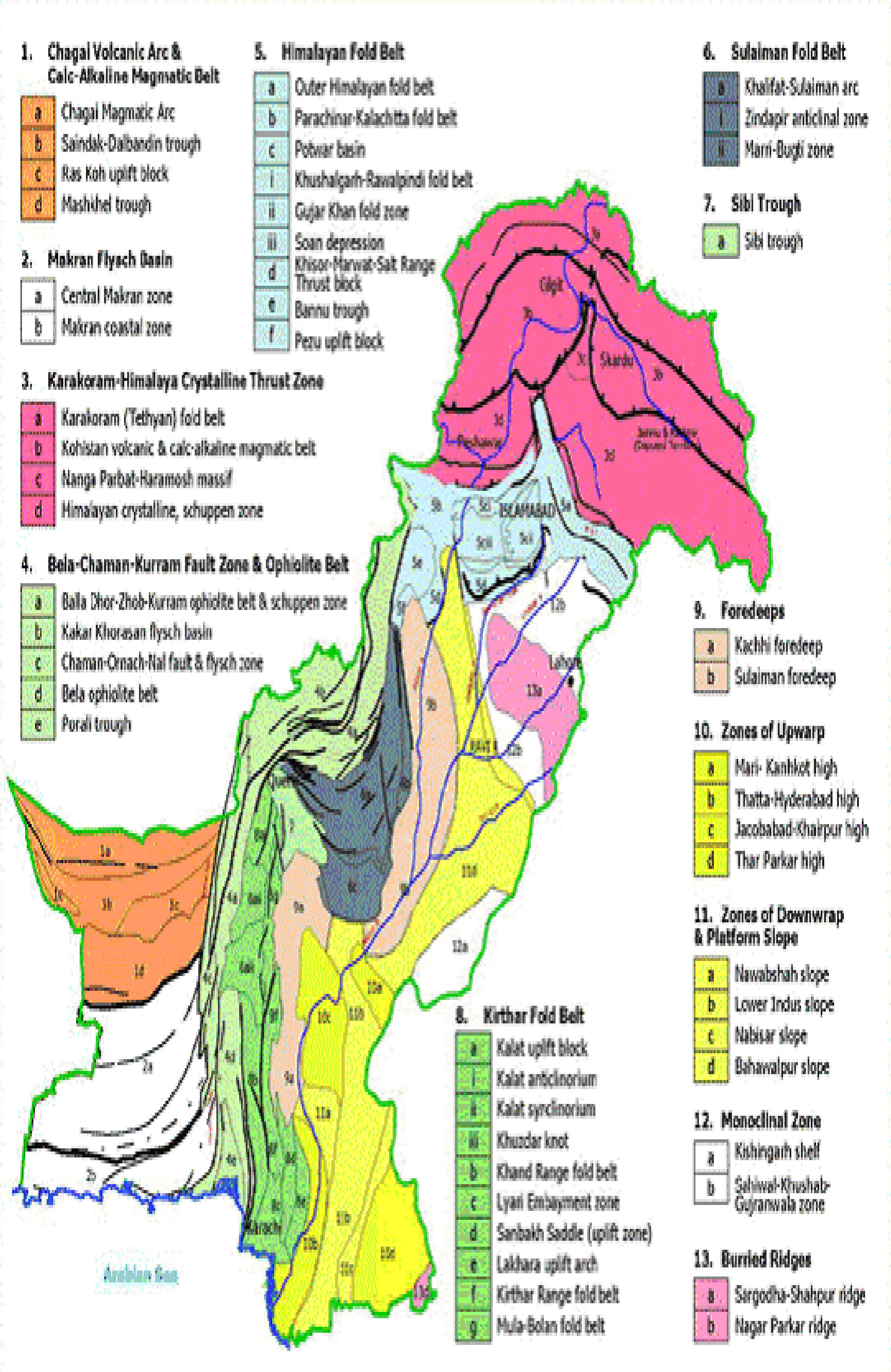

Figure 2.2: **Tectonic map of Pakistan (Kazmi & Jan 1998)**

Paleozoic succession of the Salt Range, the abundant oroclinal flexures and enigmatic syntaxes in its mountain ranges, and the deep gorges and canyons that highlight the antecedent drainage.

2.3 Tectonics of Pakistan

Modern concepts of plate tectonics and availability of satellite remote sensing data integrated with field geology and seismic data have led to a better understanding of the sedimentary basins of Pakistan. According to Fateh et al (1984), active plate boundaries of various types are exceptionally well exposed in Pakistan. These plate boundaries and their offshoots give rise to fascinating array of features (Figure2.2) in different sedimentary basins.

Tectonics of Pakistan is characterized by two active convergent boundaries:

1. In the northeast there us an active continent-island arc continent collision boundary, the west end of the Himalayan orogen;
2. In the southwest, there is an active boundary of oceanic lithosphere subducting beneath arc-trench gap sediments and continental sediments, the oceanic part of the Arabian plate passing under the Makran arc-trench gap and Afghan microplate.

These two convergent boundaries are connected by very large displacement north-south, left lateral strike-slip faults of Chaman Transform Zone.

Pakistan is segmented in following main tectonic segments;

1. Northern Collision Belt (Figure 2.1),
2. Subduction Complex Association of Balochistan,
3. Chaman Transform Zone,
4. Ophiolites and Ophiolitic Mélanges,
5. Platform Areas.

2.4 Kohat Potwar Plateau

The area is located north of Salt Range and Trans-Indus Salt Range culminating in the Parachinar-Kalachitta fold belt. Structurally Potwar Plateau comprises the northern folded zone and the platform zone while the Kohat Plateau consists of Kohat Eocene Salt Zone and Bannu Depression. The Kohat Plateau structures differ from those of the Potwar Plateau largely on account of the higher salt detachment horizon (Eocene) in the Kohat Area, against that of Precambrian in Potwar.

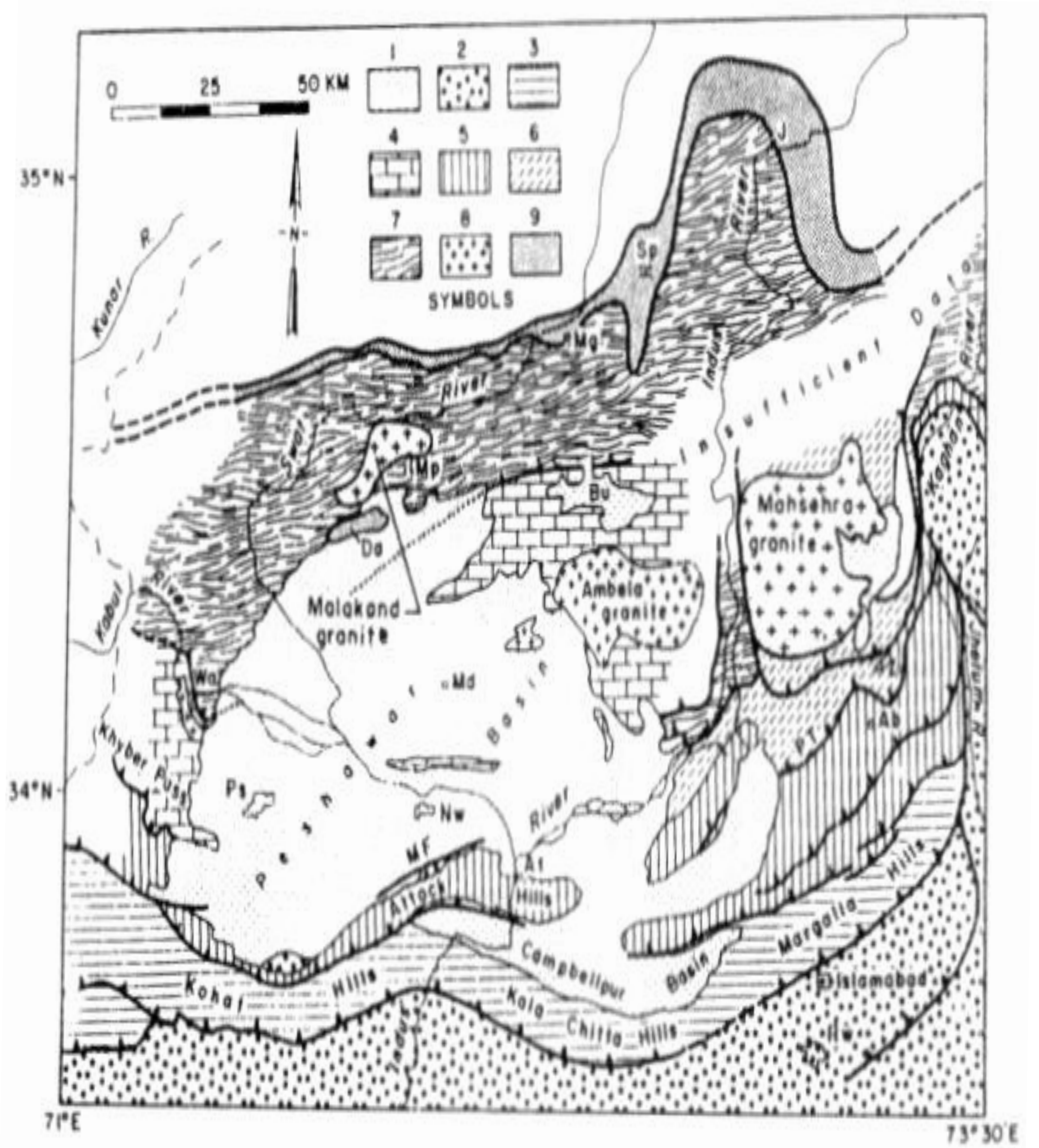

Figure 2.3: Tectonic sketch of northwestern Pakistan from the Hill Ranges to Southern Kohistan. Geologic units 1) Quaternary basins, 2) Murree and Siwalik Strata, 3) Mesozoic and Cenozoic rocks with stratigraphic affinities to Sulaiman Range, 4) Late Precambrian to Paleozoic sedimentary rocks with stratigraphic affinities to Kashmir, 5) Late Precambrian and lower Paleozoic rocks with stratigraphic affinities to the lesser Himalaya, 7) Salkhala-type Tanawal-type metamorphic rocks and included lower Paleozoic gneisses, 8) Alkaline granitic rocks of Ambela, Warsak and Malakand. 9) Suture Zone complex included ophiolite of the Main Mantle Thrust. Locations: Da=Dargal Klippe, Mp= Malakand Pass, Mg=Mingora, Sp=Shangla Pass, J=Jijal, Wa=Warsak, Ps=Peshawar, Md=Mardan, Nw=Nowshera, Bu=Buner, PT=Panjal Thrust, Ma=Mansehra, Ab=Abbottabad, MF= Manki fault, At=Attock, Rw=Rawalpindi. (Modified after Lawrence and Yeats, 1984)

2.5 Tectonic Setting of Potwar Plateau

This plateau is roughly defined by the river Indus in the west and Jhelum river in the east, the Kalachitta-Margalla Hill Ranges to the north and the Salt Range to the South (Figure 2.4). It is largely covered by the Siwalik sequence, though at places Upper Eocene shale and limestone crop out locally in folded inliers. Its northern part, known as the North Potwar Deformed Zone (NPDZ) is more intensely deformed. It is characterized by east – west, tight and complex folds overturned to the south and sheared by steep-angle faults.

NPDZ is followed to the south by asymmetrical, wide and broad Soan Syncline, with a gently northward dipping southern flank along the Salt Range and a steeply dipping northern limb along NPDZ (Figure 2.5).

In its eastern part the strike abruptly changes to the northeast and the structures comprise tightly folded anticlines and broad synclines (fold wave length 10 – 12 km). Axial zones of most anticlines dip steeply or are overturned. Faulting of the anticlines is rare (Pennock et al. 1989). This east to west difference in the structural style has been attributed to the reduced thickness of Evaporites and lesser basement slope in the eastern part of the Potwar and Salt Range (Figure2.4). Increased drag at the base of the section has formed relatively complicated structures due to greater internal deformation (Lillie et al. 1987).

