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ESTIMATION OF HYDROLOGICAL SOIL PROPERTIES OF NARSINGPUR DISTRICT

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ABSTRACT

This study deals with the estimation of hydrological soil parameters of the doab between Sher, Umar river and Bargi left bank canal falling in Narsingpur district of M.P. The soil properties determined are Soil Texture, Saturated Hydraulic Conductivity using Guelph Permeameter (for In-Situ measurement) and ICW Permeameter (for Laboratory measurement) and Soil Moisture Characteristic curves.

Twelve locations have been selected in the study area. In-Situ measurement of saturated hydraulic conductivity was carried out at all locations using Guelph Permeameter. The undisturbed soil samples (from 12 locations) and disturbed soil samples (from 12 locations at three different depths) were collected and brought to the Soil & Groundwater Laboratory of the Institute. Undisturbed soil samples were used with ICW Permeameter and Pressure Plate Apparatus to determine saturated hydraulic conductivity and soil moisture characteristic curves. Disturbed soil samples were used for textural analysis and to determine soil moisture characteristic curves.

1.0 INTRODUCTION

1.1 General

A prime requirement for successful irrigated agriculture is the development and maintenance of soil root zone in which the water-air-salt balance is favourable for plant growth. When a water table rises or water gets stagnated in the fields and remains in the root-zone for longer period, the yield of the crop gets seriously affected due to the air deficiency in the root zone. This air deficiency requires drainage facilities in the cropped area. A simple but comprehensible definition of drainage is the removal of excess water from root zone which permit some air for normal plant growth. If the prime objective is to lower the ground water table below a certain level below root zone of the crops, then subsurface drainage system is necessary.

Selection of the optimum drainage plan and the design and construction of adequate and successful drainage facilities depend upon the reliability and adequacy of the basic drainage data. The basic data must provide the knowledge of soil texture, saturated hydraulic conductivity of the soil and topography of the area under consideration.

Topography is the prime importance in drainage. Topography maps shows land slopes, length of slopes, location and direction of natural drainage, and others special conditions, which affect drainage. In subsurface drainage design system the textural analysis of the soil is an important parameter which governs the movement of the water in subsurface soil. The design and functioning of subsurface drainage systems also depends to a great extent saturated hydraulic conductivity of the soil. The soil moisture characteristic curve is another parameter, which affects the drainage of the system.

The present study area is the doab between Sher, Umar river and Bargi left bank canal, which falls in Narsingpur district of Madhya Pradesh. Narsingpur is about 100 kms away from Jabalpur. This area comes under the command area of Bargi irrigation project. The Bargi dam is constructed on river Narmada.

1.2 General Description of the Study Area

The study area, Fig. 1, is a part of Narsinghpur tehsil of Narsinghpur district, Madhya pradesh. This area comes under the command area of Bargi irrigation project, which is a multipurpose project constructed on river Narmada. The area selected for the present study is the doab of river Sher, Umar and left bank canal of Bargi irrigation project. This area is bounded by river Sher in west, river Umer in the east and north, and Bargi Left Bank Canal in the South (under construction) as shown in Fig.1. This is one of the most fertile and densely populated part of Narsinghpur.

The study area lies between longitudes E79°10' to E79°32' and latitudes N 22°53' to N 23°03'. The general topography of the area appears to be flat except in the vicinity of the rivers, where deep gullies and ravines have formed giving rise to undulating to rolling topography. As such the entire area is a broad plain of low relief and local differences in elevation is small. The general slope of the area is towards north and North-West.

The drainage pattern in the study area is dandretic type as shown in Fig 2. The landscape of the command area is such that most of the surplus rain water drains through rivers and streams. The natural drainage follows the general slope of the land.

The study area enjoys a sub-tropical climate. The annual rainfall of Narsinghpur district varies from 563.3 mm to 1893.6 mm, with average annual rainfall of 1162 mm. Most of it precipitate during monsoon season i.e. end of June to end of September. The summer temperature goes as high as 45°C. The extremes of cold and heat are experienced during winter and summer respectively.

Soils of the area are alluvial in nature. The thickness of alluvium increases towards north. Soil of whole of the Bargi Project in Jabalpur and Narsingpur district have been derived from trap rock but with regard to soils only Deccan trap is important one which has given rise to Characteristic colour and properties to the soils of the area. Deccan trap is the great formation of horizontally bedded basaltic lavas that occupies a large portion of the western part of India. Kankars have been observed at a depth of 80 cm to 150 cm. In some place, soils have been formed from sand stone parent material in which lot of textural variation ifs found. It varies from sandy loam to clay and soil crust is deep having fair amount of gravel or kankar (impure form of calcium carbonate nodules). The soil survey of the study area had been carried out by Soil Survey Unit, Jabalpur under department of Agriculture, Govt. of M.P. The survey shows that there are only three types of soil clay, clay loam and silty loam.

The study area is mostly agricultural area having no forest. Forest lies beyond the Bargi canal in the south. The main crops grown in the area are Soyabean, Gram, Arhar, Masoor, Moong, Jwar, Wheat and Sugar Cane. Rice is also cultivated in some of the low-lying areas.

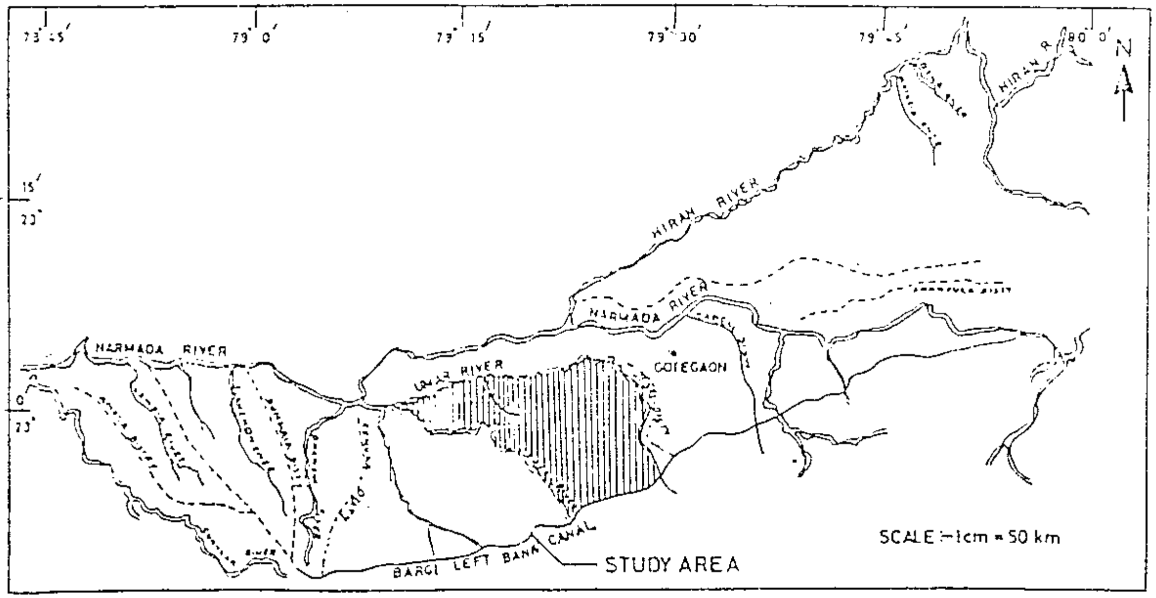


FIG.1 : Location map of the Sher-Umar river doab.

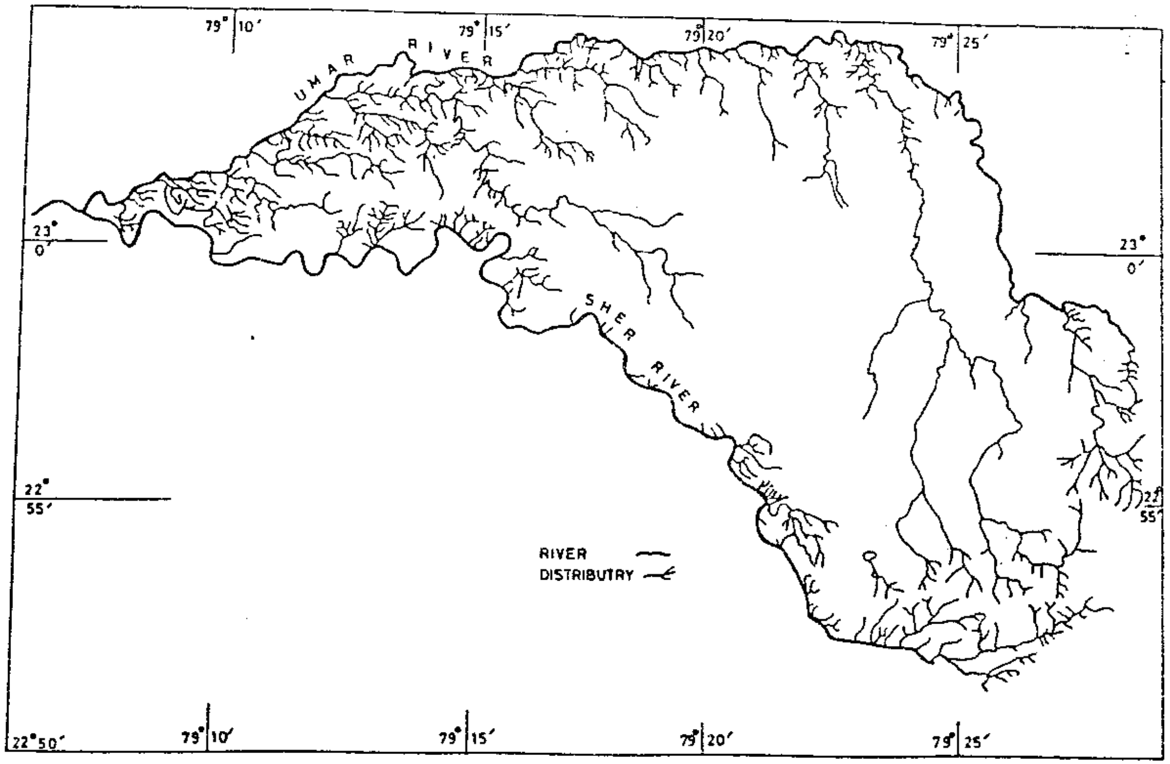


FIG. 2 : Drainage map of the Sher-Umar river doab.

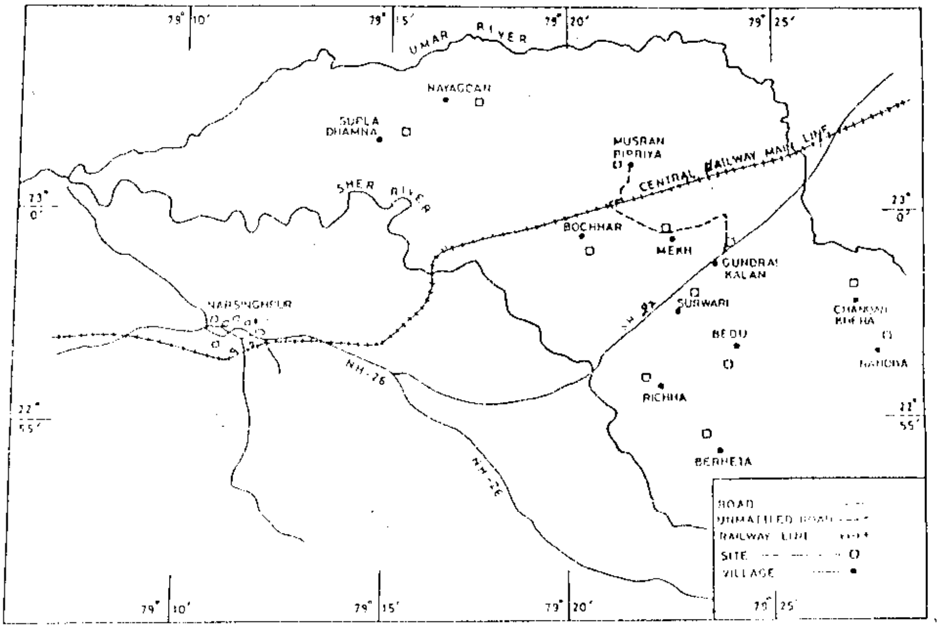


Fig. 3 **Location Map of Soil Sample Collection Sites in the Study Area (Sher-Umar River Doab)**

2.0 METHODOLOGY

2.1 Particle Size Distribution

Particle size distribution is an attempt to determine the relative proportions of the different grain sizes that makes a given soil mass. The relative proportion of sand, silt and clay determines the soil texture. The diameter of the particles present in the soil sample makes the soil to be coarse, medium and fine. Table 1 gives the textural class names of soils as per particle diameter. The soil texture is determined by separating sand, silt and clay fractions and measuring their proportion, which is called the mechanical analysis. The soil texture triangle is then used to convert quantitative data from detailed gradation analysis of separates less than 2mm in diameter to textural class names of soils.

