RAIN WATER HARVESTING IN SANDY SOIL RESERVOIR (POND)

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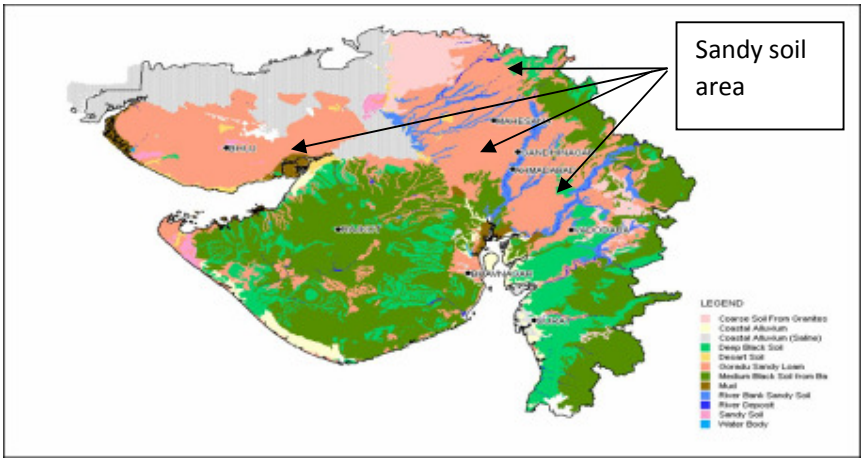
ABSTRACT: *water resulting in augmentation of pressure on the permitted freshwater resources. Ancient method of damming river and transporting water to urban area has it own issues of troubles of social and political. In order to conserve and meet our daily demand of water requirement, we need to think for alternative cost effective and relatively easier technological method of conserving water in Sandy soil area of north gujarat. First of all, required data are collected i.e. catchment areas & hydrological rainfall data. Water harvesting potential of sandy soil strata and reservoir capacity with suitable design is being considered. Finally preparing a reservoir bed with appropriate method in detail.*

Keywords: Details of Sandy soil in north gujarat area, Laboratory test on clay, design of impermeable bed, Comparison, Conclusion

1) Introduction: In north Gujarat water resources are less than the water requirement. surface water is not available in sufficient quantity. Also in this region no perennial river exists. Hence ground water utilized as the main sources for agriculture, irrigation, industrial and domestic purposes.
Ground water table is being reduced rate of 3 to 5 m per year, as the removal of water is more than recharge in these regions. In north Gujarat more power electricity consumed as ground water is removal from the depth of more than 300 mt, through tube well. About more than 40% of total power consumption in the state is only for water removal salinity of ground water poses a serious problem, due to water removal from the high depth of the earth. More than 2500 habitations have been reported as having problem of salinity per year. In a view of above Gujarat faces quantity/quality contamination problem of salinity, fluoride and nitrates. This is difficult task to ensure safe and protected water supply to the community. In north Gujarat available district as banaskantha, patan, Mehasana, sabarkantha. Water supply of these region through dhroi dam. And tubewell. People of north Gujarat depend on dharoi dam for the water requirement. Water supply through the dharoi dam only 2 hours per day in various palaces in north Gujarat. It is limited water supply source. And part of places of north Gujarat used tube well for get water from the ground water. So ground water depth is increases in now a days. North Gujarat is water scarcity region declare by the govt of Gujarat. However, scientific management of water resources with emphasis on artificial recharge or improvement in recharge system will address the problem of water scarcity. So, addressing the problem of water scarcity improvement in reservoir pond to make and design of impermeable layer of the reservoir bed. With cost effectively and less time consume during construction method adopted.

. Figure 1.1 Map of sandy soil reservoir.

Map of Study area:



. Figure 1.1 Map of sandy soil region

Details of Study area:

Soil: Mostly red sandy soils are seen in the study area. The rate of infiltration through such soils is relatively fast. The thickness of the soil, on the whole is within 1 m. Further south, very much outside the study site, the regional geology changes from a dominantly hard-rock.