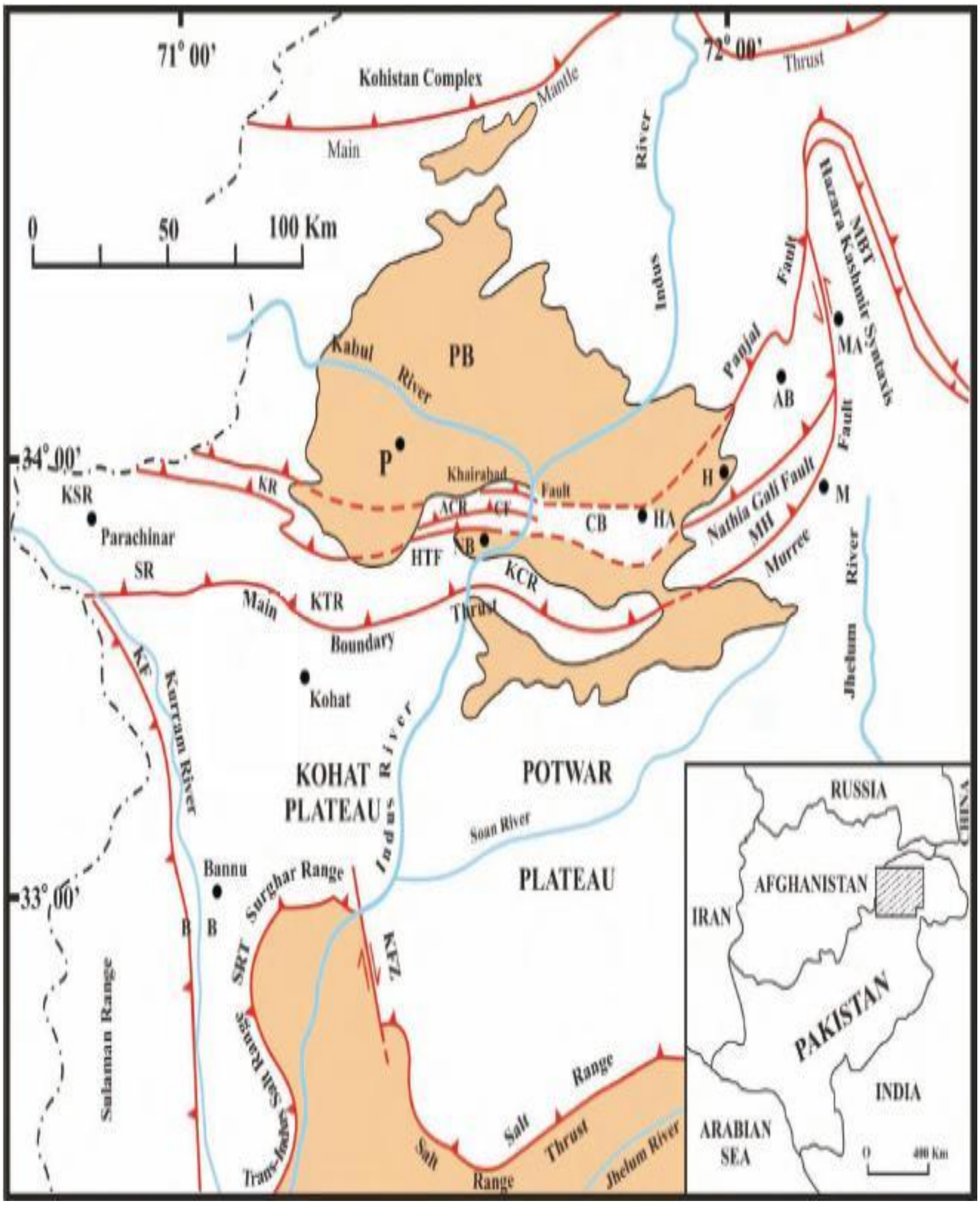

Figure2.4: Tectonic map of Pakistan, showing major structural boundaries. Abbreviations: ACR Attock-Cherat Range, BB Bannu Basin, CF Cherat Fault, HTF Hisartang Fault, KCR Kalachitta Range, KF Kurram Fault, KFZ Kalabagh Fault Zone, MBT Main Boundary Thrust, MH Margalla Hill ,NB Nizampur Basin , SRT Surghar Range Thrust.(Modified after Hylland et al.1998). The shaded area of the map shows recent sediments of Rawalpindi Group

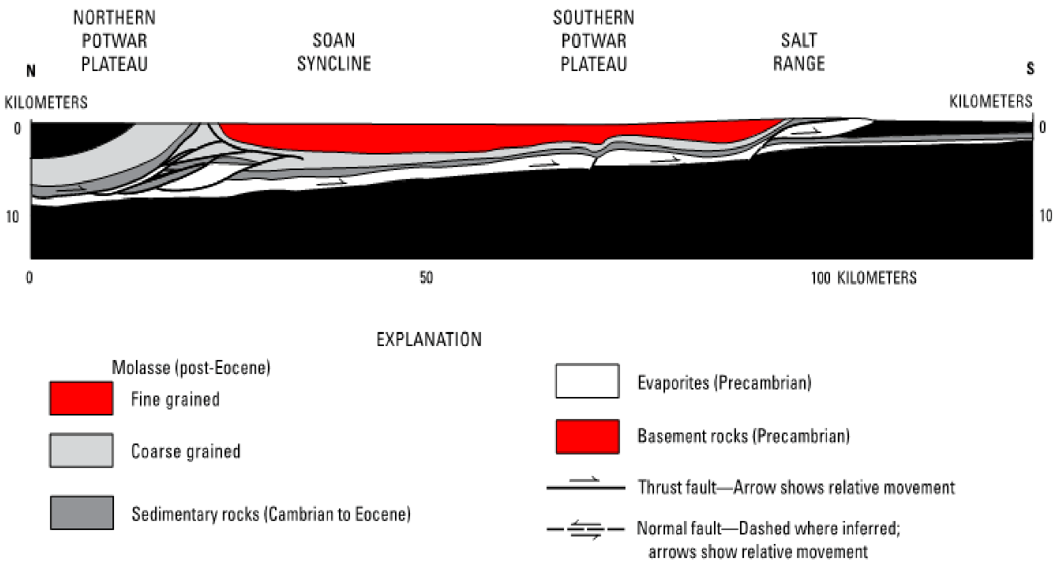

Figure 2.5: Generalised cross-section across western Potwar Plateau and west-central Salt Range (after Jaume and Lillie, 1988; Gee, 1989)

2.6 Local Geology of Rawalpindi area

As Rawalpindi is in the northern half, therefore major controlling factor of the geology and tectonics is the convergence of the Pakistan-India and Eurasian tectonic plates and their collision about 20 Ma ago. This event produced complex structures and stratigraphy in the Rawalpindi area. Many geologic units of various ages have been grouped together on the basis of their physical properties, and much of the structural detail has been omitted due to structural complexities

2.7 Stratigraphy

The sedimentary rocks of the Islamabad area record a long period of gentle geologic fluctuations and slow deposition while the Pakistan-India tectonic plate drifted northward across the Indian Ocean, followed by much more vigorous tectonic processes and rapid deposition in the shorter period since the Pakistan-India and Eurasian plates converged. Consequently, the 150-million-year (m.y.) period from deposition of the Samana Suk Formation (Middle Jurassic) to the beginning of deposition of the Muree Formation (lower Miocene) is represented by only about 675 m of primarily marine sedimentary rocks, whereas the last 20 m.y. are represented by more than 7,572 m of continental sedimentary rock (Table 2-1, Figure 2.6). During the uplift and structural deformation of the last 1.5 m.y., erosion has dominated over deposition, so that the only sediments preserved are thin, discontinuous bodies of alluvium and eolian silt.

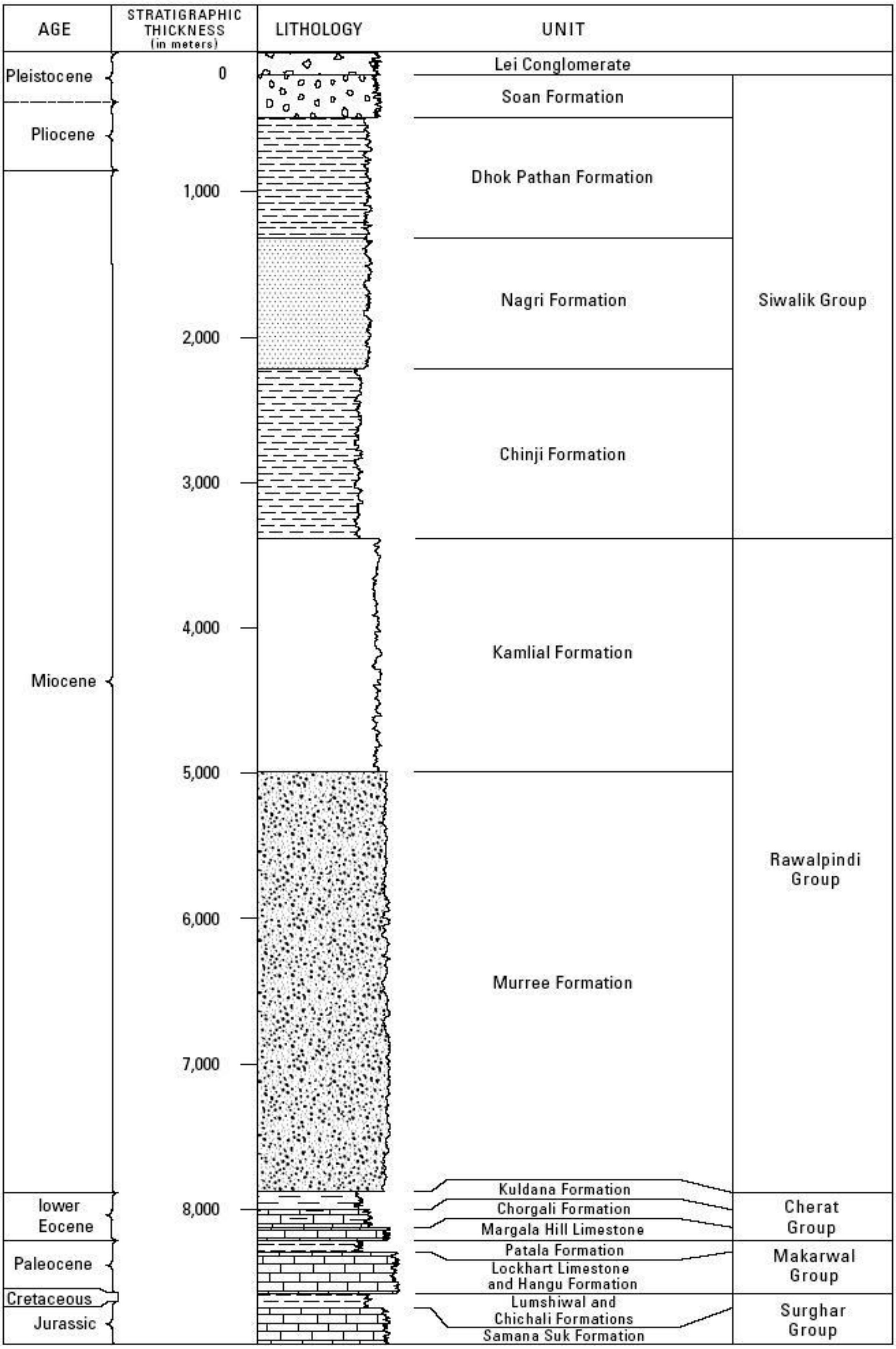

Table 2.1: Stratigraphic section for Islamabad - Rawalpindi area.