Table 1: Textural classification as per Particle Diameter

Material	Diameter
Stones	> 10 inches
Cobbles	10 - 3 inches
Coarse gravel	3 - 0.5 inches
Fine gravel	0.5 - 2 mm
Very coarse sand	2 - 1 mm
Coarse sand	1 - 0.5 mm
Medium sand	0.5 - 0.25 mm
Fine sand	0.25 - 0.1 mm
Very fine sand	0.1 - 0.05 mm
Silt	0.005 - 0.002 mm
Clay	<0.002 mm

To carry out the particle size distribution, first of all the oven dried soil sample weighing 500 gm is washed through the sieve of number 200. The portion of the soil particles retained on sieve is subjected to sieve analysis and the particles passing through the sieve is subjected to sedimentation analysis.

In sieve analysis, the portion retained on each sieve is collected and weighted. The percentage of soil sample retained on each sieve on the basis of total weight of soil sample and the percentage of weight passing through each sieve is calculated (Bowles, 1986).

In the Indian Standard (IS: 460-1962), the sieves are designated by the size of aperture in mm, whereas in BS (410-1962) and ASTM (E11-1961) standards, the sieve sizes are given in terms of the number of openings per inch. These are described in Report TR-82 by Dr. Seth, 1990.

The fraction of the soil, which is finer than 75micron size, is used for sedimentation analysis. This analysis is based on the stokes law which states that all other factors being constant the velocity at which grains settle out of suspension is dependent upon the weight, shape and size of grains. Assumptions are made for the analysis that the soil particles are spherical and all the particles have some specific gravity. This assumption leads to the fact that coarser particles settle more quickly than finer ones. The detail procedure of sieve and sedimentation analysis is given in Bowles, (1986).

The sieving process does not provide information on the shape of the soil grains. It only yields information on grains that can pass through rectangular sieve opening of a certain size. Information obtained from the grain size analysis is presented in the form of a curve. In such a curve, the y-axis or the ordinate in the graph indicates the percentage of soil particles having diameter finer than indicated on X-axis.

The capacity of soil to hold water is related to surface area as well as pore space volume. Hence, Water holding capacity is related to both structure and texture of the soil. In general, fine textured soils have the maximum total water holding capacity, but maximum available water is held in medium-textured soils. Soil texture is especially important in subsurface drainage as it has a direct relationship with hydraulic conductivity and water retention (David 1982).

2.2 Saturated Hydraulic Conductivity

Hydraulic conductivity is the measure of the ability of a soil to transmit water under a unit hydraulic gradient. For a particular soil, It represents its average water transmitting properties, which depends mainly on the number and the diameter of the pores present. In Darcy's law, hydraulic conductivity is the proportionality constants K. This K usually stands for the hydraulic conductivity of a saturated soil. Under unsaturated conditions, the hydraulic conductivity varies with the soil moisture suction. Hydraulic conductivity decreases as the soil water suction increases. This relationship is called the conductivity pressure head relationship.

Hydraulic conductivity can be determined either in the field or from soil samples in the laboratory. Both methods impose certain flow conditions on a soil body, after which discharge is measured and hydraulic conductivity is calculated with a formula describing the relation between hydraulic conductivity, the flow conditions and the discharge.

Field measurement of hydraulic conductivity can be done either in non-saturated soils (above the water table) or in saturated soils (below water table). In the presence of the water table, the auger hole method is a simple and reliable technique for measuring saturated hydraulic conductivity in relatively uniform soils. The methods for measuring hydraulic conductivity in the absence of the water table are double tube method, the infiltrometer method and the inverse auger hole method.

The Guelph permeameter can be used to determine in-situ K_{fs} (where subscript `fs' stands for field saturated) for a particular soil. The Guelph permeameter method (Reynold et. al., 1985) measures the steady state liquid recharge necessary to maintain a constant depth of liquid in an uncased cylindrical well finished above the water table. Detail experimental procedures are given in Shukla & Soni (1993) and Soni & Srivastava (1996).

Once the soil water suction is measured, the hydraulic conductivity (K) at that soil water suction (φ) can be readily estimated by relationship

$$K = K_{fs}(e^{\alpha^{*}\varphi})$$

where,

α = Alpha is a parameter, indicating slope of the curve relating natural log of K to φ

φ = Soil water suction in cm of water

e = 2.71828 (base of natural logarithm)

K_{fs} = Saturated hydraulic conductivity of the soil

Guelph permeameter can measure matric flux potential (ϕ_m) which is the measure of a soil's ability to pull water by capillary force through a unit cross sectional area in a unit time. The matric flux potential (ϕ_m) in sq.cm/sec is given by following relationship

$$\phi_m = 0.0572 \text{ X } R1 - 0.0237 \text{ X } R2$$

Alpha parameter (α) is the slope of the curve relating the natural log of hydraulic conductivity (K) to soil water suction in cm expressed by following relationship

$$\alpha = K_{fs}/\phi_m$$

Laboratory measurements of hydraulic conductivity are conducted on soil samples, contained in cylinders of known dimensions. Stainless steel cylinders with a thin wall and one sharpened end are used to extract soil samples above the ground water table.

Hydraulic conductivity of undisturbed soil samples can be determined by a simple method known as the ICW laboratory permeameter method. In this method, a difference in water pressure on both sides of a well, saturated soil sample is created, which causes the water to flow through the sample. This flow is measured and forms together with pressure difference and sample dimensions the essential data for permeability calculations.

2.3 Soil Moisture Characteristic Curves

Soil moisture retention curves, also called moisture characteristic curves, are the plots of moisture content versus suction head. It shows the amount of moisture in a given soil holds at various tensions.

The moisture characteristic curve of a soil sample can generally be determined by equilibrating a soil sample at a succession of known tension value and each time determining the amount of moisture. The graph is plotted between the tension and corresponding soil moisture value to obtain the soil moisture characteristic curve. Different soil type gives different characteristic curves.

Pressure plate apparatus is a standard method for obtaining the soil moisture characteristic curves. It consists of a pressure chamber in which a saturated soil sample (either disturbed or undisturbed) is placed on a porous ceramic plate through which the soil solution passes but no soil particle or air can pass easily. The soil solution, which passes through the membrane is in contact with atmospheric pressure. As soon as the air pressure inside the chambers are raised above the atmospheric it takes excess water from the soil and flow out of the chamber through the membrane outlet. Soil water will flow out from the soil sample until the metric potential of the unsaturated flow is same as the applied air pressure. The air pressure is then, released and the moisture content of the soil is gravimetrically determined for that particular tension. When air pressure in the chamber is increased flow of water from the samples starts again and continue until a new equilibrium is reached. The same procedure is repeated at various pressures. The pair of pressure and moisture content data so obtained is used to construct the soil moisture characteristic curves.

Soil moisture characteristic curves are useful to understand the amount of water that is available to plants, the water that can be taken up by the soil before percolation starts, and the amount of water that must be used for irrigation (Micheal, 1986).

A soil water matrix potential of about -1/3 bars has been found to correspond to the field capacity, where as a soil water matrix potential of about -15 bars has been found to correspond to wilt point (Henry, 1984). The water present in the soil between field capacity and wilting point is known as available water. It is generally considered to be matrix potential in the range of -0.3 to -15.0 bars.

3.0 PROCEDURE

3.1 Soil Sampling

The study area as shown in Fig.1 was selected for the estimation of hydrological soil properties of the area. Study Area map has been prepared indicating road networks and villages of the area as shown in Fig. 3. Twelve sites have been selected and located on the map. These sites were tentatively chosen in such a way that different types of soils found in the area are covered and the sites are easily approachable and are well distributed all over the study area. These twelve sites are Nayagaun, Dhamna, Musran Piparia, Bochhar, Mekh, Gudrai Kalan, Surwari, Bedu, Richha, Berheta, Chandan Khera and Nandiya, which can be seen in Fig. 3. Disturbed and undisturbed soil samples were collected from these 12 sites and at different depths as indicated in the Fig. 3. Disturbed soil samples were collected for grain size distribution and soil moisture characteristic curve analysis, whereas undisturbed soil samples were collected to measure the saturated hydraulic conductivity in the laboratory by ICW permeameter and for soil moisture characteristic curve analysis. Measurement of field saturated hydraulic conductivity was also carried out at 12 different sites by Guelph Permeameter.

3.2 Grain Size Analysis

1. Oven dried soil sample weighing 500 gm was taken and soaked with water for 24 hours.
2. This soil sample was washed through sieve No. 200. The washing was carried out carefully using distilled water.
3. Two groups of soil, one passing through the sieve No. 200 i,e -75 microns (called as fine particles) and another retained on the sieve No. 200 i,e +75 microns (called coarse particles) were collected separately.
4. Both the fractions of soil were than oven dried. The group retained on sieve i,e +75 microns was subjected to sieve analysis and the group passing through the sieve i,e -75 microns was subjected to sedimentation analysis.

A. *Sieve Analysis*

1. Oven dried soil sample retained on Sieve No. 200 were taken for the sieve analysis.
2. The soil sample was sieved through a set of sieves i.e. 4, 10, 14, 20, 40, 60, 70, 200

Sieves No. The sieving was performed with mechanical sieve shaker for 10 to 15 minutes.

3. The stack of sieves was removed from sieve shaker and weight of material retained on each sieve was calculated. The percentage of total soil sample retained on each sieve was also calculated.
4. The percentage of weight passing through each sieve was calculated. The calculation was started with 100 percent and subtracting the percentage retained on each sieve as a cumulative procedure as given by

   Percentage passing = Percentage arriving-percentage retained
5. A plot of grain size versus percent passing was plotted on semi logarithmic scale.

B. Hydrometer Analysis

1. The soil group passing through the Sieve No. 200 was oven dried and 50gm of the sample was taken for hydrometer analysis.
2. The soil sample (50gm) was soaked with 100 ml of sodium hexametaphosphate solution for 24 hours.
3. All the contents were transferred into the mixer cup and suitable quantity of water was added. The mixing was carried out for 2 to 3 minutes. The mixture was then carefully transferred to the sedimentation cylinder.
4. The cylinder of soil suspension was covered with rubber stopper and the suspension was carefully agitated for one minute. The jar was placed at constant temperature and the cap was removed. The hydrometer and thermometer were then inferred in the controlled jar and readings of hydrometer were taken out 0.5, 1, 2, 4, 8, 15, 30, 60, 120, 240 and 1440 minutes.
5. The temperature of suspension was also recorded to the accuracy of 1°C for each hydrometer reading.
6. Between the hydrometer readings, hydrometer was placed in another jar containing 100 ml of dispersive agent and 900ml of water and placed at the same temperature as other jar. The reading of hydrometer was calculated to find out the hydrometer corrections.