Temperature: After mid-March, normally there is a rapid rise in temperature. May and first half of June are the hottest months. Temperature shoots up to 45 ^{0}C in the month of May and remains around that for about a month. Even the night temperature is about 35^0 C during that period. After October both night and day temperature decreases to 20 ^{0}C and 32 ^{0}C respectively. Cool months are from mid December to mid-February

Rainfall and Evaporation: The average annual rainfall is around 680 mm but is highly variable. The monsoon occurs by the second week of June. July and August are the peak monsoon months. About 80% of the rainfall occurs in these two months. The highest rainfall of 1458 mm was experienced in 1994.Similarly, the lowest rainfall of 309 mm was experienced in 2002.

Scope of work: Development of rain water harvesting in sandy soil reservoir in region of north Gujarat. For rain water harvesting in reservoir applying various method like as preparing a impermeable layer of reservoir soil. and design of impermeable bed of reservoir.

2) Literature Review:

On literature Paper Soil amelioration techniques for improving runoff characteristics of soils for better water harvesting are available and include using plastic sheets, bitumen spreads, concrete layers and chemical additives mixed into the top soils to improve bonding of the soils particles. The use of less permeable soils as a top layer dressing to reduce infiltration and enhance runoff. This will especially be useful in areas with sand, sandy loam and loamy sand soils having high infiltration rates. Various locations in Ghana especially along the coastal stretch of the country and in some inland valley alluvial plains could benefit from this process if these areas are consciously lined with laetrile and clay soils[2].

The water resources most important issue today the country is divided into hydro rich and poor rich regime and both cases local technology has been maintaining all kind of water stress. local technology like artificial reservoir, Tube well ,Infiltration galleries.

3) Methodology:

- Literature study of various rain water harvesting technique.
- The first step is to work out the water requirement for various needs.
- Collection of rain fall data.
- Preliminary test on Clay sample.
- Prepare reservoir bed with clay, lime, fly ash
- Test of bed for permeability.
- Calculate catchment area of reservoir.
- Calculation of harvest water.
- Cost analysis and comparision.
- Conclusion.

4) Data Collection:

Water requirement of various needs: The quantity of water required for the domestic use mainly depends on the habits, social status, climatic condition and custom of people.

Table 4.1 Per capita consumption

Use	**Demand in L / H / D**
Domestic use	135
Industrial use	50
Commercial use	20
Public use	10
Losses , wastage , thefts	55
Total	**270**

This quantity of water (270 l/h/d) when multiplied with the population of the town shall give the total quantity of water required by the per day. In north Gujarat include Mahesana, banaskantha, and patan district.

Table 4.2 Water need per day[1]

Sr.No	**District Name**	**Population**	**Water need liter per capita per day for Domestic use**
1	Patan	133,736	18.05×10^6
2	Mehasana	184,132	24.85×10^6
3	Banaskantha	2,504,246	338×10^6
4	Sabarkantha	2,427,347	327.70×10^6

Annual Rainfall data of North Gujarat Region:

Table No 4.3 Rain fall data[2]

District/ Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Patan	282	720	603	750	1675	1005	763	287	671	765	563	865
Sidhdhpur	238	541	468	2029	1397	1290	570	363	912	725	339	991
Chansama	142	495	526	824	566	595	426	256	480	549	276	641
Harij	180	805	517	702	766	835	554	303	461	685	316	771
Sami	163	880	356	729	685	1065	600	263	880	525	320	776
Palanpur	250	843	411	781	629	560	344	254	882	688	452	729
Radhanpur	209	989	453	427	1107	989	576	576	311	825	178	1137
Total in mm	**1464**	**5263**	**3334**	**5247**	**6825**	**6369**	**3833**	**2037**	**5111**	**5020**	**2444**	**5910**
Avg in mm	**209**	**752**	**476**	**749**	**975**	**909**	**548**	**291**	**730**	**717**	**349**	**844**

Table 4.4 Rain fall data

Sr .No	**Sub - Region**	**Rainfall (mm)**
1	Southern Hills	1500 above
2	South Gujarat	1000 to 1500
3	Middle Gujarat	800 to 1000
4	**North Gujarat**	**400 to 700**
5	North Saurashtra	400 to 700
6	South Saurashtra	645 to 700

Infiltration Rate of various Soil : Above data get information about water requirement per day of study area. Annual rain fall of sandy soil region. Infiltration rate of particular soil. In sandy soil region infiltration occur high, so decrease infiltration rate in sandy soil reservoir providing impermeable bed. The aims of this research are to design and develop Impermeable bed according to head and area of reservoir so, decrease infiltration rate and harvesting water by preparing impermeable layer. For Prepare Impermeable layer using clay or fly ash, water proofing chemicals or pvc coating. After prepare Impermeable layer then perform various type of testing to check permeability of layer. For prepare impermeable layer colleting clay sample from deep black soil region.