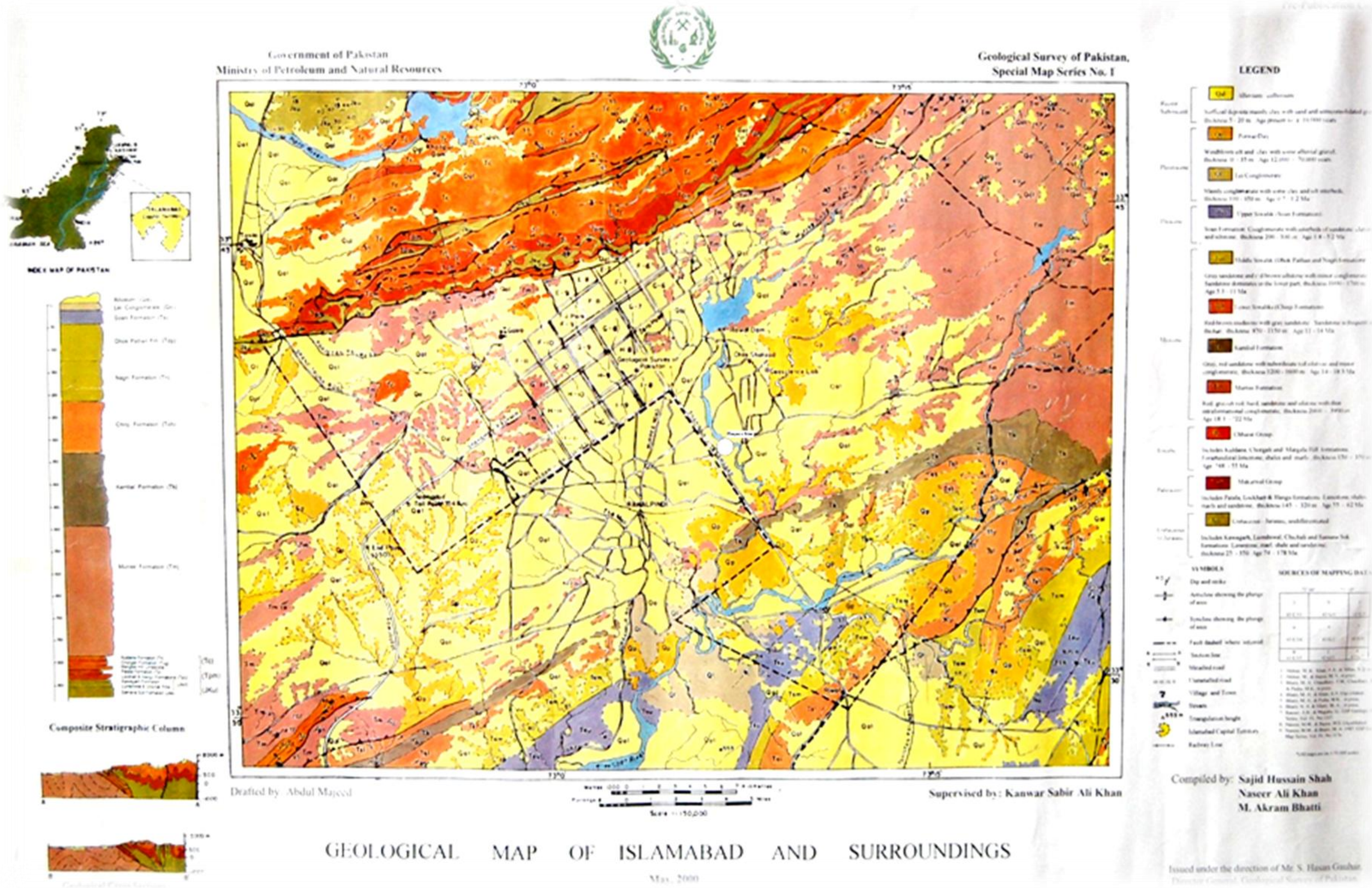

Figure 2.6: Geological map of Islamabad and Rawalpindi area *(GSP, May 2000*

2.7.1 SURGHAR GROUP:-

The Surghar group consists of three formations that are Samana Suk, Chichali and Lumshiwal formation. The age of these formations are Jurassic to Cretaceous.

2.7.1.1 Samana Suk Formation: The name Samana Suk is derived from Samana Suk peak in the Samana Range. The formation is exposed in Tran-Indus Ranges, Kalachitta and Hazara. The formation is largely composed of medium to thick-bedded, grey, oolitic and at places shally and dolomitic limestone with interbedded marl and calcareous shale. Its thickness varies from 190 to 366 m. The formation contains *bivalves, gastropods, crinoids, brachiopods and ammonites*. The fauna indicates a Middle Jurassic age.

2.7.1.2 Chichali Formation: The Chichali Pass in Surghar Range is the type locality. The formation is exposure Trans-Indus, Kalachitta, Salt Range, Potwar and Hazara. The formation consists of mostly dark green glauconitic sandstone with grey silty glauconitic Shale in lower part. In western Salt Range- Kohat area it is composed of a lower sandy glauconitic, phosphatic shale member, middle sandstone member and upper glauconitic sandstone member. The thickness of formation varies from 12 m to 17 m. The fossil in the formation are *cephalopods and Belemnopsis*. The age is late Jurassic.

2.7.1.3Lumshiwal Formation: The formation named after the Lumshiwal Nala in Surghar Range. The formation consist of grey, thick bedded to massive, current-bedded, feldspathic and ferruginous sandstone but contain silty, sandy glauconitic shale at the base. The formation grades into a mostly marine sequence of sandstone, siltstone and Shelly limestone. The thickness of the formation varies from 38 m to 194 m. The fossil in the formation are *brachiopods, bivalves, gastropods, ammomoids, belemnites and echinoids.* The age of the formation is cretaceous.

2.7.2 Makarwal Group:-

The Paleocene in the Kohat-Potwar area is termed as Makarwal Group by Gee (1989). The Makarwal Group has been deposited over the eroded surface of the rock of cretaceous to Cambrian. The Group consists of the three formations that are Hangu Formation, Lockhart Limestone and Patala Formation.

2.7.2.1 Hangu Formation: The formation is mainly consist of the quartzitic sandstone and shale often claystone, lateritic clays and bauxite. The formation is dominantly comprised of dark brown to reddish brown, medium to thick bedded quartose sandstone and few meters thick shale interbedded with lenticular coal seam. The formation is rich with the fossil such as *Foraminifers, corals, gastropods and bivalves.* The thickness of the formation varies from 8m to 95m.

2.7.2.2 Lockhart Limestone: The formation consist of cliff forming, grey to dark grey, crystalline, thick bedded to massive, nodular and rubbly Limestone with the subordinate marl and Shale. The marl is grayish black and fossiliferous. The shale is olive gray to greenish gray and has weakly developed cleavage. The formation thickness ranges from 70 to 280 m. *foraminifera, corals, mollusks, echinoids and algae.* The fauna indicates upper Paleocene age.

2.7.2.3 Patala Formation: The formation is comprised of shale and marl with subordinate limestone and sandstone interbeds. The shale is dark greenish grey, carbonaceous as well as calcerous and friable with selenite crystals. The limestone is light grey in color, medium bedded and nodular and sandstone is yellowish brown. The marl is dark gray and fossiliferous. The Patala Formation represents primarily marine deposition. The formation is abundantly fossilferous and contains *Actinozoa, Foraminifera, Alcyonaria and Ostracoda.* The thickness ranges varies from 27m to 300m.

2.7.3 CHERAT GROUP:-

The Cherat Group is of lower Eocene and consists of three formations. The formations are Margalla Hill Limestone, Chorgali Formation and Kuldana Formation.

2.7.3.1 Margalla Hill Limestone: The Margalla Limestone is comprised of Limestone with subordinate marl and shale. The limestone is grey, weathering pale grey, fine to medium grained, nodular, medium to thick bedded and rarely massive. The marl is grey to brownish grey while shale is greenish brown to brown in color. The formation contains larger benthonic foraminifers and thickness varies from 60m to 90m.

2.7.3.2 Chorgali Formation: The formation comprised of shale and limestone and is divisible into 2 distinct units. The lower unit composed of white to light grey, thin to medium bedded, finely to very finely crystalline dolomite with interbeds of grey to greenish grey, calcareous shale. The upper part consists of shale with one thick bed of dark grey and argillaceous. The shale is greenish grey, red occasionally variegated and calcareous. The formation varies 30m to 150m in thickness at different area. Formation rich in *foraminifera, molluscs and ostracodes.*

2.7.3.3 Kuldana Formation:- The formation dominantly consists of red and green shale and marls with a few thin, grey limestone and red, fine-grained sandstone beds. The claystone is variegated in color and has gypsum intercalations. The claystone is of shelf marine origin. The thickness ranges from 60m to 600m. The formation is best known for its fossil mammals, including primitive cetaceans *Pakicetus, Gandakasia and Lchthyolestes.*

2.7.4 Rawalpindi Group:-_ In the Himalayan fold belt, the lower part of molasse sequence is referred to as the Rawalpindi Group. It comprises Muree Formation at the base and Kamlial Formation at the top. The age of this Group is Miocene.

2.7.4.1 Muree Formation:- The Muree Formation is comprised of a dark red to maroon color siltstone and clay interbedded with red, brown and grey color sandstone. The claystone is purple to dark red and contains lenses of pseudo-conglomerate. The sandstone and claystone is of continental origin. The measured thickness ranges from 2,000 to 2,895 m in the area. The age of this formation is Lower Miocene.

2.7.4.2 Kamlial Formation:- The formation composed of dark grey to greenish grey sandstone about 75%, interbedded with dark red to maroon color siltstone about 20% and subordinate intraformational conglomerates. The sandstone exhibits spheroidal weathering that gives rubbly appearance. The sandstone is fine to medium grained, multistoried, cross-bedded, channelized and intercalated with lenses of intraformational conglomerate or with thin layers of clay. The formation thickness varies from 50 to 650m. Age of this formation is Lower to Middle Miocene.

2.7.5 SIWALIK GROUP: - Siwalik Group consists of Chinji Formation, Nagri Formation, Dhok Pathan Formation and Soan Formation. The age of the Siwalik Group is late Miocene to Pliocene.

2.7.5.1 Chinji Formation:- The Chinji Formation is consist dominantly of bright red and brown orange color siltstone interbedded with ash-grey sandstone. The siltstone-sandstone ratio averages 4:1 near the type section. The formation also contains claystone and it brick red, friable and hard. Thickness of formation is 400m to 1200m. The age assigned to this formation is middle to upper Miocene.

2.7.5.2 Nagri Formation:- It is composed of multistoried, green-grey, medium to fine grained sandstone interbedded with brown and reddish brown siltstone and claystone. The claystone is brown, reddish grey, and orange and is sandy or silty. The formational contain occasional pebble layer and conglomerate beds. The age is upper Miocene. Thickness measured of the formation is 500m to 3800m.

2.7.5.3 Dhok Pathan Formation:- The formation is comprised of deep orange to red color siltstone and grey sandstone, claystone and the occasional beds of conglomerate. The claystone is orange red and chocolate brown, hard, and compact. The sandstone fine to medium grained, medium bedded and cross-bedded. The measured thickness is varies from 700m to 1820m. The age of this formation is upper Miocene to Pliocene.

2.7.5.4 Soan Formation:- Sandstone, siltstone, subordinate interbeds of claystone and conglomerate make this formation. The conglomerate clast range from pebbles to boulders and around 80% quartzite, 10% volcanic trap rock and 10% sedimentary and metamorphic rock of Siwalik Group embedded in calcareous sandy matrix. The sandstone is greenish grey, coarse grained and soft. The claystone is orange, brown, pale pink and soft. The fossil represent the age of this formation is late Pliocene to Pleistocene.