The diameter and the percentage finer with respect to each time interval elapsed was calculated. The grain size was plotted against percentage finer on semi log paper (Fig.5 to 16). The sand, silt, and clay percentage are determined from the textural classification curve, Fig. 4, on the basis of grain size and it is given in Tab. 2.

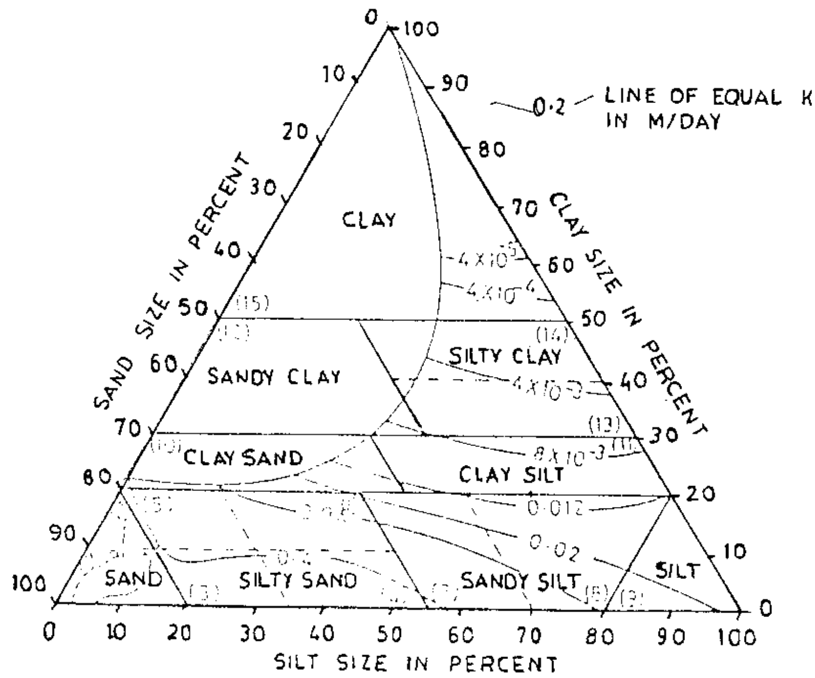


Fig. 4 **Textural Classification of Soil based on Percentage of Sand, Silt and Clay**

3.3 Saturated Hydraulic Conductivity

Insitu measurement by Guelph Permeameter

1. A well hole was prepared at the site with the help of soil auger and sizing auger. The hole was dug with the help of soil auger to a depth of 15 cm less than the desired for final well depth. The depth of 15 cm was dug with the help of sizing auger to produce a debris free well hole of uniform geometry of via 6 cm and bottom flat.
2. Tripod was centered over the well hole and permeameter was lowered so that the

support tube entered into the well hole.

3. After the permeameter is placed, it is filled with water. Verification was then made for ensuring that both the reservoirs were connected.
4. The air inlet tip was slowly raised to establish 5 cm well head height (H1).
5. The rate of fall of the water in the reservoir was measured at a regular time interval. The difference in readings at consecutive time interval divided by the time interval gave the rate of fall of water level, R1 in the reservoir.
6. The rate of fall of water in the reservoir was continuously monitored until it was almost same for three consecutive intervals. This rate of fall of water is called R1 and is defined as steady state rate of fall.
7. A well head height (H2) of 10 cm was established and the rate of fall of water, R2, in the reservoir was obtained for stable value of R2.
8. The field saturated hydraulic conductivity (K_s) was then calculated using following equation (Tab 3).

   $K_{s = 0.0041}$*X*R2 - 0.0054*X*R1

   where,

X	=	Reservoir constant, equal to 35.19 when reservoir combination is used and 2.16 when only inner reservoir is used.
R2	=	Steady rate of fall of water in the reservoir for a head of 10cm.
R1	=	Steady rate of fall of water in the reservoir for a head of 5cm.

9. The metric flux potential (ϕ_m) and alpha (α) were calculated using following equations.

   $\phi_m = 0.0572 * X * R1 - 0.0237 * X * R2$

   $\alpha = K_{fs}/\phi_m$

3.4 Soil Moisture Characteristic

Soil samples were prepared after drying, light hammering and passing through 2.0 mm sieve. The passing soils from 2.0 mm sieve were used for determining soil moisture characteristic by applying 0.10, 0.33, 0.50, 0.70, 1.00, 3.00, 5.00, 10.00, 15.00 bars pressure respectively.

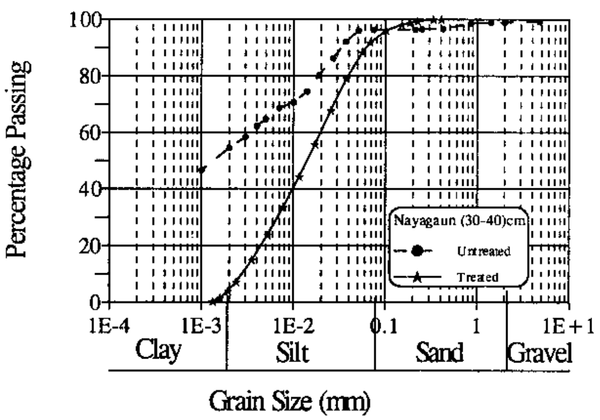
Pressure plate apparatus (Soil Moisture Corporation Co. USA) was used to test the soil moisture retention behavior of the soil samples. Each of these samples, were tested against 0.10, 0.33, 0.50 and 1.0 bar, by one bar pressure plate. Where as 3 bar, by 3 bar plate and 5 bar, by 5 bar plate as well as 10 bar and 15 bar with 15 bar pressure plate and following procedures were followed in the experiment.

1. First of all saturate the pressure plates and then prepared soil sample placed on plate in three separate rings and soaked with water for complete saturation.
2. Saturated plate containing soil samples were placed in pressure chambers and applied desired pressure till it reached equilibrium.
3. Samples were taken out from the pressure chambers and weighed on the high precision microbalance to record the moist weight of the samples.
4. These weighed samples placed in the oven at 105 C-110 C till weight became constant on drying. The dry weight was recorded by weighing and soil moisture by weight was determined from the moist and dry weight of the sample.

Soil moisture measurement for all soil samples of 12 sites at 21 points were carried out and results are given in the Table 4. Soil moisture retention curves are also plotted and are shown in Fig. 17 to 27 respectively.

4.0 RESULTS AND DISCUSSION

The soil samples were collected at 12 locations in the study area to find out the grain size distribution. The grain size analysis were carried out in the soil water laboratory of the Institute. The grain size distribution has been determined for soil particles and it was plotted against percentage finer on semi log paper (Fig.5 to 16).