Table 4.5 Infiltration rate[3]

Soil type	Basic infiltration rate (mm/hour)
Sand	less than 30
sandy soil	20 – 30
Loam	10 – 20
clay loam	5 – 10
Clay	1- 5

Losses in Reservoir Pond:

1.Evaporation Losses: These mainly depend on the reservoir(pond) surface area. The other factors influencing these losses are temperature, wind velocity, relatively humidity. In north Gujarat in summer highest temperature about 46^0 c to 49^0 c. at that time duration maximum evaporation occurs. The evaporation losses sometimes become enormous and certain chemical compound such as hexadecanol are sprinkled over the surface of water, so reduce the activity of evaporation from the pond.

Table 4.6 Evaporation Rate[4]

Sr,No	Month	Evaporation in cm
1	December to March	10 to 18
2	April to August	18 to 25
3	September to November	10 to 15

2. Percolation losses or Leakage:

In certain particular cases, when the walls of reservoir pond are made of badly fractured rocks or having continuous seams of porous strata, serious leakage may occur.Sometimes pressure grouting may have to be used to seal the fractured rock. The cost of grouting has to be accounted for, in economy of the project, if the leakage is large.

3.Growth of Vegetation and bushes:

The removal of trees, bushes and other vegetation from the reservoir area is known as reservoir clearance.
It is an expansive operation and difficult to be justified on cost – benefit consideration.
Non – clearance of such vegetation may create decay of oraganic material may create undesirable odours and tastes, and hence, important for water supply reservoir pond.
Bushes, trees etc will float and may create debris problem at reservoir site.

Permeability of soil[5]

Permeability is defined as the property of soil which permits flow of water through it. A soil is highly pervious when water can flow through it easily .e.g. **Gravels.** In an impervious soil, the permeability is very low and water can-not easily flow through i.e. **Clays.** Rocks and clays are impermeable.
seepage is the flow of water under gravitational forces in a permeable medium.

Table 4.3 Permeability of Soil

Sr.No	Soil Type	Coefficient of Permeability (K) cm/sec
1	Gravel	1.0 and greater
2	Coarse Sand	$1.0 – 1 \times 10^{-2}$
3	Fine Sand	$5 \times 10^{-2} – 1\times 10^{-3}$
4	Silty Sand	$2\times 10^{-3} – 1\times 10^{-4}$
5	Silt	$5\times 10^{-4} – 1 \times 10^{-5}$
6	**Clay**	**1×10^{-6} and smaller.**

Conclusion of collecting data: Above data get information about water requirement per day of study area. Annual rain falls of sandy soil region. Infiltration of particular soil. In sandy soil region water not harvesting in reservoir because infiltration rate occur is high, evaporation rate high due to high temperature and minimum rainfall in study area, not providing water for various purpose so decrease infiltration rate in sandy soil reservoir by providing impermeable bed. For Prepare Impermeable layer using clay, fly ash, lime, water proofing chemicals or pvc coating. After prepare Impermeable layer then perform various type of testing to check permeability of layer. For prepare impermeable layer colleting clay sample from deep or medium black soil region.