2.7.6 Surficial Deposits:- With the uplifting of Margalla hills the lie conglomerates is interpreted as an alluvial basin-fill sequence of coarse, angular gravel (figure 2.7). This finer sediment was derived from sandstone and shale of the Rawalpindi group along the axis of the subsiding Soan syncline the above unit is deposited. At the some places the conglomerates are well cemented and are resistant to erosion and form ledges and hills. The uncemented conglomerates beds are source for groundwater aquifer in the area. The thicknesses of the surficial deposits are up to 106m.

2.7.6.1 Lei Conglomerates:- The formation is composed of coarse boulder and pebble conglomerates, with minor coarse and cross-bedded sandstone. The Lei conglomerate is essentially regarded as a valley fill, lid down as fluvitile, lacustrine

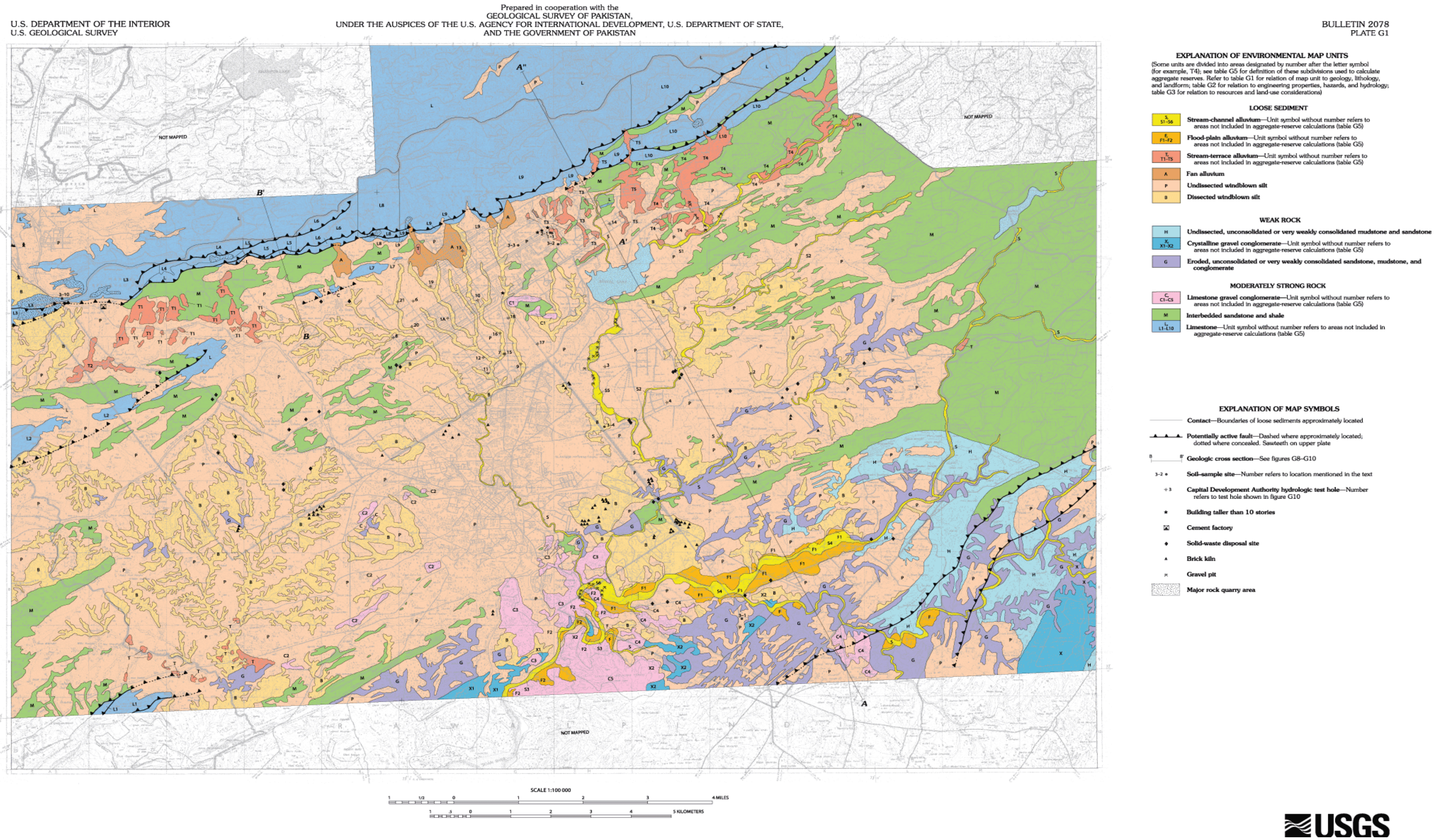

Figure 2.7: Recent to sub-recent surfical deposits in the Islamabad-Rawalpindi Area

and piedmont outwash deposits in the lower parts of the structural depressions. The Lei Conglomerate is generally flat lying, but locally it is folded and faulted.

The Lei Conglomerate is interpreted as an alluvial basin-fill sequence of coarse, angular gravel derived from the uplifting Margalla Hills to the north interbedded with finer sediment derived from sandstone and shale of the Rawalpindi Group and windblown silt. The unit was deposited along the axis of the subsiding Soan syncline. Cemented conglomerate beds are resistant to erosion and form ledges and hills. Uncemented conglomerate beds are the most important ground-water aquifer in the area. The exposed thickness is 106 m, (Ashraf & Hanif, 1980).

2.7.6.2 Potwar Clay (Pleistocene and Holocene): It is mainly windblown silt and clay and subordinate amounts of alluvial gravel (figure 2-8). Sediment is light brown to gray, very fine grained, hard, compact, and calcareous. The windblown sediment averages 71–74 percent silt-size and 15–16 percent clay-size material. The unit is 14–18 percent calcium carbonate. The mineral composition is predominantly quartz, but subordinate amounts of feldspar and clay minerals are present, such as kaolinite and illite (Rendell, 1988, p. 392). The well-developed vertical partings and lack of bedding suggest that much of the sediment is atmospheric dust, but stratification of

Figure 2.8: Cultivation field on Potwar Clay in the area

some of the sediment indicates partial reworking by surface wash and streams. Locally, the silt is intercalated with cross-bedded lenses of sand and gravel and with the Lei Conglomerate. The silt and clay beds are very erodible; hence, deep, steep-sided gullies and badlands are extensive. The Potwar Clay is subject to loss of bearing strength when wet. Its thickness is highly varied, depending on the relief of the underlying unconformity. The exposed thickness is 1–35 m. similar deposits intercalated with the Lei Conglomerate extend to a depth of 152 m (Ashraf & Hanif, 1980).

2.7.6.3 Terrace alluvium (Pleistocene and Holocene): This formation is mainly gravel, clay, and silt locally cemented by calcium carbonate. Clast-supported boulders, cobbles, and pebbles of sedimentary rocks enclose a sandy and clayey matrix. These former stream-channel and flood-plain deposits no longer receive sediment because subsequent downcutting by streams has left them high above flood level. Repeated episodes of uplift or climate change and erosion have left terrace deposits at several levels. The terrace-alluvium unit resembles the Lei Conglomerate but is younger and retains its depositional form. The unit is divided into older and younger subunits.

- **Older terrace alluvium (Pleistocene):** is terrace alluvium whose depositional surface is more than 5 m above modern flood level. The older terrace-alluvium unit is generally preserved as discontinuous remnants of gravel capping ridges and flat-topped hills. The maximum thickness is about 3 m.

- **Younger terrace alluvium (upper Pleistocene and Holocene):** is also terrace alluvium whose depositional surface is less than 5 m above modern flood level. The younger terrace alluvium generally forms benches along the sides of modern stream valleys. The thickness is about 3 m.

2.7.6.4 Alluvium and windblown silt (upper Pleistocene and Holocene): Eolian silt and stream-channel, flood-plain, terrace, and slope-wash alluvium intermixed in small areas are present in this unit. Such deposits typically occupy small depressions in the Margala Hills and are less than 10 m thick.

2.7.6.5 Flood-plain and fan alluvium (Holocene): It is moderately bedded and sorted sand and gravel channel and debris-flow deposits overlain by a thin veneer of sandy silt and clay from overbank flooding and slope-wash deposition. The flood-plain and fan alluvium was typically deposited adjacent to streams or in fan-shaped bodies at the mouth of canyons or gullies. The maximum thickness beneath flood plains is about 6 m, and that beneath fans is about 20 m.

2.7.6.6 Streamchannel alluvium (Holocene):-Unconsolidated gravel, sand, and silt that are subject to stream transport each year comprise the unit. The stream-channel alluvium is poorly to moderately sorted and contains low-angle cross bedding. The alluvium is generally without soil or vegetation. It forms low islands and bars within braided and meandering stream channels. The maximum thickness is about 3 m.

Chapter No.03

ENGINEERING GEOLOGY

3.1 Introduction:-

Engineering geology is the application of the geologic sciences to engineering practice for the purpose of assuring that the geologic factors affecting the location, design, construction and maintenance of engineering works. Engineering geologists investigate and provide geotechnical recommendations, analysis and design. This of type studies can be utilized during the planning, civil engineering design, and environmental impact analysis. Works completed by the engineering geologist include geologic hazards, geotechnical, and materials properties land slide and slope stability.

Engineering geologic studies may be performed:

For residential, commercial and industrial developments;

For government and military installation;

For public works such as roads, airports runway, bridge, building, dam etc

3.2 History:-

Engineering geology grew as a separately identifiable subject, starting in the late eighteenth century and being derived from the practical contribution made by geologists and civil engineers to construction projects, and to the study of geological hazards.

By the start of the twentieth century there was abundant documentary evidence that a prior understanding of geology should be an essential component of any major construction project. It was, however, to be some decades before this came to be universally recognized, and still longer for the consequences to begin to be implemented. Civil engineers, for some time to come, either ignored geology or sought out geological knowledge for themselves.

Although the growth of engineering geology in the first four decades of the twentieth century can be best illustrated from the United States, there were significant developments elsewhere. The occurrence of major landslides in quick clays on the railway system in Sweden resulted in the establishment of, first, a research institute and then a geotechnical commission in 1914. Maurice Lugeon, in France, became closely associated with the geological aspects of the sitting, investigation and construction of dams. His contribution is still preserved as the name of the unit applied to the results of in situ permeability tests in boreholes in rock which he devised (Lugeon, 1933). The status which engineering geology had achieved by the late 1930's is effectively illustrated by Robert Legget's book (1939, 1962), which was derived from a comprehensive study of case history experience. Legget recognized that his approach was descriptive; containing neither mathematics nor formulae, cogently arguing that there was no substitute for sound observation and good judgment. By this time, therefore, there was increasing acceptance, and application, of the role of geology in the civil engineering of many countries. Engineering students were being taught some geology and engineering geology on a systematic basis, but training of geologists in engineering geology was effectively non-existent. The consequence was that geological advice on engineering projects was still normally provided by geological consultants who were commonly based in universities. The larger scale deployment of geologists on engineering projects, as in the United States, was exceptional.

During the opening decades of the twentieth century Terzaghi recognized that close links existed between geology and the engineering behavior of soils and rocks and, throughout his life and writings, there was a continual search to understand, through engineering geology, the geological influence on engineering projects.

The growth in construction from the 1940's onwards resulted in both larger and more sophisticated structures being built as well as the need to develop sites which were less favorable geologically. The consequence was the recognition that some aspects of geological uncertainty could be answered by the application of fast, sophisticated computational methods in rock mechanics associated, for example, with concrete dam foundations, large underground structures, tunnel support, and rock slope design which were capable of handling large amounts of data. The construction industry is responsible for the building of visible structures that can directly influence and contribute to day-to-day life, the role of engineering geologists has progressively widened into the environmental impact of surface development and mineral extraction, the remediation of Brownfield sites, waste disposal, and geological conservation. In addition, engineering geologists have the appropriate skills and awareness needed for the identification of risks, and the consequences of geological hazards and processes. This aspect of engineering geology, which self-evidently embraces social issues, is generally termed environmental geology (Knill, 1970).