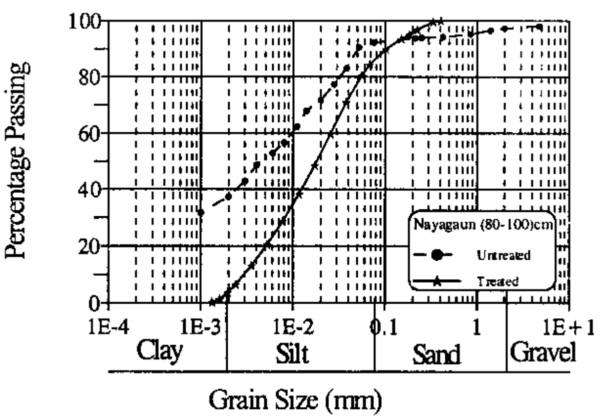


Fig. 5 Grain Size Distribution at Nayagaun

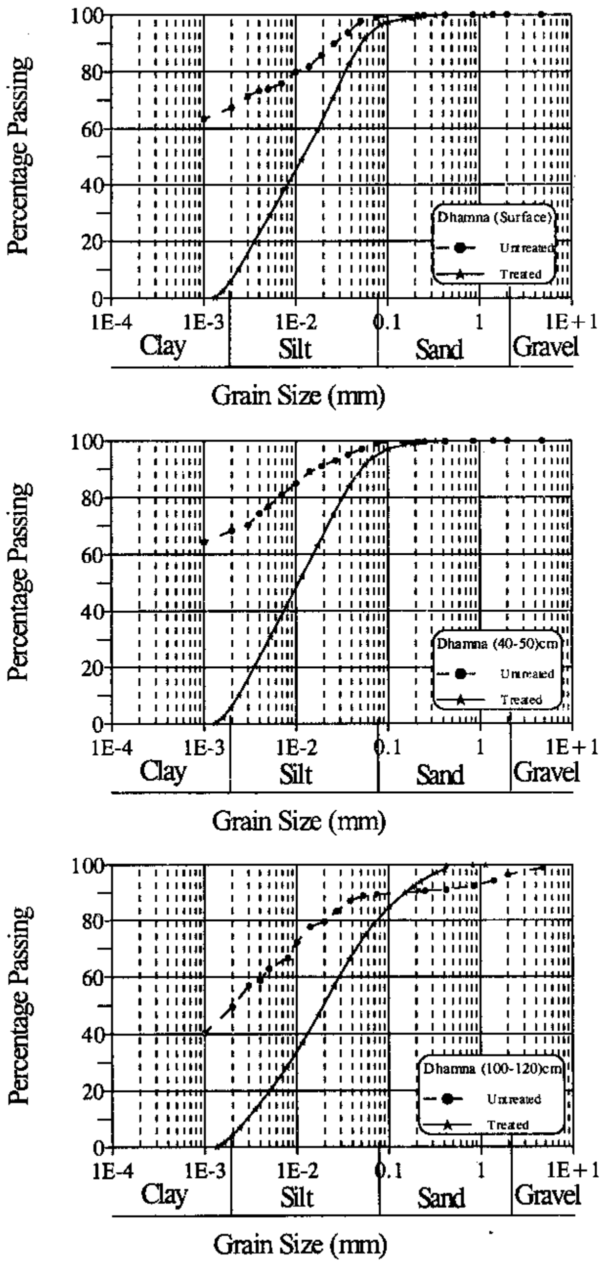


Fig. 6 Grain Size Distribution at Dhamna

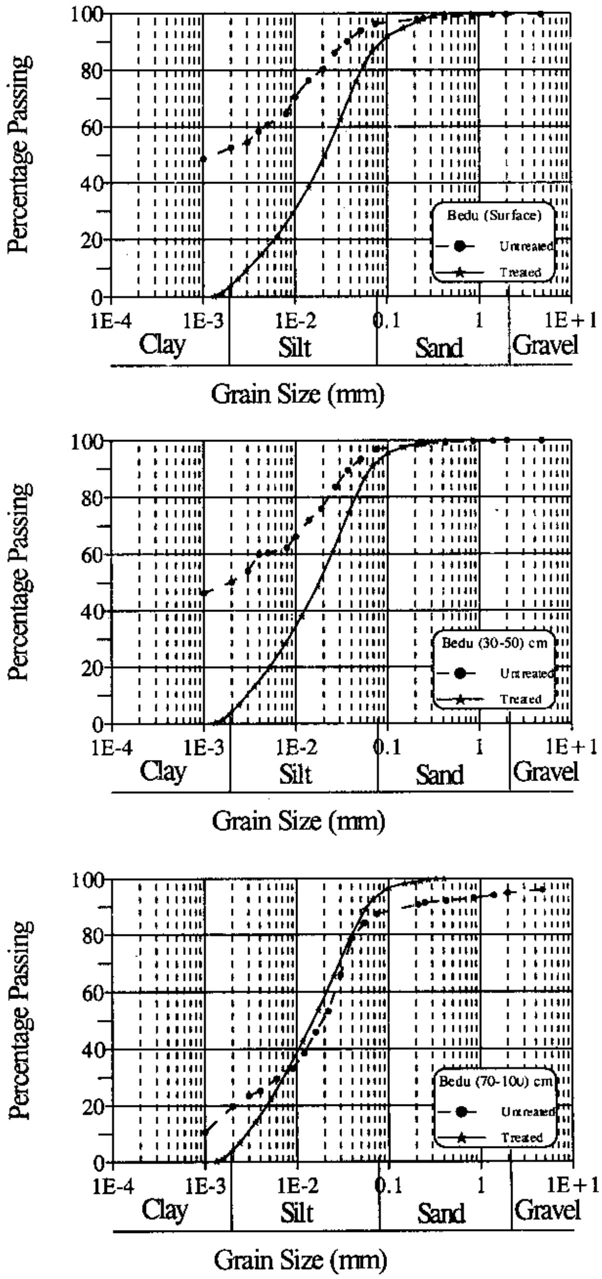


Fig. 7 Grain Size Distribution at Bedu

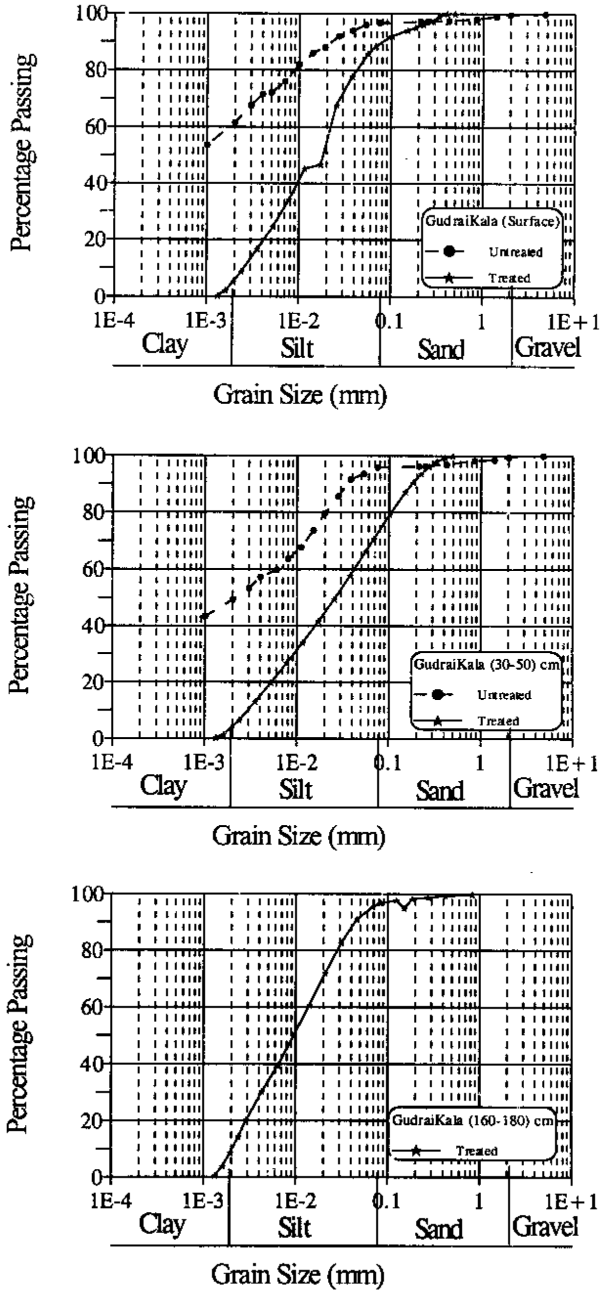


Fig. 8 Grain Size Distribution at Gudraikala

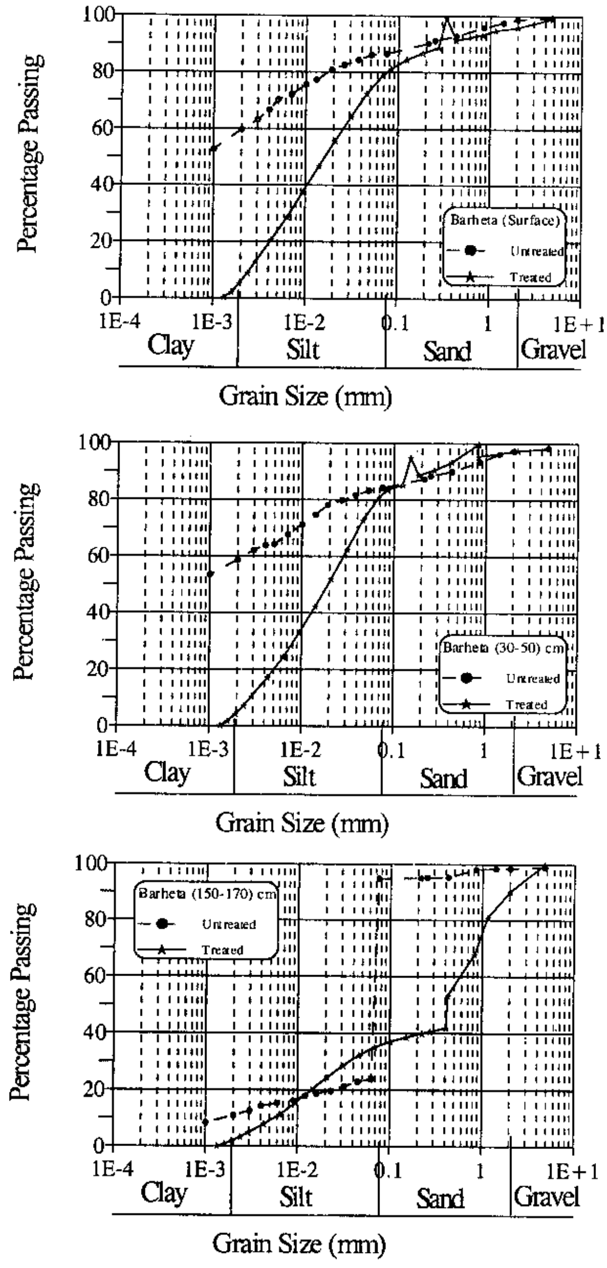


Fig. 9 Grain Size Distribution at Barheta

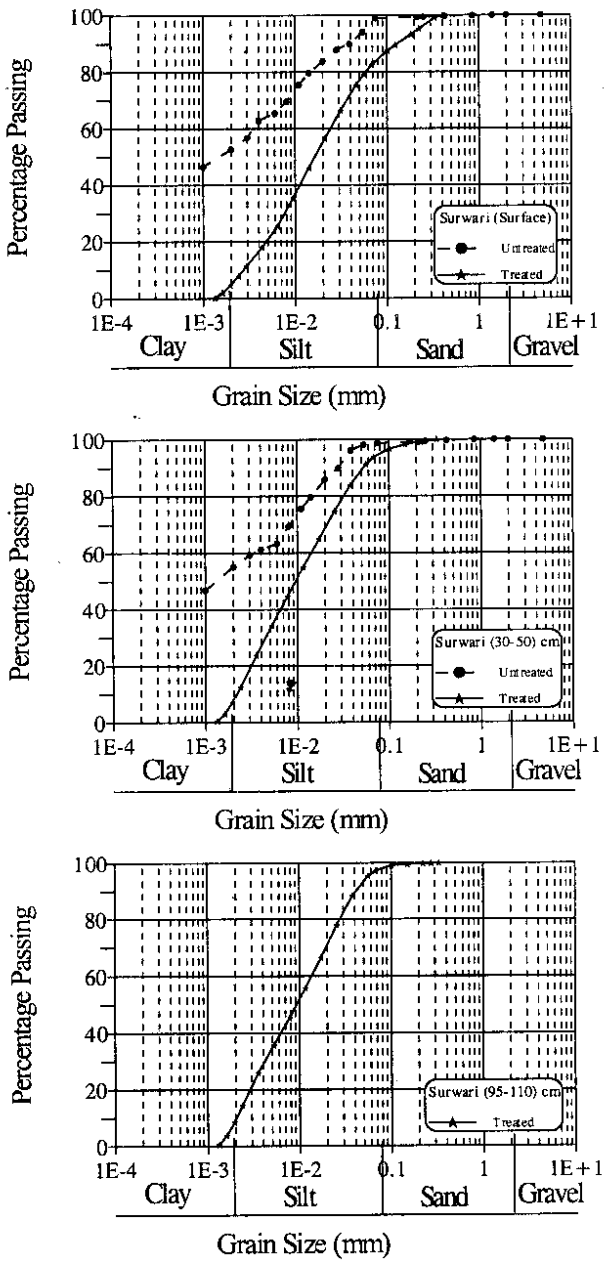


Fig. 10 Grain Size Distribution at Surwari

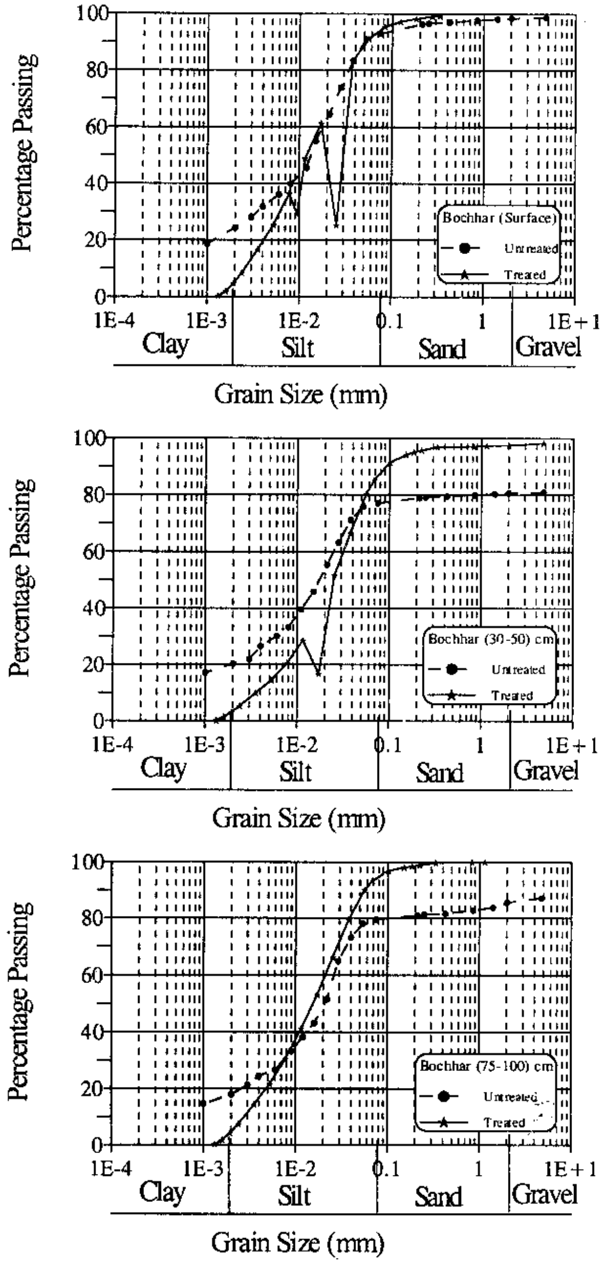
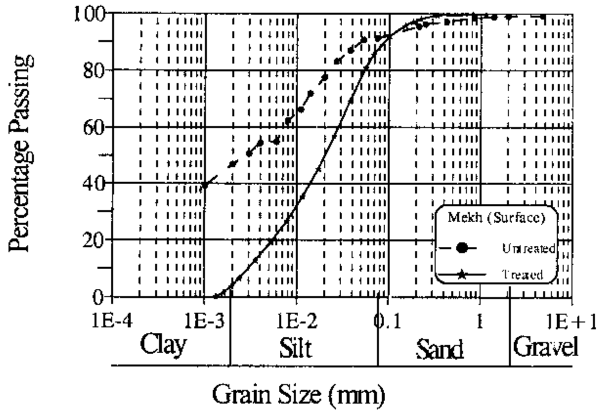
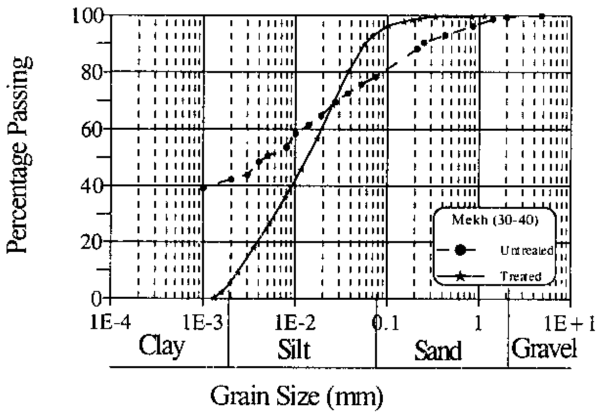