Region of black soil (Clay) :

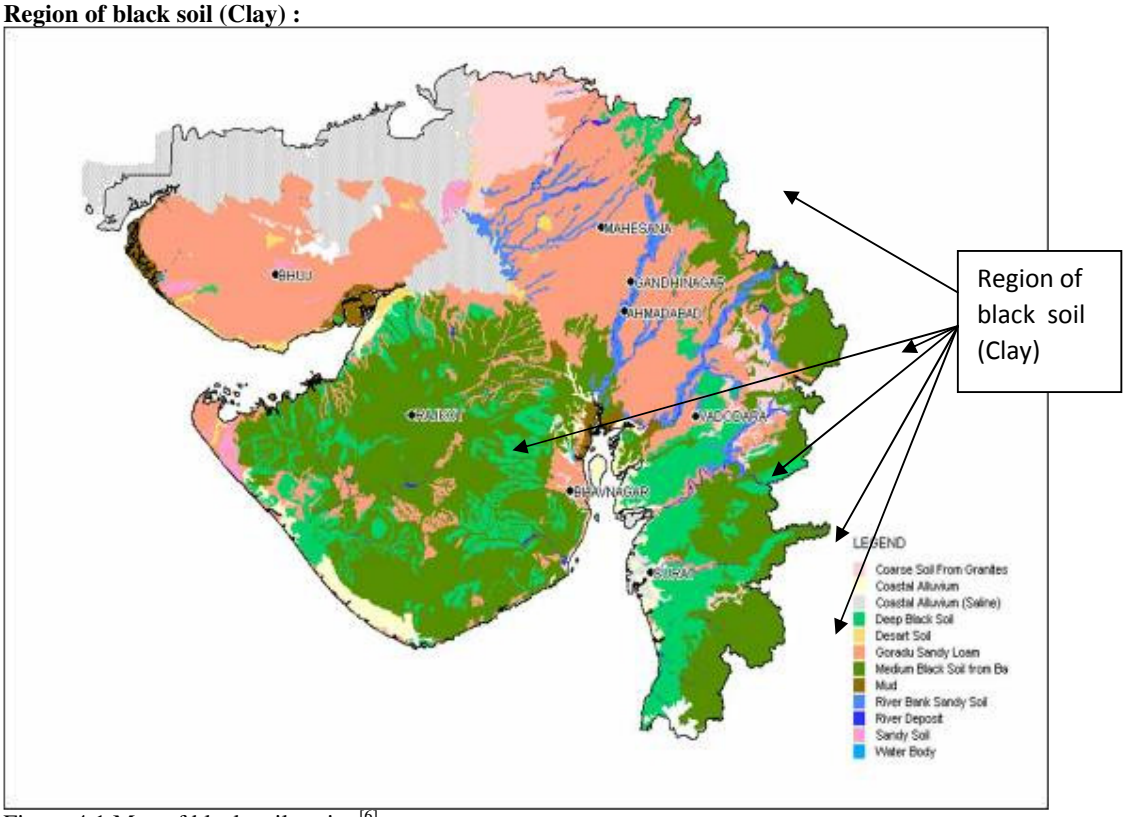


Figure 4.1 Map of black soil region[6]

The Medium black soils: They are residual soils having basaltic parent material. They are found largely in **sabarkantha** and **panchmahal district**, developed from granite and gneiss parent material.The color of soils varies from dark grey to light grey, are silty to clay in texture, with neutral to alkaline in reaction.The depth varies from 40 cm.

The Deep black Soils: These soils formed through deposition of basaltic trap material transported by river.They are dominating in the district of **bhavanagar**, **surat, valsad** and south **vadodara**. The depth varies from 60 cm to as few meters. The soils are dark grey brown colour , containing 60 -70 % clay.

Preliminary test on Clay sample:

Table No 4.7 Test result

Sr.No	Description	Result
1	Grain size distribution	**99% Silt and Clay present in sample**
2	Liquid limit	**65%**
3	Plastic limit	**27**
4	shrinkage limit	**17.1**
5	Standard Proctor test	**1.69 gm/cc dry density And 20.7 % moisture content**
6	Free swell index	**47.5 %**
7	Permeability test	**10^-7 cm/sec**

Collection of material: For design impermeable bed of reservoir with, clay, fly ash, lime

Collection of clay: Black cotton soils are clays of high plasticity; they contain the clay mineral montmorillonite. These soils have high shrinkage and swelling characteristics, and highly compressible.These soils have formed from the basalt rocks. In Gujarat these soil available at sabarkantha, panchmahal district,

Bhavnagar and south Gujarat.Color of these soils varies from dark grey to light grey. Quantity of clay soil available in Gujarat is 3200 in lacs tons. Clay soils easily available in nature only calculate transportation cost.