By the close of the twentieth century, therefore, engineering geology had established itself, with soil mechanics and rock mechanics, as one of the component members of the field of geotechnical engineering. The strength of the subject undoubtedly lies within the practical application of the subject which has, almost universally, been highly successful. However, unlike soil and rock mechanics, the practical application of the subject has not been matched by the development of a scientific rationale for the subject which provides the foundation for a scientific rationale for engineering geology as a subject. It could be that the parts of the jigsaw exist but they have never been brought together to create a logical whole, but it may be that those parts of the jigsaw which appear to exist could never be fitted together.

3.3 Background of Rawalpindi Ring Road:-

Rawalpindi is the fourth largest city of Pakistan inhibiting 2 million people. Growth in its traffic has acquired an alarming situation and put tremendous pressure on infrastructure of the city. Rawalpindi Development Authority conducted the series of traffic surveys during pervious decade. A guided development plan was formulated to develop proper road infrastructure, a series of main & sub-main traffic corridors. The plan is supposed to be implemented soon. With the passage of time, road alignment plans are required to be updated with respect to the ongoing development activity in the area.

3.4 Engineering aspect of Potwar clays:-

The Potwar Clay consists of thick wind-deposited dust that has been accumulated during Quaternary period and covers present days gently slopes of the Potwar Plateau. Brick kilns are widely spread across the Islamabad-Rawalpindi area where the clay content of the Potwar Clay (loessic silt and clay) is sufficient for making bricks. Potwar Clay consists predominantly of clay with minor silt, and sand. Kaolinite and illite are the most common clay minerals in it but most of the fine particles are quartz.

Study on Potwar Clay used as brick clay reveals that it contain 0.2% organic material, 0.64% total dissolved solids and 0.11% sulfur dioxide content. It exhibit moderate bearing capacity when dry but may lose strength in shallow water table thus marking erodible slopes. Other average physical characteristics are water content 15.19%, bulk dry density 1.62 g/cm^3, specific gravity 2.64, friction less than 75μm is 80.50 %, liquid limit 33%, plastic limit 21% and plasticity index is 12.70 %. Modified compaction test reveals that Potwar Clay have maximum dry density as 1.82 g /cm^3 with optimum moisture content 15.87 %. Potwar Clay can easily excavate.

Chapter No 04

METHODOLOGY

4.1 Sieve Analysis (ASTM C 136 – 05 / AASHTO T 27-91)

The sieve analysis is globally used for soil classification. It determines distribution of different soil particle size by mechanical sieving. Soil sample of the known of dry aggregate mass is passing through series of square sieves (Figure 4.1) which is ignited by mechanical sieve shaker, for the determination particles larger than 75 µm. For soil particles finer than 75µm, sedimentation test based upon Stoke's law is used to determine silt – clay fraction.

Soil sample is homogeneous mixed and is reduced to test fraction by either quartering or split-box technique. The test sample is than oven-dried dried to constant mass at 110˚C ±5. The test specimen of known mass is than put into series of square sieves with progressively smaller openings at bottom. These sieve set are vibrated by mechanical sieve shaker for 10 – 15 minutes. The percentage retained of individual soil fraction to total test mass is calculated.

Figure 4.1: ASTM square test sieves

In order to prevent any error in mass calculation, each test sieves should periodically be cleaned. For massive test sample, distribute test specimens in part, for analyzing.

4.2 Sieve analysis of the finer materials than 75 µm (sieve no.200) by washing (ASTM C 117 – 04 / AASHTO T 11-91)

This method is applicable for soil specimen containing material finer than 75µm. Due to electromagnetic forces between soil grains, finer particles (< 75 µm) coincide themselves with coarser particles, resulting abnormal increase in their dimension. To overcome this abnormal behavior of soil particles, soil specimen is wet washed in order to determine the amount of finer materials than 75 µm (silt – clay content).

The test is performed by using either clean water or water-soluble wetting agent. But the most common in practice method is using clean water washing. A test specimen dried to a constant temperature of 110 ± 5 ˚C, is weighted. Pour the test specimen in wet wash sieve with mesh opening of No. 200 (figure 4.2) and squirt with water. This

Figure 4.2: Wet wash sieve with mesh opening No. 200

results, material finer than 75 µm to drain out leaving behind material coarser than 75 µm on wash sieve mesh. The left-over material is carefully collected and is oven-dried to a constant temperature of 110 ± 5 ˚C. The oven-dried sample is weighted and calculates its amount of material passing a 75-µm (No. 200) sieve following formula;

$$A = [(B - C)/B] * 100$$

Where;

A = percentage of material finer than a 75-µm (No. 200) sieve,
B = Mass of oven-dried soil specimen before washing &

C = Mass of oven-dried soil specimen after washing.

In order to obtain better result;

- Soil sample should properly dried,
- Rinse soil sample in water till clean water is obtained which indicates that is all fine materials have been removed.

4.3 Atterberg Limits (ASTM D 4318 – 00/ AASHTO T 89-93 & T 90-92)

During late nineteen century, Albert Atterberg purposed relationship between degrees of saturation to soil volume change in order to determine consistency of fine grained soil (figure 4.3). The minimum water content when soil begin to flows under imposed

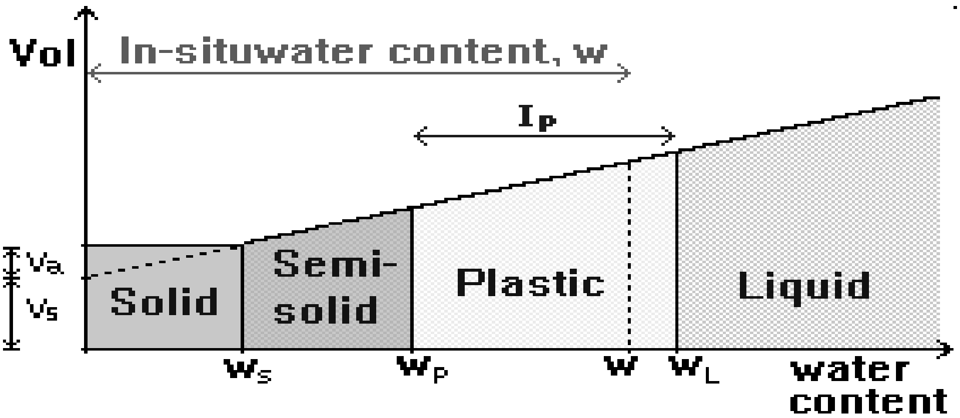

Figure 4.3: Relationship between degree of saturation to change in soil volume

pressure is known as liquid limit whereas, plastic limit is minimum water content when it passes from plastic phase to semi-solid phase. For soil classification usage, Atterberg limits (liquid & plastic limits) are determined as follows;

For soil liquid limit determination, soil specimen passing sieve No.40 (425 µm) (normally material finer than fine sand) is used. The most common method for determining the liquid limits is multi point method developed by Casagrande. Test specimen is mixed with different degree of moisture content and the soil pat is placed in Casagrande apparatus (figure 4.4). The pat is leveled with specula and grove (approximately 12.7mm apart) with grooving tool (figure 4.5). The Casagrande apparatus is ignited till grove is closed by 12.7mm (figure 4.5). A soil sample slice is collected where grove is closed for moisture content determination. A graphical presentation is made between moisture content against corresponding number of blows. Moisture content against twenty-five (25) number of blows with marks liquid limit for test specimen.

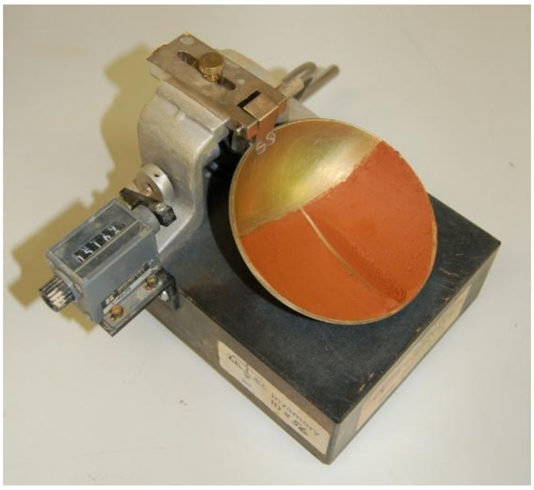

Figure 4.4: Casagrande liquid limit test apparatus

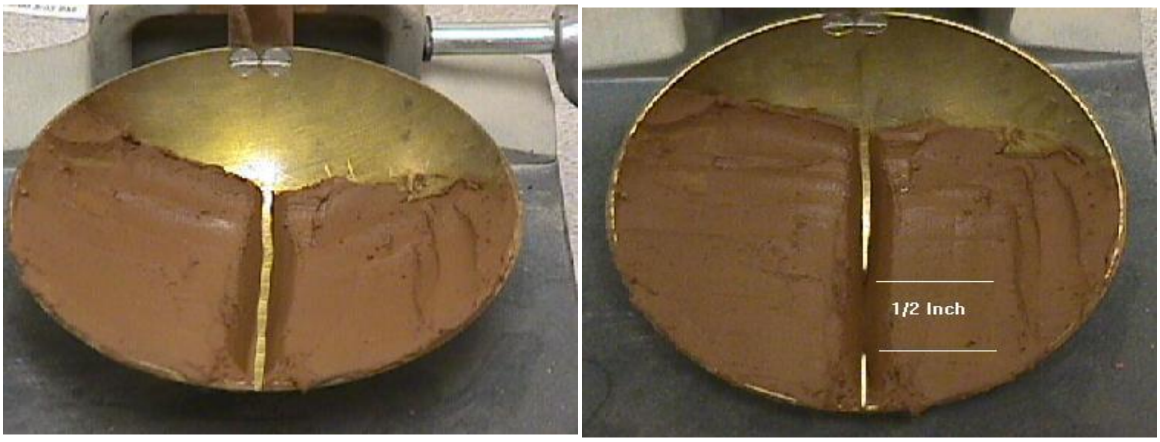

Figure 4.5: Soil specimen in Casagrande apparatus

For numerical accuracy, the test procedure should be repeated thrice with different water content. The soil sample should thoroughly mix with water and no air voids be present in soil pat.

For plastic limit determination, soil threads are made using passing #40 sample. Soil specimen is uniformly mixed with water and begin to roll (figure 4.6) until thread of 3.2mm (⅛") is achieved. The moisture content for this thread will give us plastic limit

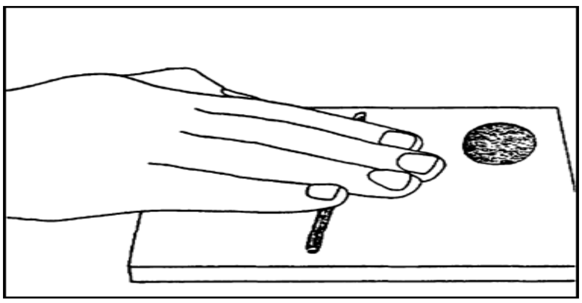

Figure 4.6: Soil thread rolling for plastic limit determination

value. For better results, soil thread should periodically be checked during test and if thread can't be achieved abandon the test procedure and report soil as non-plastic.

The numerical difference between the liquid limit and the plastic limit is known as soil's plasticity index. Soil classification can further be modified with the introduction of group index as follows;

Group index (G.I.) = {(F-35) [0.2+0.005(LL-40)]} + [0.01(F-15) (PI-10)]

Where;

F= Percentage of the materials passing from the sieve no# 200,

LL= Liquid Limit,

PI= Plasticity Index

Soils with lower group index values are consider best for subgrade embankment.