Fig. 11 Grain Size Distribution at Bochhar





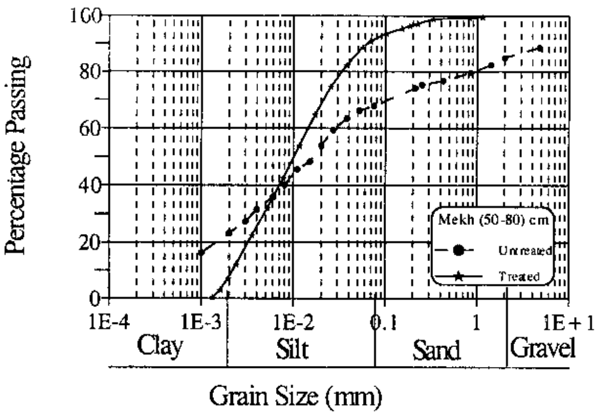


Fig. 12 Grain Size Distribution at Mekh

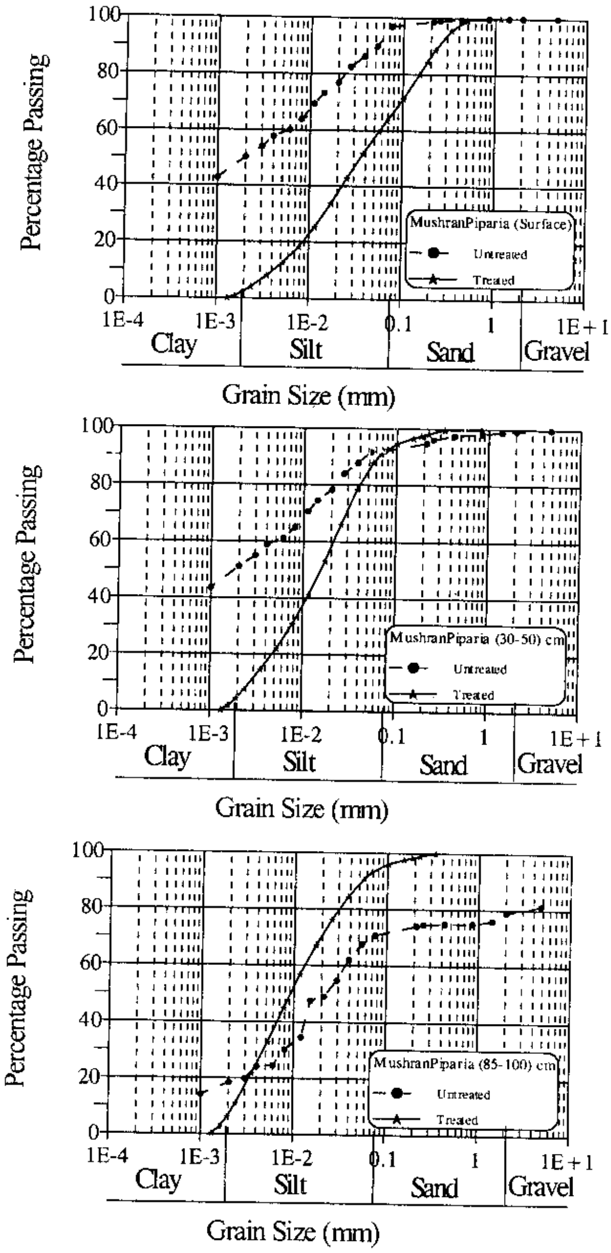


Fig. 13 Grain Size Distribution at Mushran Piparia

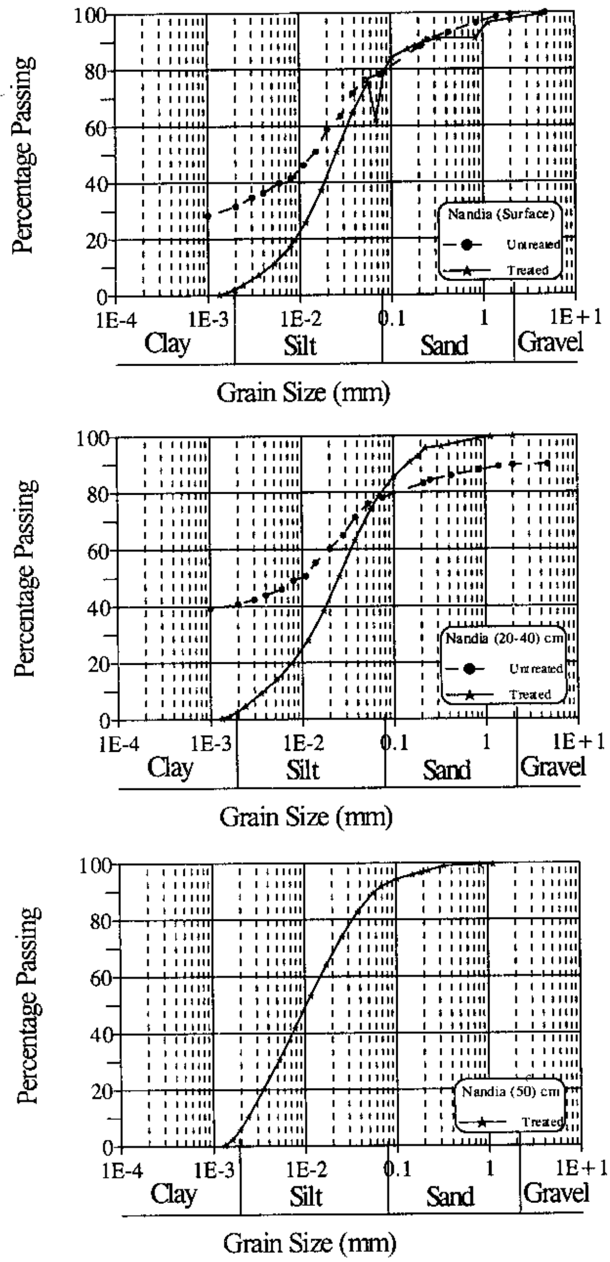


Fig. 14 Grain Size Distribution at Nandia

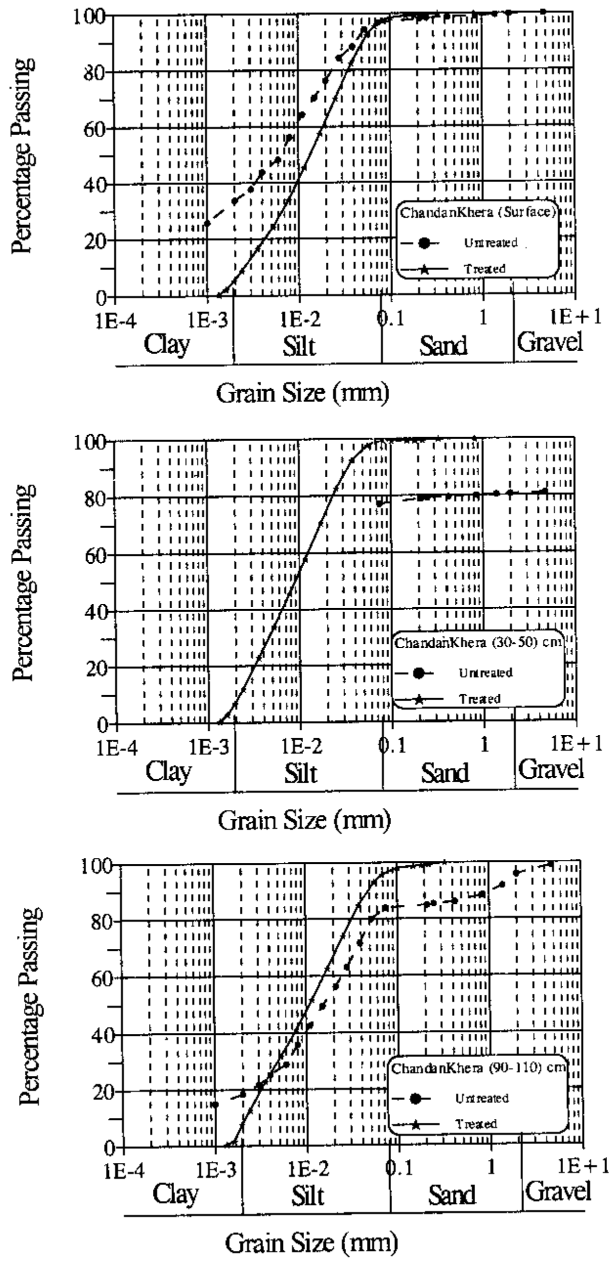


Fig. 15 Grain Size Distribution at Chandan Khera

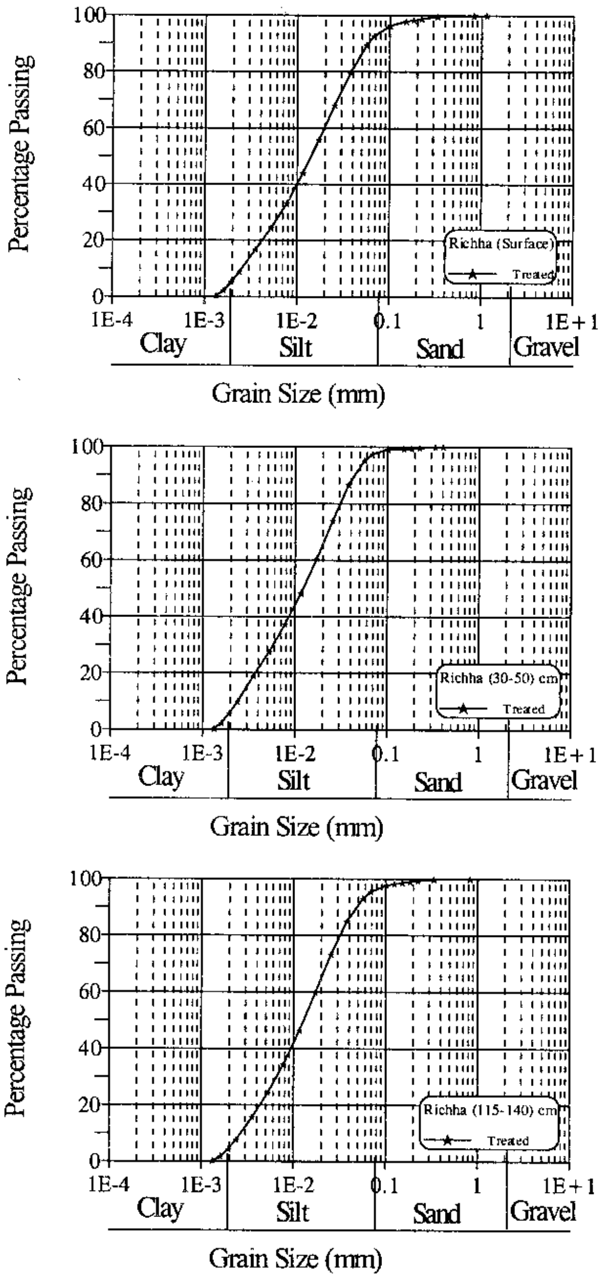


Fig. 16 Grain Size Distribution at Richha

From the particle size distribution curves the grain size distribution of the soil samples were estimated. Using soil triangle graph (Fig. 4) the textural classification of the soil of study area was found and is given in Tab.2. The grain size analysis of the soil samples has been done in two ways. First, the soil has been collected and analyzed as it is. Second, the analysis has been done after the treatment for removing the carbonates and irons. These two methods have given different results, which can be seen from the Fig. 5 to Fig. 16. The grain size distribution of untreated soil sample shows that in general gravel contents varies from 0 % to 5 % except for Bochhar, Mushran Piparia and Chandan Khera whereas for treated samples it is nil, except Barheta and Surwari. The sand content for untreated soil sample varies from 1.0% to 13%, except Mekh and Nandia, whereas for the treated soil sample it varies from 2 % to 20 % except Gudrai Kala and Barheta. Silt content for untreated soil samples varies from 25 to 68 % except at Barheta whereas it varies from 69 to 92 % for treated soil samples. Clay for untreated soil samples varies from 18 to 68% and for the treated soil samples it varies from 4 to 7 % except Surwari, which is up to 9 %. The textural classification of untreated soil samples shows that soils are mostly clayey and some are silty clay except Bedu, Bochhar and Chandan Khera, which is sandy silt. However, the textural classification of treated soil samples shows that soils are silty except Gudraikala, Barheta and Nandia which are sandy silt. The grain size analysis of the treated soil samples and untreated soil samples shows different results. The grain size analysis of untreated soil samples shows that most of the samples are clay and some are clay-silt. The treated soil samples shows that the most of the samples are silt and some are sandy-silt. In general, it has been seen that after the treatment of the soil sample, all the particles should come in their own original size. It means all the flocculated/clogged particles break into smaller particles after treatment. In this case, the distribution shows that the clay particles are nothing but carbonates and iron, which are dissolved at the time of treatment and remaining samples are silt and sand. The particle size distribution curves are also prepared by plotting the grain size in millimeter and the percentage passing on a log-normal scale for all the soil samples.

Table 3 shows the type of soil at surface, at a depth of 30-50 cm and at a depth of 70-100 cm from surface. For the surface soil, it can be seen from table that mainly there are two types of soil, which are clay and silty clay. Soils of all sites at surface are clayey except Mekh, Nandia and Chandan Khera, which have silty clay. For the depth of 30-50 cm, all sites have clay except Gudrai Kalan, Mekh, Nandia and Chandan Khera, which have silty clay. For the third layer, all the sites have sandy silt except Nayagaun, Dhamna, Barheta and Mekh, which have clay, Silty clay, silt and clay silt respectively. It can be seen from Tab. 3 that soil types are all most same upto the depth of 50 cm and than particles size increases towards sandy silt.

Types of soil in the study area at the surface are shown in Fig. 17 after the analysis of grain size. It is clear from Figure that there are three types of soil in the study area, in which two are major. First is the clay and second is the silty clay and third is the clay silt.

The saturated hydraulic conductivity of the soil samples measured by Guelph permeameter is given in Tab. 4. The insitu values of saturated hydraulic conductivity are varies from 0.0118 to 0.3427 m/day, except Mushran Piparia, which has value of 0.54 m/day. The saturated hydraulic conductivity obtained at Barheta, Surwari, Nandia and Richha were very small, even second reading didn't come. The depth of water table varies from 2 to 8 m deep. The hydraulic conductivity values obtained from Johnson's graph are given in Tab 4.