Collection of Fly-ash: Fly ash produced from the burning of lignite or sub – bituminous coal, in addition to having pozzolanic properties, also has some self – cementing properties. Raw material required are fly-ash a byproduct of thermal power station, hydrated lime , gypsum, locally available at Redy mix concrete plant. The rate of fly ash per cum 7.00 Rs. Based on S.O.R of Ahmedabad.

Collection of Lime: Lime is calcium oxides, which used extensively for waste water treatment with ferrous sulfate. Lime has many complex qualities as a building product including workability, flow ability, bond strength and reduce cracking in soil. Lime generally available at Building material Shop. Lime is very cheap building material it 's rate is 5 kg per 25 Rs as per S.O.R. of Ahmedabad.

5) Design :

- Mixing of clay, fly ash, lime
- Design of bed of Reservoir
- Stability of Slope of Reservoir
- Test of bed after design

Mixing:

Figure 5.1 Test Specimen of Plastic and Liquid limit

Table 5.1 Mix Proportion

Sr. No	**Clay**	**Lime**	**Fly ash**	Liquid Limit	Plastic Limit	Plastic Index
1	**60**	**5**	**35**	46	28.79	19.21
2	**40**	**10**	**50**	45	25	20
3	**30**	**10**	**60**	47	26	19
4	**20**	**20**	**60**	47	29	18
5	**88**	**2**	**10**	56	33	23
6	**88**	**4**	**10**	56.5	34	22.5
7	**78**	**2**	**20**	53	32	21
8	**76**	**4**	**20**	53	30	23

Above mixing Proportion got liquid limit, plastic limit Moderate. Liquid limit range should be 40 to 48 % here 45 to 48 %. So mix the proportion is unique. Take above any Proportion for making reservoir bed. Mixing in Proper way till liquid limit should be range of 40 to 48 **%,** because soil containing high water content is in liquid state, It has no shear strength. The minimum water content at which soil start getting shear strength, is called liquid limit of soil. As the water content is reduced, the plasticity of soil also decreases.

Select proportion is 60 % clay, 35 % fly ash, 5 % lime. It's liquid limit 46, Plastic limit 28.7 and Plasticity index 19.21.

Decide Thickness of reservoir bed:

Thickness of bed changing according to head of reservoir. Thickness of bed decided by falling head permeability equation.[**($2.3\ aL \log h_1/h_2$) / At].** Thickness of bed layer assume till permeability of soil 10^-7 coming.

Here, a = area of rainfall

L = Thickness of bed layer

H_1 = Total head of reservoir with thickness of bed

H_2 = Head of reservoir without thickness of bed

A = Area of Reservoir, T = time duration, K = permeability of bed.

Table 5.2 Different Head

Sr.No	Head	**Thickness of bed**
1	5 m	**0.42 mt**
2	10 m	**0.84 mt**
3	15 m	**1.26 mt**
4	20 m	**1.68 mt**

