ADSORPTION OF METHYLENE BLUE FROM AQUEOUS SOLUTIONS ONTO PONGAMIA PINNATA BARK DERIVED CARBON: KINETIC, EQUILIBRIUM ANDTHERMODYNAMIC STUDY

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ABSTRACT

The present research work investigated the adsorptive characteristics of Methylene blue (MB) dye from the aqueous solutions onto Pongamia pinnata bark carbon (PPBC). Batch adsorption studies were carried out to determine the influence of parameters like adsorbent dose (m), initial pH (pH_0), contact time (t), initial concentration (C_0) and temperature (T) on the removal of MB. Optimum conditions were found to be: m = 2 g/L, pH_0 = 7.2 and t = 60 minutes. Pseudo second order kinetic model represented the adsorption kinetics of MB onto PPBC. The adsorption equilibrium isotherms were studied by Langmuir, Freundlich, Temkin, Redlich-Peterson, Toth and Radke-Prausnitz models. The positive values of standard entropy change (ΔS^0) and heat of adsorption (ΔH^0) indicates randomness and endothermic nature of adsorbent for MB; and the negative values of Gibbs free energy change (ΔG^0) indicate feasible and spontaneous adsorption of MB onto PPBC.

Keywords: *Adsorption kinetics, Adsorption thermodynamics, Isotherms, Methylene blue, Pongamia pinnata bark carbon.*

1. Introduction

Dyes and dyestuffs are extensively used in various industries such as textile, printing press, plastic, food, cosmetic, carpet and paper. The dyes which are available commercially are more than ten thousand and approximately up to seven hundred thousand tons of dyes are produced annually (Zolinger, 1987). Textile industry itself consumes more than 80 percent of the total production of dye stuff making it the largest consumer (Arokiaswamy, 1994). Around 10-15 percent of textile dyes used are released in wastewater streams, making the effluent highly colored and aesthetically unpleasant (Dod et al., 2012). Hence, the presence of dyes in wastewaters is one of the major complex environmental problems. It is therefore utmost necessary to treat these dye-based wastewaters before its disposal (Gottipati & Mishra, 2010).

Methylene Blue (MB) dye, which is categorized as cationic/basic dye, is widely used in printing press, textile industries, etc. for colouring paper, dying wools and cottons, and for coating of paper stocks (Han et al., 2009). It is found to have some hazardous effects on living things. It is toxic to blood, lever, reproductive system, upper respiratory tract, central nervous system, skin and eye contact (Oliveira et al., 2008). Various physico-chemical processes have been found to be considerably effective in the treatment of these dye-based wastewaters (Lakshmi et al., 2009), however with some short comings.

The process of adsorption, has been proven to be an appealing and effective treatment method for dye-based waste waters (Hubbe et al., 2012; Hesas et al., 2013).It is arising as a promising technology due to its merits, viz., economical, simplicity, easy to use, no sludge formation, regeneration capacity of the adsorbent and superior-quality product (Choy et al., 1999). Activated carbon (AC) is the most common and widely used adsorbent due to its inherent properties. Adsorption technique has been successfully used by Al-Husseiny (2014) and DjatiUtomo et al. (2015) in the removal of MB dye from water and wastewater.

Pongamia pinnata bark obtained from Pongamia pinnata (*Karanja*) tree as an agricultural waste have lignocelluloses characteristics which aids in its adsorptive properties. Karanja bark has been used for the adsorptive removal various impurities like Lead, Copper, Zinc and Ferrous & Ferric ions (Mamatha et al., 2012a, b, 2013a, b). In this study an attempt has been made to explore the possibility of using PPBC for the removal of MB from the aqueous solutions in batch experimental studies. The effect of parameters like adsorbent dose (*m*), initial pH (*pH_0*), contact time (*t*) & initial

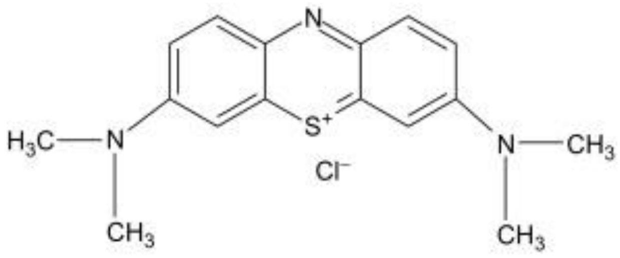


Figure-1: Molecular structure of Methylene

MB concentration (C_0) and temperature (T) on the adsorption of MB on PPBC has been investigated.

2. Materials and Methods

2.1. Adsorbent

Pongamia pinnata bark was obtained from the trees within the area of Laxminarayan Institute of Technology Campus, Nagpur, India. The bark was then cut and chopped into pieces, sun dried for 3-4 days and then oven dried at 105^0C for 12 hours in hot air oven. Dried pieces of bark were ground well to get fine powder and used as a precursor. The bark powder was chemically activated with orthophosphoric acid (H_3PO_4) in the weight to volume ratio of 1:1 (w/v in g/mL) for 24 hours. This mixture was then charred at 450^0C in muffle furnace for 1 hour to complete the carbonization and activation process. The resulting carbon was then washed thoroughly with doubled distilled water (DDW) till a neutral pH of the slurry was obtained. The carbon was then oven dried at 105^0C for 12 hours. The dried material was ground well to fine powder and sieved (Indian Standard Sieve IS460) in the size range of 150–300 μm (Sujatha et al., 2008; Tarawou et al., 2014) and stored in air tight container for further use further referred as Pongamia pinnata bark carbon (PPBC).