The soil moisture measurement for undisturbed soil samples were carried out at seven pressures (0.1, 0.33, 1.0, 3.0, 5.0, 10.0, 15.0 bar) are given in Tab.5 and for undisturbed soil samples are also given Tab. 6. The value of field capacity varies from 23% to 34.95% and wilting point varies from 18.19% to 29% respectively. The available moisture that is useful to plant varied from 3 to 7%. The soil moisture characteristic curves of undisturbed samples have been plotted and are shown in Fig. 18 to 28 for different locations.

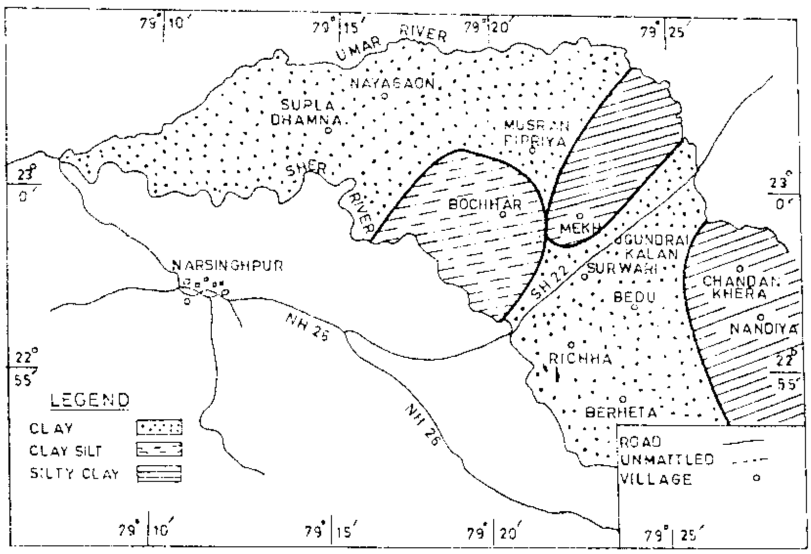


Fig. 17 Types of Soil in the Study Area (Sher-Umer river Doab)

Table 2 Textural Classification of Soil

Sl. No.	Location	Depth (cm)	Untreated Soil					Treated Soil				
			Grav. %	Sand %	Silt %	Clay %	Soil Texture	Grav. %	Sand %	Silt %	Clay %	Soil Texture
1	Nayagaun	30-40	0.98	2.66	41.95	54.43	Clay	0	7	89	4	Silt
		80-100	2.68	5.01	54.97	62.66	Clay	0	14	82	4	Silt
2	Dhamana	Surface	0	0.9	31.73	67.37	Clay	0	5	89	6	Silt
		40-50	0	0.9	30.79	68.31	Clay	0	5	90	5	Silt
		100-120	3.62	7.13	39.73	49.52	Silty Clay	0	20	77	3	Sandy Silt
3	Bedu	Surface	0.45	3.17	43.95	52.43	Clay	0	13	84	3	Silt
		30-50	0	3.16	46.70	50.14	Clay	0	7	90	3	Silt
		70-100	5.08	7.52	67.64	19.76	Sandy Silt	0	6	91	3	Silt
4	Gudrai- kala	Surface	0.47	2.84	35.15	61.54	Clay	0	11	84	5	Silt
		30-50	0.53	3.56	46.6	49.31	Silty Clay	0	28	69	3	Sandy Silt
		160-180	-	-	-	-	-	0	28	69	3	Sandy Silt
5	Barheta	Surface	1.22	12.21	26.90	59.67	Clay	4	16	75	5	Sandy Silt
		30-50	2.59	13.06	25.73	58.62	Clay	3	15	77	5	Sandy Silt
		150-170	1.39	3.79	83.95	10.87	Silt	10	54	34	2	Sandy Silt
6	Surwari	Surface	0	1.12	46.25	52.63	Clay	6	11	78	5	Sandy Silt
		30-50	0	1.34	43.66	55.00	Clay	1	5	86	8	Silt
		95-110	-	-	-	-		0	2	89	9	Silt

7	Bochhar	Surface	1.63	5.41	68.71	24.25	Clay Silt	0	5.5	89.5	5	Silt
		30-50	19.4	3.52	56.86	20.22	Clay Silt	2.5	10.5	84	3	Silt
		75-100	14.41	6.06	61.6	17.93	Sandy Silt	0	6	89.5	4.5	Silt
8	Mekh	Surface	0.9	7.82	44.43	46.85	Silty Clay	0	13	82.5	4.5	Silt
		30-40	0.65	21.04	36.08	42.23	Silty Clay	0	7	87	6	Silt
		50-80	15.05	17.13	44.67	23.15	Clay Silt	0	9	83	8	Silt
9	Mushran Piparia	Surface	0	3.11	46.67	50.22	Clay	0	35	62.5	2.5	Sandy Silt
		30-50	0.64	7.33	40.92	51.11	Clay	0	8.5	91	5	Silt
		85-100	21.13	8.14	52.32	18.91	Sandy Silt	0	6	87	7	Silt
10	Nandia	Surface	0.64	21.17	46.76	31.43	Silty Clay	2.25	27.75	67.5	2.5	Sandy Silt
		20-40	10.35	11.59	37.28	40.78	Silty Clay	0.1	20	76.9	3	Sandy Silt
		50	-	-	-	-	-	0	8	86	6	Silt
11	Chandan Khera	Surface	0.32	2.96	63.06	33.66	Silty Clay	0	4	90.5	5.5	Silt
		30-50	19.4	3.53	46.80	30.27	Silty Clay	0	1	91.5	7.5	Silt
		90-110	4.27	11.88	65.49	18.36	Sandy Silt	0	4	88	8	Silt
12	Richha	Surface	-	-	-	-	-	0	7	87.5	5.5	Silt
		30-50	-	-	-	-	-	0	2	92	6	Silt
		115-140	-	-	-	-	-	0	4	91	5	Silt

Table 3 Types of Soil at Surface, 30-50 cm and 70-120 cm depths

Sl. No.	Location	Types of Soil			K (m/day)
		Surface	30-50cm	70-120 cm	
1	Nayagaun	Clay	Clay	Clay	$2.38X10^{-2}$
2	Dhamna	Clay	Clay	Silty Clay	$1.18X10^{-2}$
3	Bedu	Clay	Clay	Sandy Silt	$2.83X10^{-2}$
4	Gudrai- kalan	Clay	Silty Clay	-	$13.48X10^{-2}$
5	Barheta	Clay	Clay	Silt	-
6	Surwari	Clay	Clay	-	-
7	Bochhar	Clay Silt	Clay Silt	Sandy Silt	$20.45X10^{-2}$
8	Mekh	Silty Clay	Silty Clay	Clay Silt	$34.27X10^{-2}$
9	Mushran Piparia	Clay	Clay	Sandy Silt	$53.734X10^{-2}$
10	Nandia	Silty Clay	Silty Clay	-	-
11	Chandan Khera	Silty Clay	Silty Clay	Sandy Silt	-
12	Richha	-	-	-	-

Table 4 Saturated Hydraulic Conductivity by Guelph Permeameter and Johnson's Graph

Sl.No.	Location	Depth (cm)	X/Y constants	R_1 cm/s	R_2 cm/s	K_{fs} (m/day)	By Johnson's Graph (m/d)
1	Nayagaun	30-40	2.23	0.011	0.0175	$2.38X10^{-2}$	$4X10^{-4}$
2	Dhamana	30-40	2.23	$2.66X10^{-3}$	$5.0X10^{-3}$	$1.18X10^{-2}$	$4X10^{-5}$
3	Bedu	Surface	2.23	$2.33X10^{-3}$	$6.66X10^{-3}$	$2.83X10^{-2}$	$4X10^{-4}$
4	Gudrai- kala	Surface	2.23	0.025	0.05	$13.48X10^{-2}$	$4X10^{-5}$
5	Barheta	Surface					$4X10^{-5}$
6	Surwari	Surface					$4X10^{-4}$
7	Bochhar	Surface	2.23	0.0183	0.05	$20.45X10^{-2}$	$8X10^{-3}$
8	Mekh	Surface	2.23	0.0366	0.09166	$34.27X10^{-2}$	$1X10^{-3}$
9	Mushran Piparia	Surface		0.7	0.61	$53.734X10^{-2}$	$7X10^{-4}$
10	Nandia	Surface		0.6	0.7		$4X10^{-3}$
11	Chandan Khera	Surface					$7X10^{-3}$
12	Richha	Surface		0.6	0.4		

Table 5 Soil Moisture Characteristic Data of Undisturbed Samples for the 11 sites