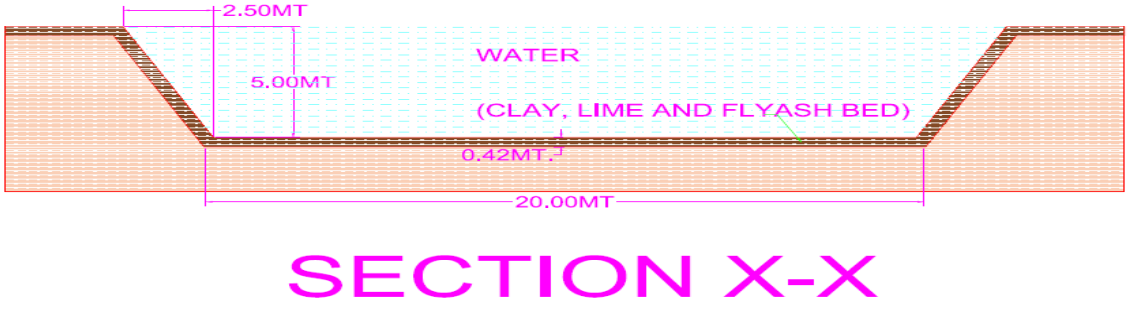
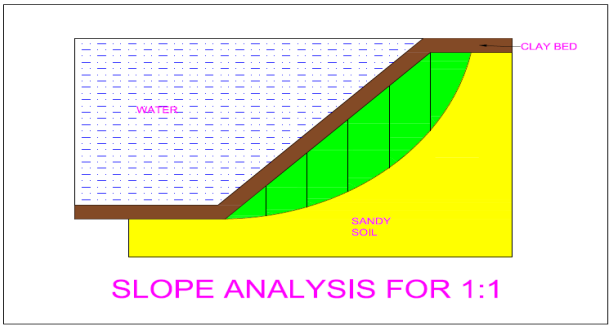
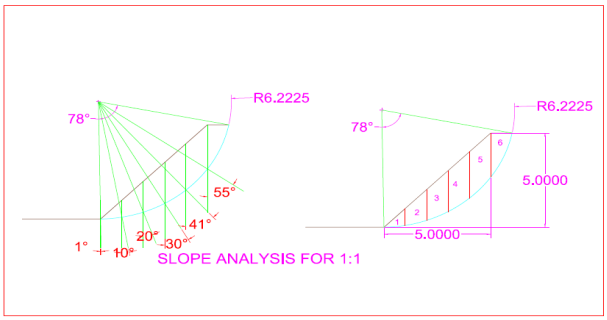


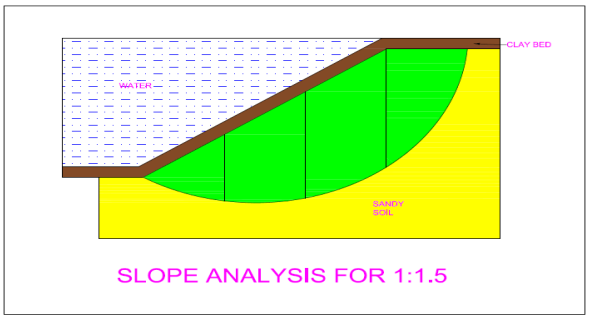
Figure 5.1 Reservoir Pond

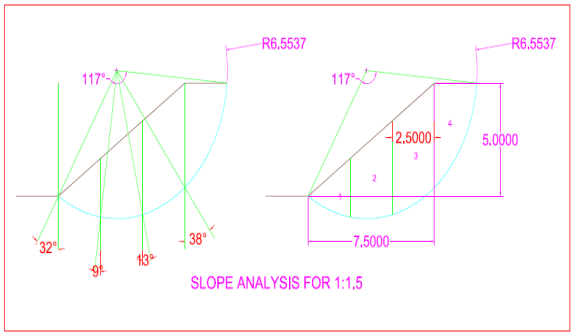
Suitable slope of Reservoir bed[7]:

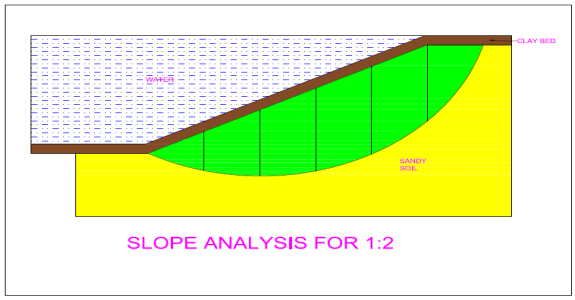
Conclusion of analysis of slope at different head. Analysis of slope done by Swedish circle method. If factor of safety is less than 1, slope is failure. If factor of safety is more than 1, slope is safe.











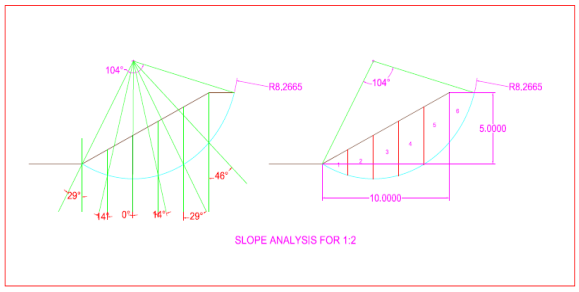


Table:5.3 Conclusion of slope

Sr.No	Head (m)	Slope	Factor of safety	Remarks
1	5	1:1	0.77	Slope Fail
2	5	1:1.5	3.15	ok
3	5	1:2	2.1	ok
4	10	1:1	0.76	Slope Fail
5	10	1:1.5	1.31	ok
6	10	1:2	2.73	ok

The circle which gives the **minimum** factor of safety **is the most critical circle. For 5 m** head maximum factor of safety **1:1.5 Slope is safe**, minimum factor of safety **1:2 Slope is critical**.
For 10 m head maximum factor of safety **1:2 Slope is safe**, minimum factor of safety **1:1.5 Slope is critical**.