4.4 Moisture density relation of soil using modified effect (ASTM D 1557 – 02 C/ AASHTO T 180-93 D)

This test determined the relation between the soil's water content and dry unit weight. For A-4 soils method C is adopted, when soil is compacted in a standard 152.4 mm diameter mold having five layers, each layer rammed by rammer (weighting 44.5N & dropping from 457mm height) 56 times producing a compactive effort 2,700 KN-m/m^3.

Soil thoroughly is mixed with water in steel tray and approximately 30 – 40 mm layer is placed in the proctor mold. Each layer is rammer by 56 blows of modified rammer and procedure is repeated till fifth layer is compacted (figure 4.7). Weight the soil in the mold and determine its dry density and moisture content.

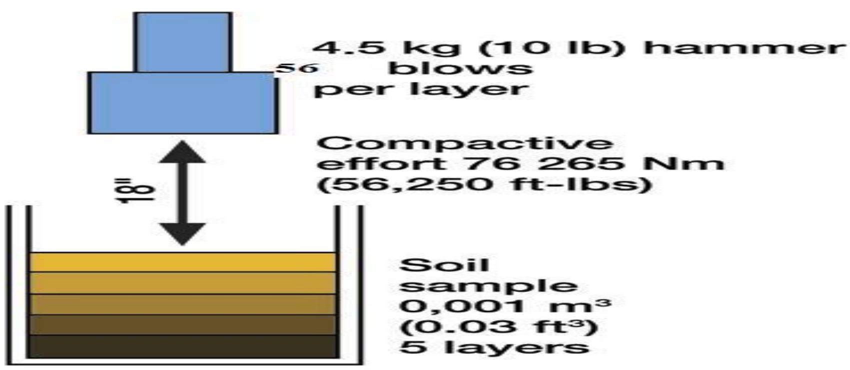

Figure 4.7: Illustration showing Modified Proctor test assembly

This procedure will be repeated till drop in moist soil weight is observed. The maximum dry density against optimum moisture content can be determined from the graphical representation between soil dry density and percentage of moisture content. For each dry density determine never reuse soil that has been previously compacted in the laboratory. For plastic soils, sample should be soaked for 1 – 2 hours, prior to the test. The proctor mold should be placed on rigid and hard surface.

4.5 California Bearing Ratio (ASTM D 1883 – 99/ AASHTO T 193-92)

The California Bearing Ratio (CBR) is an empirical test for evaluating strength of cohesive soils as road embankment. The test is primarily intended to determine ratio of the force required to penetrate a circular piston into soil compacted in a special container at a rate of 1.27 mm/min, to that required for similar penetration into a standard sample of compacted crushed rock. This ratio is determined at penetrations of 2.54 & 5.08 mm and the higher value is used for embankment designing.

CBR= Measured force / Standard force %

Test specimen is split into three equal parts which are subjected to three different degree of compaction in standard molds (normally 10, 30 & 65 blows / layer) in order to determine their dry unit weight at optimum moisture content. Later each sample is soaked in water for maximum 96-hours in order to determine its swell potential. Afterward, each specimen is placed in CBR machine and is penetrated by cylindrical piston of 1935 mm^2 (figure 4.8). The percentage penetration force at 2.54 & 5.08 mm penetration is measured against standard force as CBR value. A graphical presentation between CBR value and dry unit weight can determine CBR (%) at desire compaction.

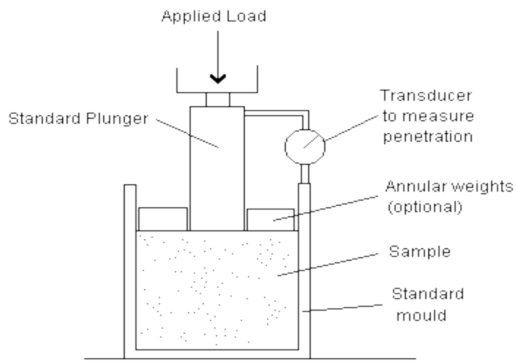

Figure 4.8: Californian Bearing Ratio instrument

4.6 In-situ compaction by the Sand-Cone Method(ASTM D 1556 – 00/ AASHTO T 191–93)

This test procedure is applicable for soil consisting maximum particle size finer than 38 mm. In place density and unit weight of soil is determinate using sand cone apparatus.

Select the area / location and level it with base-plate. Nail base-plate on level surface and dig the hole through the center of the base-plate. Carefully collect all excavate soil into sample bag by cleaning the flange of the baseplate hole and record its weight. Mix the all materials and determine the water content. Invert the cone and seat the funnel into the flanged hole at the same position and marked calibration. Open the valve and allow the sand to fill the hole and when sand stops from flowing then close the valve (figure 4.9). Determine the mass of the sand that remains with the apparatus and calculate the mass of sand that are use.

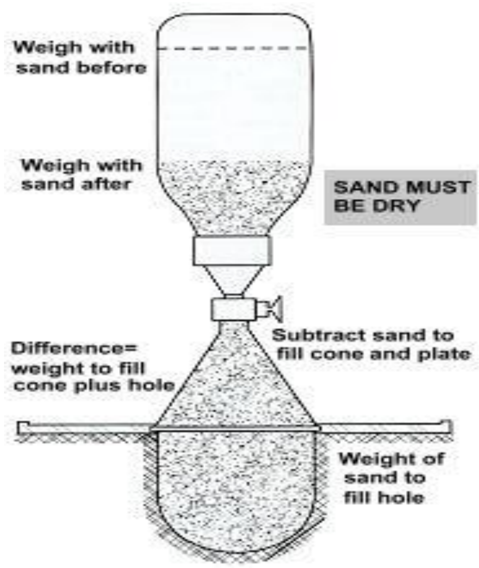

Figure 4.9: Sand-cone apparatus

Determine volume of hole from ratio between sand dry unit weight and mass of sand in hole. Calculate wet density of soil as ratio between mass of soil excavated from hole to hole's volume. Determine in-situ soil dry density as following;

Dry density (DD) = (100 * Wet density) (%-age Moisture content + 100)$^{-1}$

In-situ compaction can be determined as following;

Compaction (%) = In-situ dry density / Laboratory dry density (modified proctor) %

This test procedure is not applicable for the saturated, highly plastic soils and organic soil because they deform and compress during the excavation of the test hole.

Chapter No. 05

FIELD STUDIES

The present study focused on the subgrade material quality evaluation, for section II (Jawa to Morgah city) of purposed new alignment of Rawalpindi Ring Road, district Rawalpindi. As per NHA guidelines for formation of embankment (Item 108: General Specifications) and adopted by project's design consultants, a test pit (one cubic meter) was excavated at every kilometer of purposed alignment or any change in surface lithology if observed (figure 5.1). An in-situ dry density was determined by sand-cone method (ASTM 1556-00 / AASHTO T 191 – 93). Beside, approximately 10kg soil sample was collected from each test pit for later its index and engineering properties. These soil properties includes, determination of grain size friction (ASTM C 136 – 04 & C 117 – 05 / AASHTO T 27 – 91 & T 11 – 91), Atterberg limits (ASTM D 4318 – 00 / AASHTO T 89 – 93 & T 90 – 92), moisture density relation of soil using modified effect (ASTM D 1557 – 02 C / AASHTO T 180 – 93 D) and Californian Bearing Ratio (ASTM D 1883 – 99 / AASHTO T 193 – 92). Based upon field observation and interpretation of laboratory test results, the engineering analysis was give for the purposed road embankment.

5.1 In-situ dry density (ASTM 1556-00 / AASHTO T 191–93):-

In-situ soil density was determined according to item 108 of NHA general specifications which states that the test should be conducted at every kilometer or change in the surface lithology, along purposed road alignment. After removing top organic layer of soil (O – Horizon) at purposed test location, in-situ dry density was determined by applying sand-cone method (ASTM 1556-00 / AASHTO T 191–93). The in-situ dry density along purpose road alignment of section II varies 1.631 – 1.705 gm /cm^3 (Table 5.1). Based upon in-situ dry density result, in-situ soil compaction was also calculated which varies from 81.0% to 85.6 %.

5.2 Index and Engineering Properties:-

A pit of one cubic meter was excavated at every purposed test location, in order to obtain representative soil sample for its index and engineering properties. A 10kgs

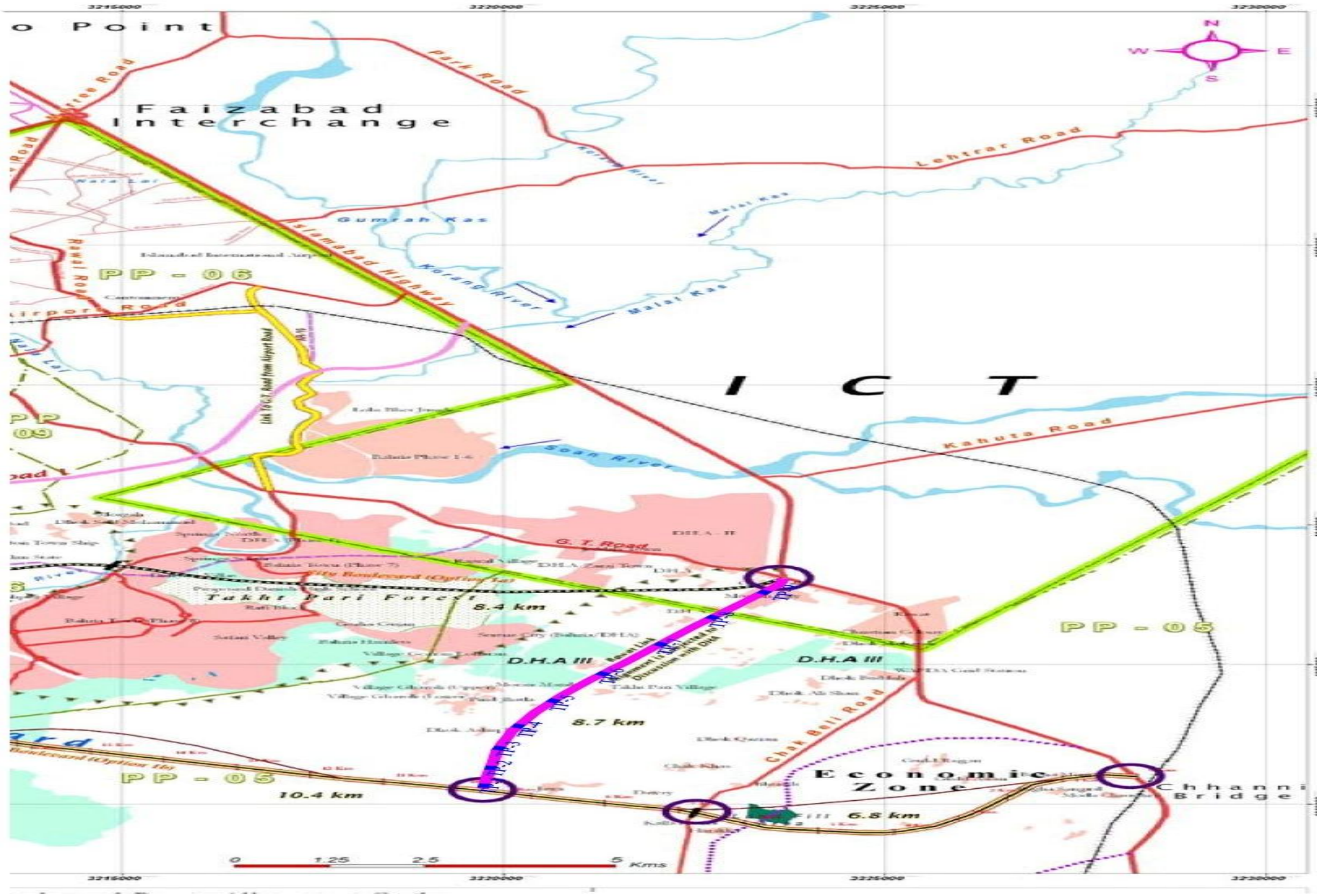

Figure 5.1: Test pit location plan for section II Rawalpindi Ring Road, District Rawalpindi