Sl. No.	Pressure head /Suction head		Moisture Content (%) for different sites										
	(Bar)	(cm)	1	2	3	4	5	6	7	8	9	10	11
1	0.10	101.98	33.48	36.59	29.37	32.37	36.51	35.00	29.41	33.69	25.77	31.82	33.85
2	0.33	336.53	28.78	34.88	28.41	30.57	34.95	33.72	26.33	31.90	23.19	30.78	33.01
3	1.0	1019.8	29.79	33.37	27.53	29.06	33.73	32.44	23.91	30.60	21.47	30.00	32.04
4	3.0	3059.4	27.51	31.36	26.17	27.34	31.74	30.57	21.87	28.74	19.97	28.49	29.83
5	5.0	5099.0	26.68	30.52	25.74	26.54	30.97	29.67	21.02	27.97	19.32	27.86	28.77
6	10.0	10198.0	25.76	29.57	25.38	25.76	30.04	29.21	19.53	26.62	18.33	26.66	27.16
7	15.0	15297.0	25.38	29.19	25.18	25.41	29.75	28.99	19.42	26.40	18.19	26.52	26.94

Table 6 Soil Moisture Characteristic Data of Disturbed Soil Samples

S. N.	Location	Depth (cm)	Pressure Ist Rows in bar, 2nd Rows in cm									
			0.10	0.33	0.50	0.70	1.0	3.0	5.0	7.0	10.0	15.0
			101.98	336.53	509.90	713.86	1019.8	3059.4	5099.0	7138.6	10198.0	15297.0
1	Nayagaun	30-40	36.93	30.73	37.81	27.28	29.23	25.72	25.98	19.93	23.00	24.65
		80-100	33.68	33.26	36.22	27.69	27.56	24.89	25.78	18.49	21.25	23.55
2	Dhamana	Surface	40.38	35.26	39.86	32.95	35.54	29.98	29.24	20.42	26.07	26.13
		40-50	39.96	35.56	36.98	30.53	34.31	28.89	28.77	18.83	25.80	26.54
		100-120	34.34	34.00	34.49	31.41	29.76	28.26	27.21	18.49	24.82	21.91
3	Bedu	Surface	28.80	28.94	28.01	23.94	23.42	19.98	19.68	17.67	19.35	20.04
		30-50	31.55	24.21	30.74	23.16	24.19	21.94	22.33	18.55	21.65	21.25
		70-100	35.39	30.30	35.32	26.87	26.77	21.66	23.57	19.70	21.70	21.16
4	Gudrai- kala	Surface	34.32	29.93	32.98	28.00	30.80	24.72	26.18	19.71	25.39	24.25
		30-50	36.43	32.36	36.07	28.64	31.20	25.09	25.35	19.93	24.41	23.17
		160-180	33.84	32.37	33.41	30.16	29.00	24.09	22.54	19.38	22.24	20.19
5	Barheta	Surface	40.92	32.63	38.92	32.18	35.37	28.92	26.21	18.89	28.01	24.23
		30-50	100.00	43.73	38.45	38.12	35.56	29.52	27.87	22.45	25.95	31.55
		150-170	100.00	23.97	20.75	21.19	18.58	20.94	14.96	12.92	13.73	14.94

6	Surwari	Surface	100.00	41.89	36.10	37.88	34.51	71.18	26.54	23.28	24.79	26.24
		30-50	100.00	40.50	34.78	36.34	34.38	27.53	25.88	21.50	24.72	23.92
		95-110	100.00	35.94	31.99	31.26	44.59	25.18	22.81	19.83	21.40	23.84
7	Bochhar	Surface	100.00	19.16	28.19	26.75	25.12	20.56	20.35	15.73	18.69	20.59
		30-50	100.00	32.88	31.15	29.96	27.74	22.59	22.98	17.24	18.63	22.05
		75-100	100.00	24.72	27.47	27.23	22.08	19.31	8.17	12.82	15.12	17.43
8	Mekh	Surface	100.00	40.05	37.33	35.69	35.65	25.20	25.24	23.19	23.74	26.11
		30-40	100.00	39.42	37.32	35.45	33.19	27.92	23.87	21.78	21.94	24.23
		50-80	100.00	38.46	35.92	34.83	32.29	26.15	22.37	24.43	21.61	23.28
9	Mushran Piparia	Surface	100.00	33.86	33.40	32.48	28.29	26.48	22.69	19.06	22.84	24.42
		30-50	41.89	37.36	39.35	37.74	31.74	28.50	23.61	24.85	24.44	25.81
		85-100	44.55	36.68	37.44	40.52	31.12	25.19	24.26	20.82	24.83	27.05
10	Nandia	Surface	29.02	21.41	19.98	19.40	17.52	14.97	11.16	10.61	11.20	15.04
		20-40	28.03	24.74	24.67	23.72	21.36	18.02	14.02	14.64	15.21	13.70
		50	-	-	-	-	-	-	-	-	-	-
11	Chandan Khera	Surface	31.84	32.74	37.13	35.78	28.33	25.22	18.64	21.77	25.00	23.85
		30-50	37.82	36.71	38.33	36.54	16.15	23.73	17.99	24.08	24.89	24.40
		90-110	32.37	31.59	30.47	30.58	25.21	25.51	18.42	19.04	19.69	21.75
12	Richha	Surface	40.11	38.49	39.39	38.12	33.96	26.90	23.29	24.52	22.98	25.54
		30-50	41.58	39.39	39.51	38.25	31.97	26.94	23.76	22.11	26.12	39.14
		115-140	43.34	43.53	39.17	39.15	34.98	28.46	24.00	23.82	27.25	22.57