Table 5.4 Various Soil[8]

Soil Type	Slope (horizontal:vertical)
Clay	1:1 to 2:1
Clay loam	1.5:1to 2:1
Sandy loam	2:1to 2.5:1
Sandy	3:1

.

Design After Test of Sample:
Design Proportion is 60 % Clay, 35 % Fly ash and 5% Lime**.**
Table: 5.5 Test Result

Sr.No	**Type of test**	**Test Method Reference**	**Result Obtained**
1	**Grain size distribution**	IS :2720 - P-4	99% Silt and Clay present in sample
222 2	**Atterberg's Limit**	IS : 2720- P-5	
	Liquid Limit %		46
	Plastic Limit %		28
	Plasticity Index %		18
3	**Modified Poctor Test**	IS: 2720- P-8	
	Maximum Dry Density (gm / cc)		1.74
	Otimum Moisture Content %		16.8
4	**Permeability**	IS : 2720 P - 36	2.1 × 10^-6
5	**Box Shear Test**	IS : 2720 - P - 13	
	Cohesion (c)		0.06
	Angle of Internal Frictional		24
7	**Shrinkage Limit**	IS : 2720 - P - 6	19
8	**Free Swell Index**	IS : 2720 - P - 40	35

6) Cost Analysis:
Estimate:
If Reservoir pond length is 50 m and width is 50 m total area is 2500 sqm.
Providing Impermeable layer of 0.42 mt thickness.

Table 6.1 Measurement Sheet

Description of work	Length (Meter)	Width (Meter)	Depth (Meter)	**Quantity in m^3**
Mixing and Laying reservoir Bed	50	50	0.42	**1050**

Quantity of material used:

- **Proportion is 60% clay , 5 % lime , Fly ash 35 %**
- So Clay needs 630 m^3 in 1050 m^3 total quantity.
- Lime needs 52.5 m^3 in 1050 m^3 total quantity.
- Fly ash needs 367.5 m3 in 1050 m^3 total quantity.

Rates of materials:

Table 6.2 Material rate

Sr,No	Material	Rates
1	Lime (5 kg)	25 Rs.
2	Fly ash	7 Rs per cum
3	Clay	Only transportation charge 1500 rs per 20 km by tractor. Tractor capacity 4m^3 .

Calculation of Material cost:

Lime :

- Rate of lime is 5 kg per 25 rs.
- Density of lime is 481 kg/cum. Know the volume of lime 52.5 m^3. So mass of lime get in kg 25,252.5 kg .
- Get cost of 52.5 m^3 of lime is **1,26,262.Rs**.

Fly ash :

- Rate of fly ash given in S.O.R is 7 Rs per cum. So cost of fly ash is **2,572 Rs**.

Clay :

- Tractor capacity 4m^3 for loading material.
- Rate of tractor for transporting 20 km is 1500 rs with royalty charges.
- So cost of clay finally is **2,36,250 Rs**.

Table 6.3 Material Cost

Sr.NO	**Material**	**Total Cost of Material in Rs.**
1	Lime	1,26.262
2	Fly ash	2,572
3	Clay	2,36,250
	Total	**3,65,084 Rs.**

Rate Analysis:

Table 6.4 Rate Analysis

Quantity	**Description**	**Rate (based on S.O.R)[9]**	**Total Amount**	**Unit**
Quantity in 1050 m^3	Filling in Reservoir pond with selected proportion of clay, lime, fly ash of 42 cm thickness including watering, ramming, vibrating and consolidation etc complete..	100 rs/ cum	**1,05,000**	**Rs**
		Material cost	**3,65,084**	**Rs**
		Total	**4,70,084**	**Rs**

Here, Prepare 2500 sqm reservoir pond by 4,70,084 rs cost. Material cost not including only construction cost. Rate of construction cost base on S.O.R of North Gujarat.