Table No. 5.1: Summery of field and laboratory tests along purposed alignment of section II of Rawalpindi Ring Road

PIT NO.	FIELD OBSERVATION		GRAIN SIZE ANALYSIS (%)			ATTERBERG LIMITS			CBR (%) AT PENETRATION		Subgrade soil classification (ASTM 3282 & AASHTO M-145)
	Dry Density g/cc	Compaction (%)	Gravel	Sand	Silt-clay	L. L (%)	P. L. (%)	P. I.	2.54 mm	5.08 mm	
1	1.668	85	2	6	92	27.4	18.20	9.2	4	5	A-4(7)
2	1.631	84	54	4	42	X	N.P	X	12	14	A-4(0)
3	1.635	83	1	19	80	28.6	22.1	6.5	6	7	A-4(4)
4	1.599	81	1	21	78	26.9	19.7	7.1	6	8	A-4(4)
5	1.644	83	2	24	74	25.0	18.76	6.2	5	7	A-4(3)
6	1.595	81	2	25	73	25.4	19.49	6.0	7	8	A-4(2)
7	1.669	83	1	29	70	23.1	17.3	5.8	6	7	A-4(2)
8	1.705	85	5	30	65	30.5	22.8	7.7	7	9	A-4(0)
9	1.633	86	10	57	33	X	N.P	X	14	16	A-4(0)

of excavated material was carefully collected in sampling bag with proper labeling. Following index and engineering properties of these samples were determined in the engineering laboratory;

5.2.1 Grain size analysis (ASTM C 136 – 04 & C 117 – 05 / AASHTO T 27 – 91 & T 11 – 91)

Soil samples were homogenously mixed, quartered and reduced to test friction in the engineering laboratory. The test sample was initially wet washed according to ASTM C 117 – 05 / AASHTO T 11 – 91 and was latterly, was sieved according to ASTM C 136 – 04 / AASHTO T 27 – 91. The test data reveals that soil is study area comprises gravel 1 – 54% (figure 5.2), sand 4 – 57% (figure 5.3)were as silt – clay friction are 33 – 92% (figure 5.4).

5.2.2 Atterberg limits (ASTM D 4318 – 00 / AASHTO T 89 – 93 & T 90 – 92)

Soil friction passing 425μm were selected for determination of Atterberg limits as per ASTM D 4318 – 00 / AASHTO T 89 – 93 & T 90 – 92. The test data reveals that liquid limit varies 23.1% to 30.5% and plastic limit to maximum 22.8% (Table 5.1). The plasticity index varies 5.8 to 9.2. Soil specimen consist of gravel concentration over 10% were found non-plastic.

Based upon grain size analysis and Atterberg limits data, the soil in study area were classified as A-4 (ASTM 3282 / AASHTO M 145) with its group index varies from 0 – 7.

5.2.3 California Bearing Ratio (ASTM D 1883 – 99 / AASHTO T 193 – 92)

The Californian Bearing Ratio for soil samples was determined using ASTM D 1883 – 99 / AASHTO T 193 – 92. For road embankment design purpose, CBR percentage at 2.54 mm is generally consider unless specified. According to NHA specification (item 108) CBR percentage at 2.54 mm should be not less than 5%. The test data reveal CBR percentage at 2.54 mm penetration varies from the 4 to 14 whereas, at 5.08 mm penetration from 5 to 16.

CBR test data at 2.54 mm penetration reveals that soil except from pit No. 1 generally meet NHA specification for road embankment.