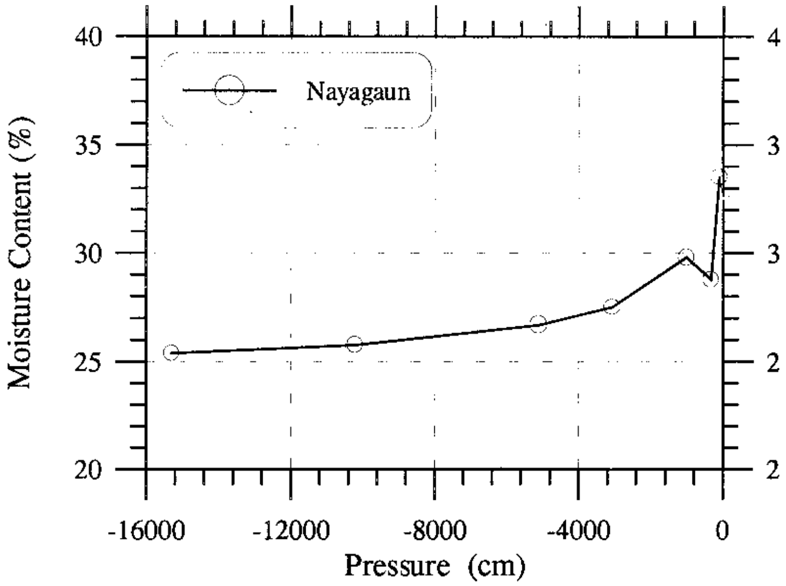


Fig. 18 Soil Moisture Characteristic Curve for Nayagaun

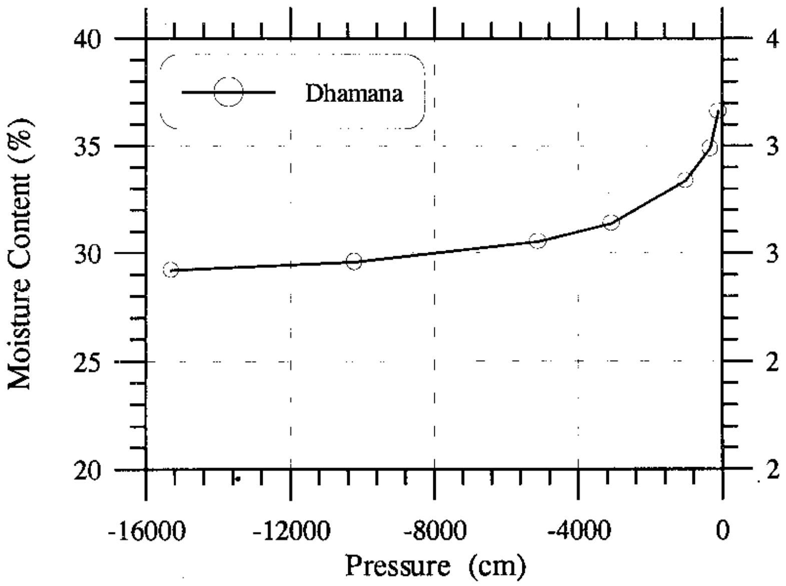


Fig. 19 Soil Moisture Characteristic Curve for Dhamna

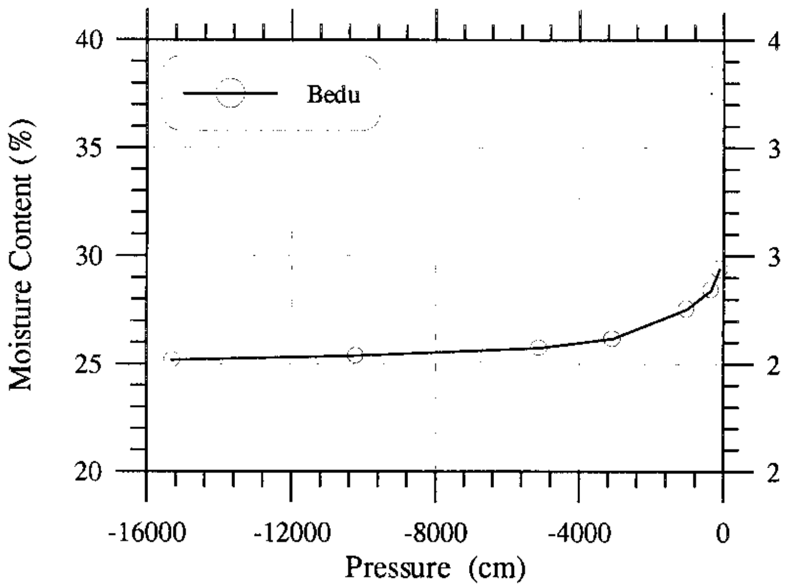


Fig. 20 Soil Moisture Characteristic Curve for Bedu

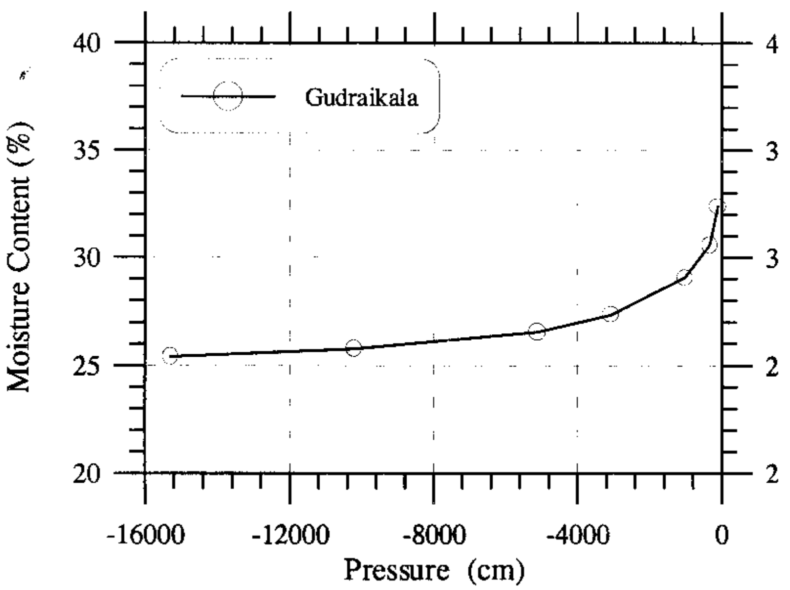


Fig. 21 Soil Moisture Characteristic Curve for GudraiKala

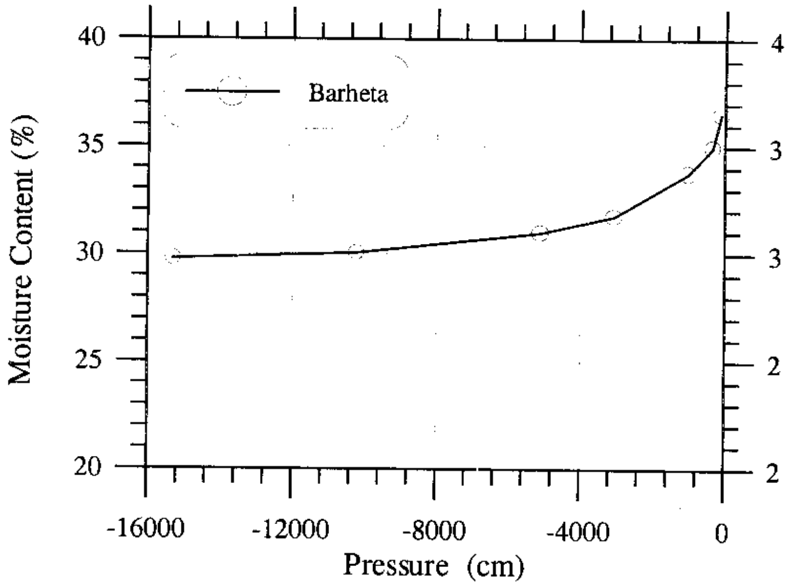


Fig. 22 **Soil Moisture Characteristic Curve for Barheta**

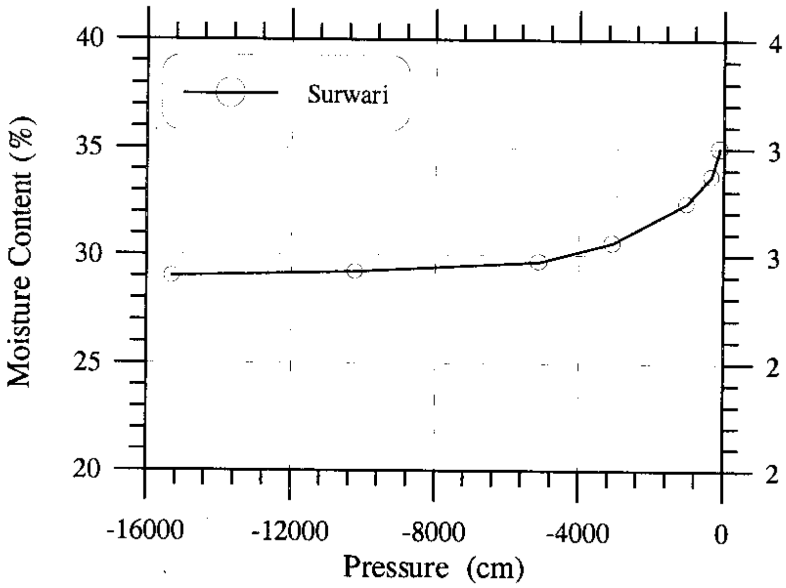


Fig. 23 **Soil Moisture Characteristic Curve for Surwari**

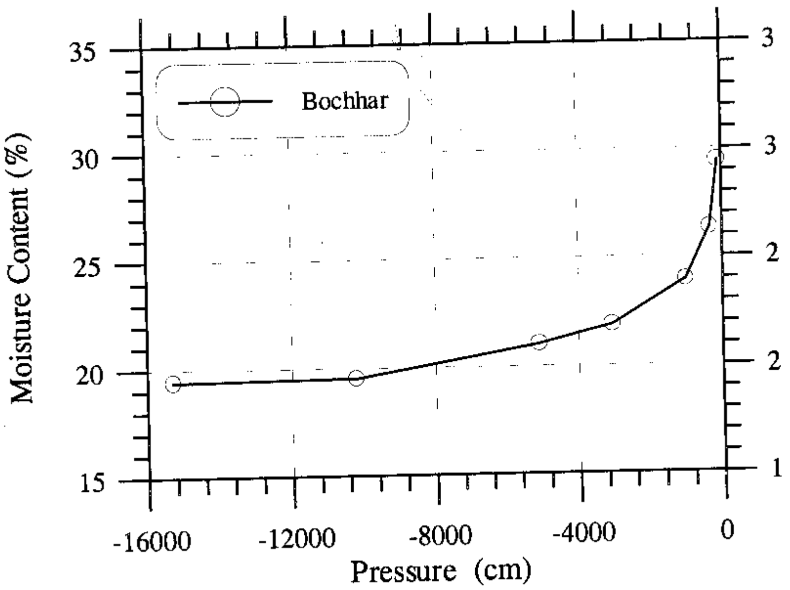


Fig. 24 Soil Moisture Characteristic Curve for Bochhar

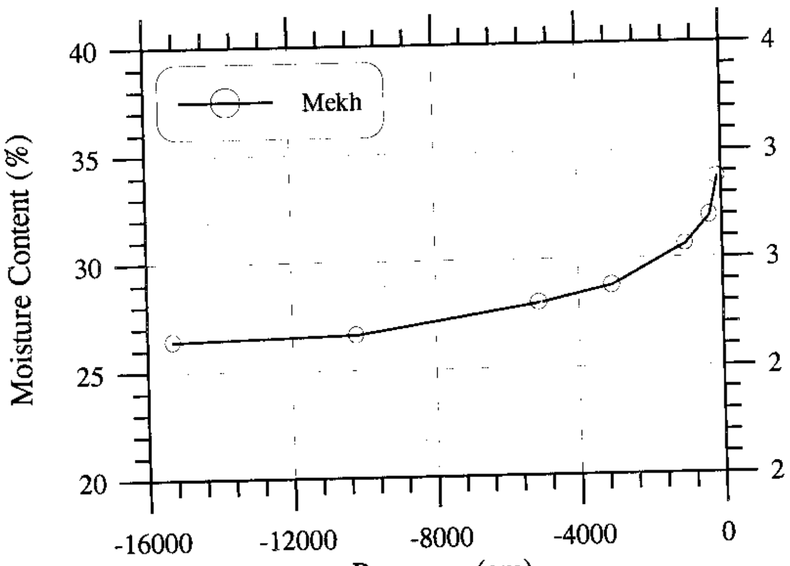


Fig. 25 Soil Moisture Characteristic Curve for Mekh

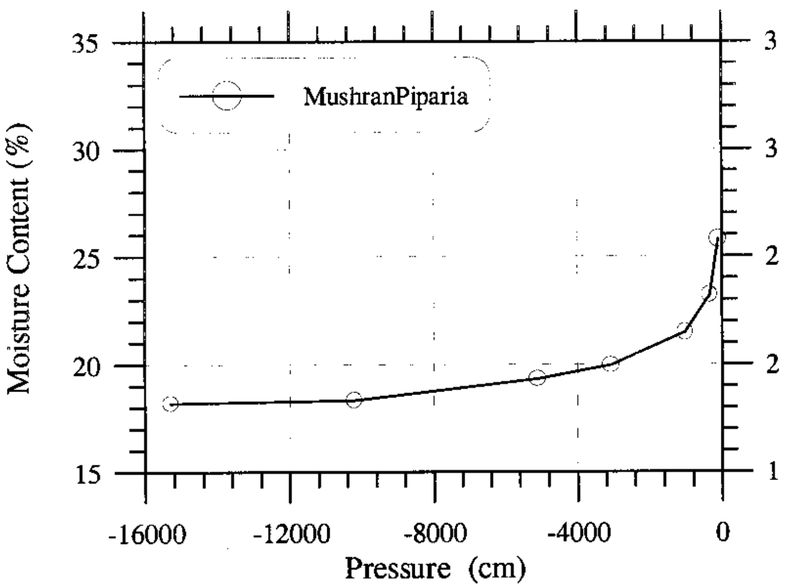


Fig. 26 **Soil Moisture Characteristic Curve for Mushran Piparia**

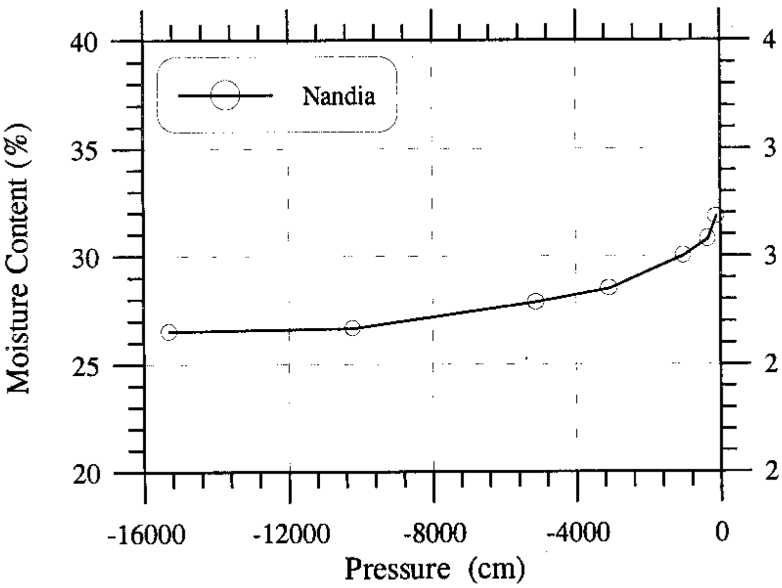


Fig. 27 **Soil Moisture Characteristic Curve for Nandia**

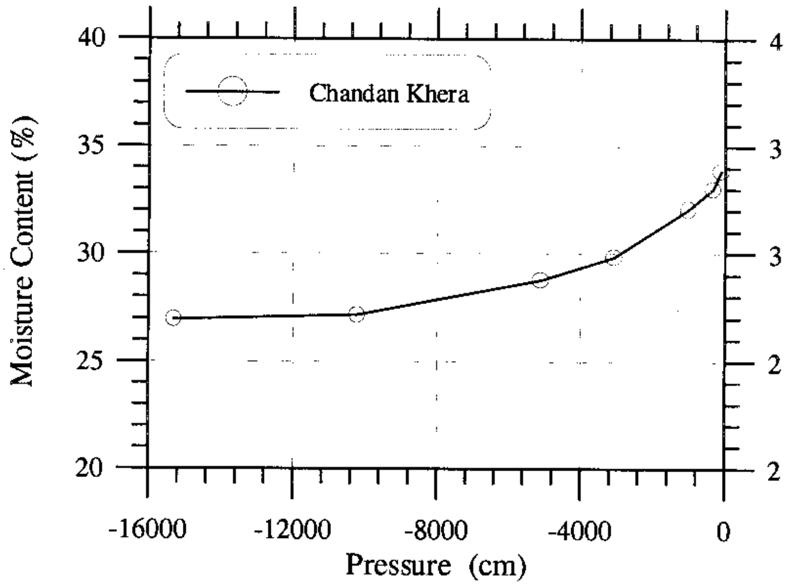


Fig. 28 Soil Moisture Characteristic Curve for Chandan Khera

5.0 CONCLUSIONS

From this study, it is observed through untreated soil samples that the study area has predominant in clay but through the treated soil samples, it is observed that predominant soil is silt. In general, it has been seen that after the treatment of the soil sample, all the particles should come in their own original size. It means all the flocculated/clogged particles break into smaller particles after treatment. In this case, the distribution shows that the clay particles are nothing but carbonates and iron, which were washed out at the time of treatment and remaining samples are silt and sand. It means the original soil samples in field have predominant in clay, which is nothing but carbonates and iron of smaller size. Soil survey organization of M. P.'s Govt. has also showed that about 90 % of the area are containing mostly clay. Consequently the hydraulic conductivity values are also low in accordance with the clay texture of the soil.

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