Finally, budget of 1m^2 of reservoir pond cost = (total cost) / (2500 sqm)

= (4,70,084 / 2500)

= 188 **Rs. For 1m^2 area of reservoir pond**.

7) Comparison:

➢ Reservoir pond with clay bed, use pcc bed , Rcc bed and Ldpe sheet use in reservoir pond bed for harvesting rain water.

Table 7.1 Comparison

Sr.No	Method use	Cost regarding to 1m^2 Area
1	Clay ,Lime, Fly ash bed	188 Rs per sqmt
2	Plain cement concrete (Pcc) bed	840 Rs per sqmt
3	Reinforced cement concrete bed (Rcc)	2100 Rs per sqmt
4	LDPE plastic Sheet Bed	340 Rs per sqmt

➢ Provide clay bed cost around 188 Rs per sqmt is very cheap and eco friendly. Maintenance is very less, No skilled labor is required, and less time consumption during construction.

➢ Provide RCC Cement bed cost around 2100 Rs per sqmt is very high amount without calculate steel reinforcement quantity.

➢ Provide Pcc bed cost around 840 Rs per sqmt.

➢ In cement bed highly amount of water absorption. Due to high temperature, heat of hydration more generate in cement bed so water seepage from the bed. Skilled labor required during construction and more time consumption in construct.

➢ Low density polyethylene sheet cost 340 Rs per sqmt. It effective and cheap method for harvesting rain water but some precaution needed in this method like don't use hook also don't drag the sheet. Don't walk on the sheet while it is being laid. Don't use rough tools or equipments for cleaning, while constructing pond, make sure there are no trees near the pond. Less time consumption and skilled labor is required during construction.

8) Conclusion:

➢ The arid and semi-arid district of north Gujarat –Mehsana, Patan, Banaskantha, Sabarkantha and kutch receive an average of 400 to 700 mm of rainfall in about monsoon period. Drought is a recurring phenomenon in these regions. Approximately 12,000 villages of north Gujarat suffer from severe water scarcity every year. In north Gujarat soil is sandy soil so rain water directly infiltrate to the soil. So Design of impermeable reservoir pond bed to harvest rainwater for various purpose.

➢ In this table shows District wise village provide 2500 sqm area of reservoir pond and storage water and use of water per day in year by applying impermeable layer of bad.

Table: 8.1 Storage of water.

S.No	District Name	No. of Villages	Reservoir area	Total Rainfall	Evaporation Co-efficient	Soil Co-efficient	Storage water	Use of water per day in year
			Sqm	in m			liters	liters
1	Banaskantha							
		1250	2500	0.7	0.8	0.35	612500000	1678082.19
2	Patan							
		525	2500	0.7	0.8	0.35	257250000	704794.52
3	Mehsana							
		616	2500	0.7	0.8	0.35	301840000	826958.90
4	Sabarkantha							
		1395	2500	0.7	0.8	0.35	683550000	1872739.73
5	Kutch							
		939	2500	0.7	0.8	0.35	460110000	1260575.34
						Total	2315250000	6343150.685

➢ In total 5 district of North Gujarat can store water 2.31×10^9 liters water. These water uses for various purposes like irrigation, domestic, commercial and public uses, without use of large amount of cost. Making an impermeable layer of clay with fly ash and lime in Sandy soil reservoir is cost effective and not required any skilled labor during construction. Reduce infiltration rate of sandy soil using clay layer. Making smooth surface of clay layer using fly ash and reduce crack in clay layer during summer using lime.

➢ This type of reservoir widely adopt in arid and semi arid region where rain fall is minimum during rainy season.

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8..National Initiative on Climate Resilient Agriculture Central Research Institute for Dryland Agriculture Santoshnagar, Saidabad, Hyderabad – 500 059, A.P., India Web:www.crida.in
9. Material rates from S.o.r 2013 ahmedabad.
For soil test refer IS code 2720 and http://www.rainwaterharvesting.org/index.html