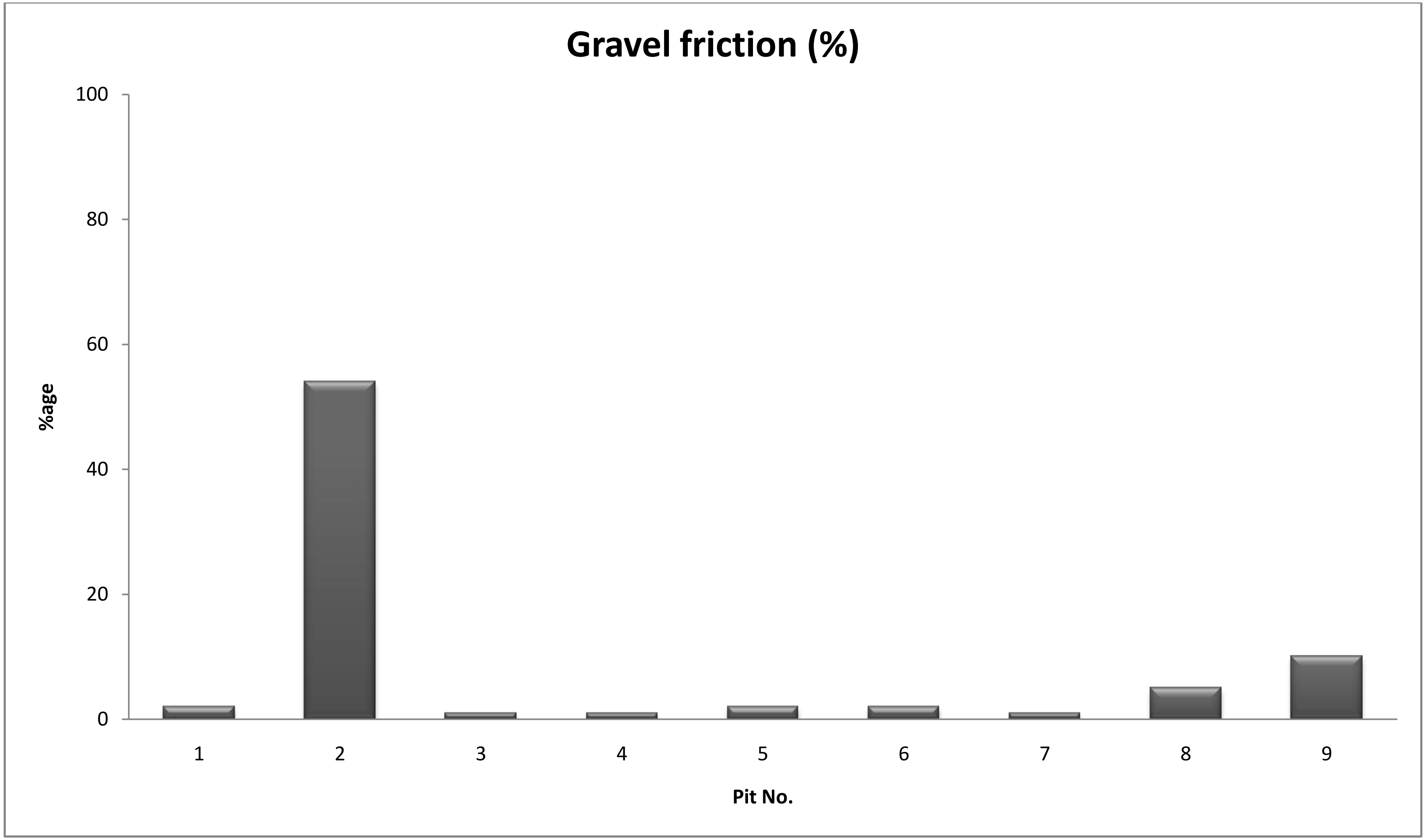

Figure 5.2: Gravel friction in different test pits

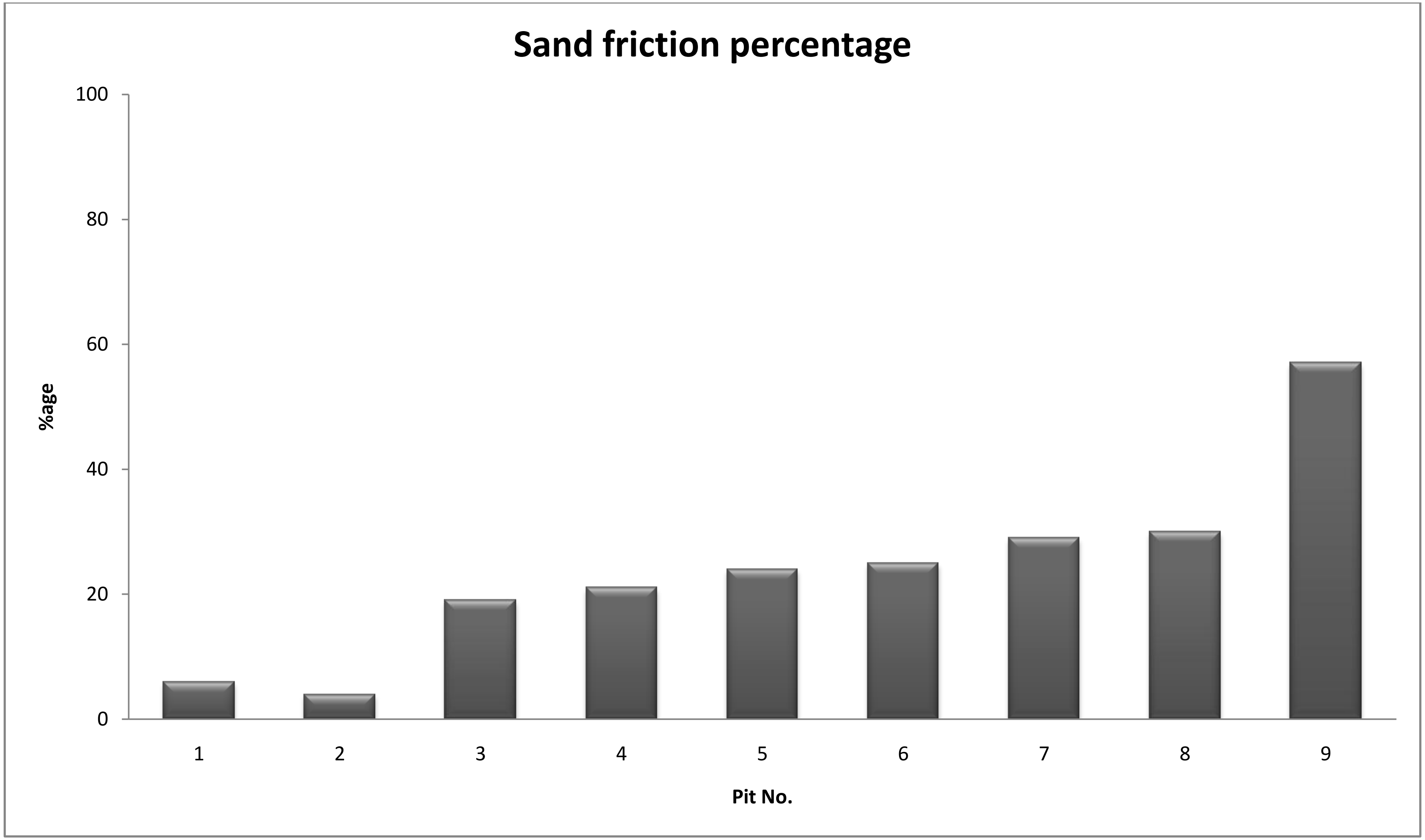

Figure 5.3: Sand friction in different test pits

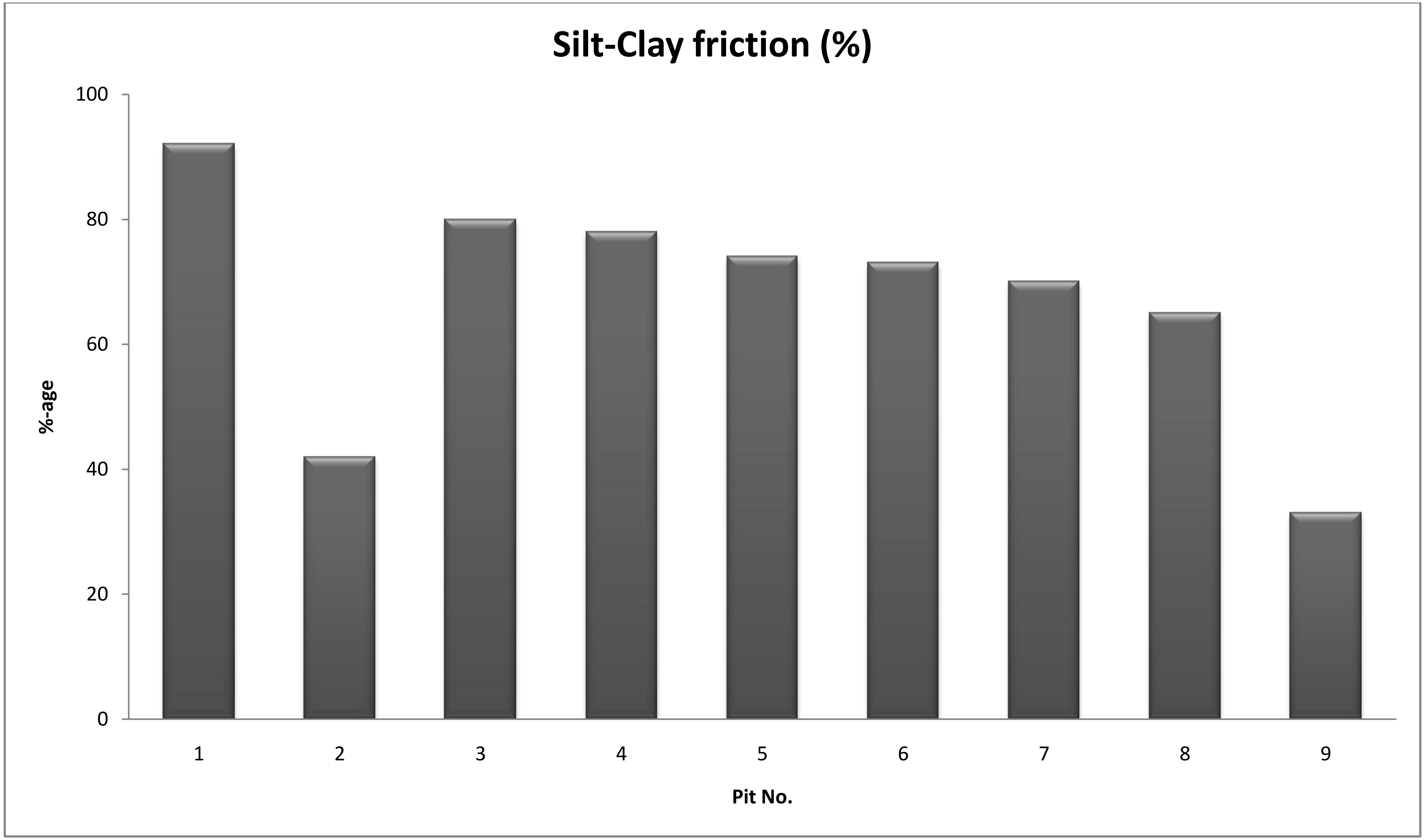

Figure 5.4: Silt-clay friction in different test pits

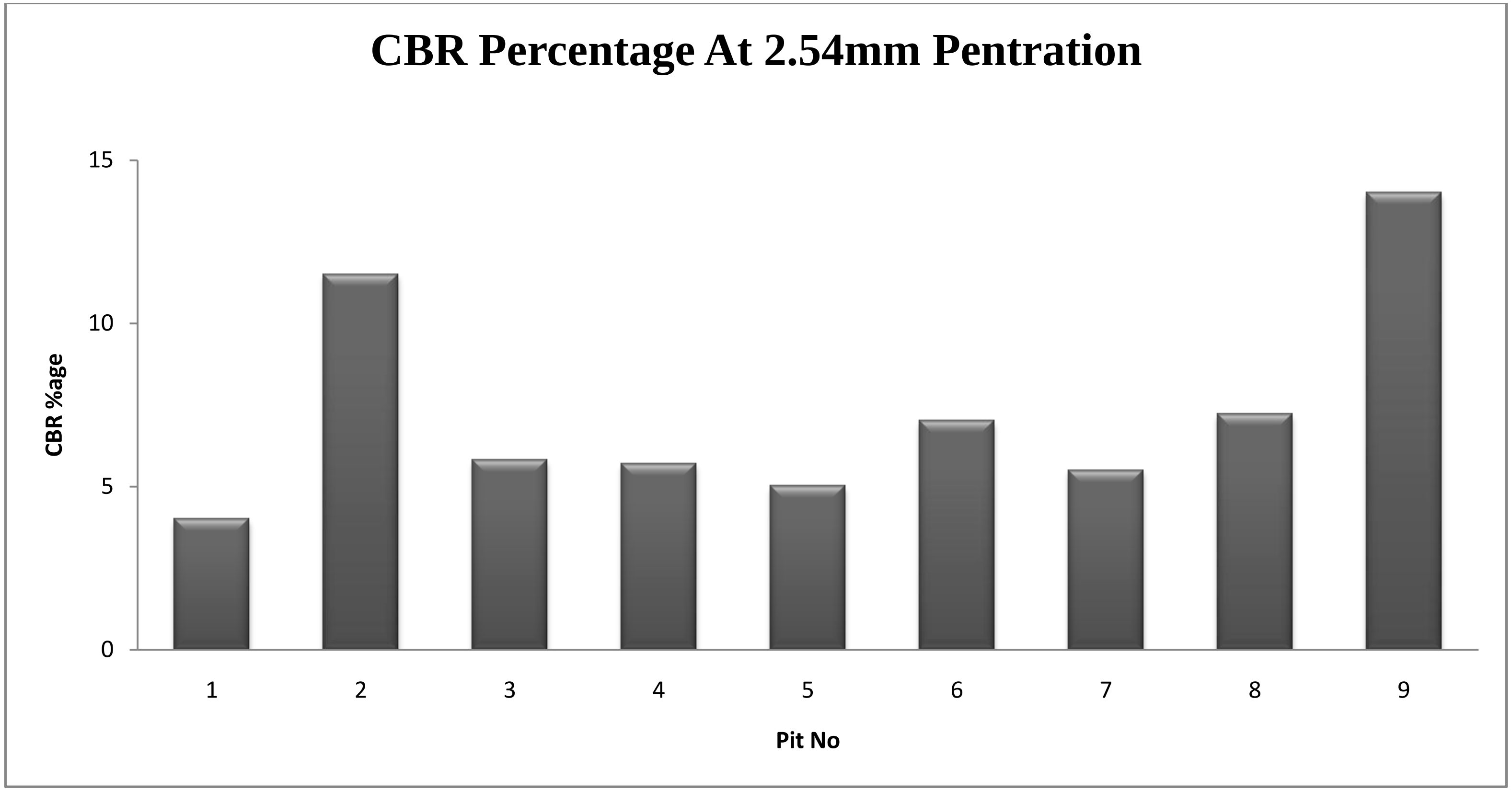

Figure 5.5: CBR Percentage at 2.54mm Pentration

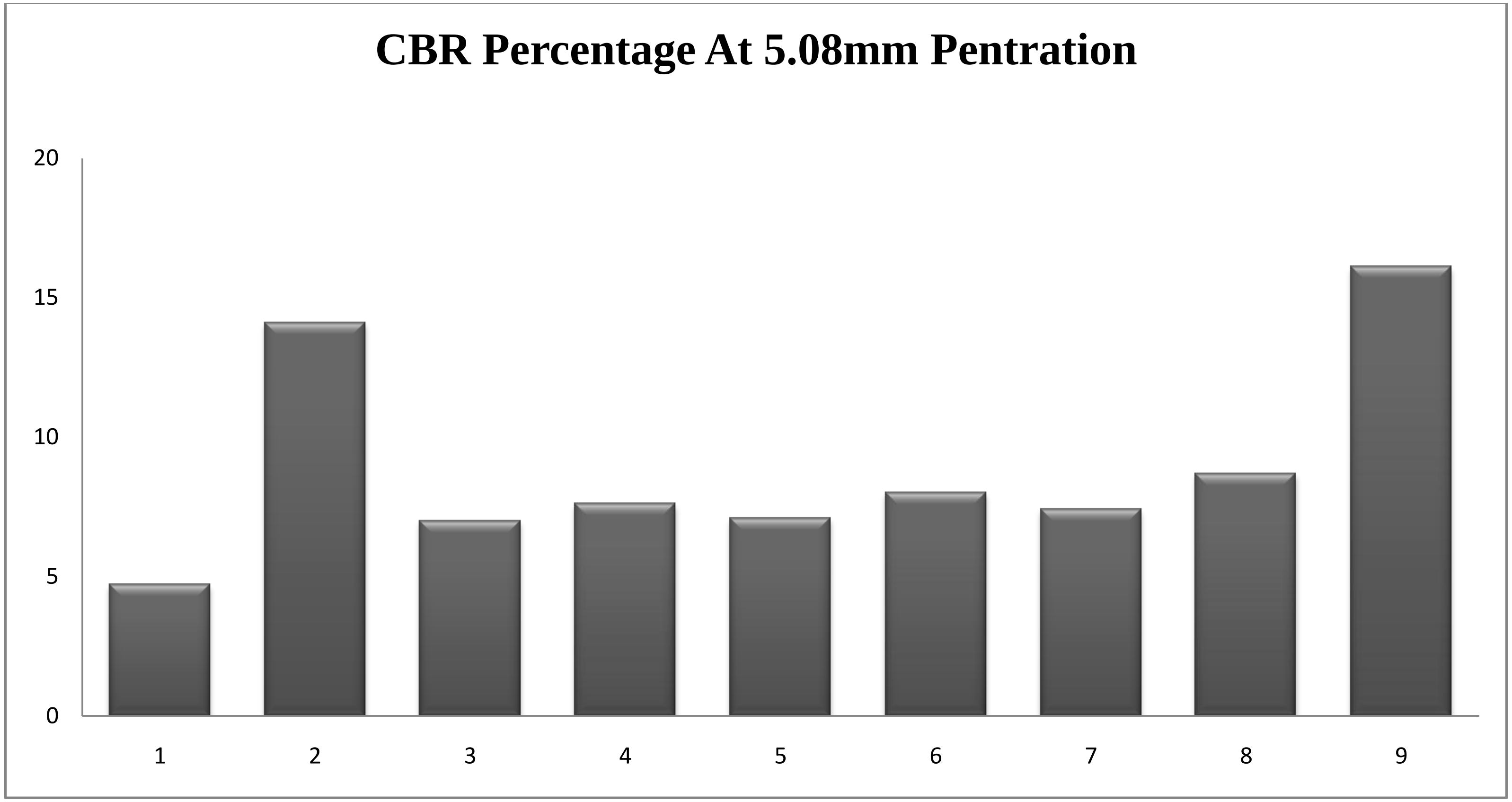

Figure 5.6: CBR Percentage at 5.08mm Pentration

Chapter No. 06

CONCLUSION AND RECOMMENDATION

6.1 Conclusion:-

The study area of section II of Rawalpindi Ring Road generally consists of Potwar clay of Quaternary period. The soil in the study area is classified as A-4 type with group index varies 0 – 7 which is generally grade as "fair" for road embankment (ASTM D 3282/ AASHTO M 145). Normally, Californian bearing ratio percentage at 2.54 mm for studied soil specimen generally meets with the NHA specification except at pit No. 1.

6.2 Recommendations:-

- Embankment material should be compacted as per following NHA guidelines;

Zone	Depth of design level above existing level (cm.)	Compaction as determined by AASHTO T 191
A	0 – 30	95
B	30 – 75	93
C	Over 75	90

- Soil with poor CBR percentage or area subjected to flood or prolonged embankment inundation, should be improved with granular material.

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