2.2. Adsorbate

The adsorbate Methylene blue (C.I. = 52015, Chemical formula = $C_{16}H_{18}N_3ClS$, Molecular weight = 319.85 g/mole and λ_{max}= 663 – 667 nm) a cationic dye was supplied by Merck Specialities Pvt. Ltd., India. The dye was of analytical grade (AR) in the form of dark green powder. The structure of MB is illustrated in Figure 1. The stock aqueous solution (1000 mg/L) of dye was prepared by dissolving an accurately weighed 1 g MB dye powder in 1000 mL of double-distilled water. Aqueous solutions of different concentrations required for experimental work were prepared by successive dilutions of stock solution with DDW.

2.3. Characterization of adsorbent

The physico-chemical properties of PPBC were analyzed by adopting standard analytical procedures. The particle size analysis was performed using IS Sieve IS460. Proximate analysis was done as per IS method (IS: 1350-Part 1, 1984) and Ultimate analysis was performed using Vario EL Cube (Elementar, Germany) CHNS elemental analyzer. Brunauer, Emett and Teller (BET) surface area and pore volume of PPBC was analyzed by ASTMD-3663-03 standard test by using ASAP 2020 (Micrometrics, USA) Surface area & porosity analyzer (Brunauer et al., 1938). The point of zero charge (pH_{pzc}) was obtained by solid addition method (Kushwaha et al., 2014). Scanning Electron Microscopy study of blank and loaded samples with MB were taken by 6380A (JEOL, Japan) Scanning electron microscope adopting secondary electron imaging method. FTIR Spectrum of blank and loaded samples with MB, were studied at room temperature. IR-Affinity FT-IR Spectrophotometer (Shimadzu, Japan), adopting pellet (pressed disk) technique was used for the analysis. X-ray diffractographs were obtained using MiniFlex II Desktop X-ray Diffractometer (Rigaku, Japan).

2.4. Analytical measurements

A UV-VIS double beam spectrophotometer UV-2450 (Shimadzu, Japan) has been used to determine the concentrations of dye samples by detecting the absorbance at the characteristic wavelength. The wavelength showing maximum absorbance (λ_{max}) as determined from this plot was 664nm. The standard curve of concentration of MB dye versus absorbance (not shown here) was prepared using this wavelength. Samples showing a high concentration of MB dye (> 0.600 absorbance) were diluted with double-distilled water to obtain an accurate MB concentration with the help of linear portion of the calibration curve.

All readings were taken twice and the mean values were presented.

2.5. Batch experimental studies

Batch adsorption studies were performed to see the effect of important parameters like adsorbent dose (*m*), initial pH(pH_0),contact time(*t*)& initial concentration (C_0) and temperature (*T*) on the sorption of MB. For each test run, 50 mL of MBof known concentration, pH_0 and a known adsorbent dose were taken in 250 mL stoppered conical flask. This mixture was stirred at 150 rpm at 303±1K in a temperature controlled Orbital Shaker. At set times the solutions were extracted and filtered throughWhatmann No.1 filter paper. The supernatant slurry thus obtained was analyzed for the residual dye concentration. Tofind the optimum dose of absorbent, 50 mL of MB of known concentration was stirred with different doses of PPBC in orbital shaker till it reached equilibrium stage. To study the effect of pH_0 on the MB adsorption process, adsorption tests were performed in thepH_0 range of 2 – 12. The pH_0 was maintained by adding required amount of 0.1N HCl and 0.1N NaOH solutions. The kinetic study was performed by analyzing adsorption of the MB from aqueous solutions at set time intervals. This was done repeatedly forvarying concentrations of dye solution. For adsorption isotherms, MB solution of different concentrations was stirred with optimum dose of adsorbent till the equilibrium was obtained. The effect of temperature on sorption of MB was studied by determining adsorption isotherms at 283, 293, 303, 313 and 323K temperatures with C_0ranging from 50 - 500 mg/L.

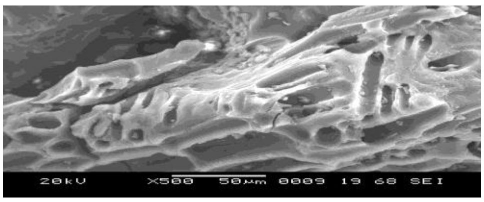
3. Results and Discussion

3.1. Characterization of PPBC

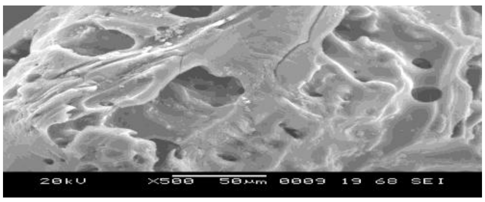
The average particle size of PPBC was found to be 225 µm. Proximate analysis of PPBC showed the presence of 4.80% moisture, 11.10% ash, 13.40% volatile and 70.70% of fixed carbon. Ultimate analysis showed 68.26% carbon, 4.28% hydrogen, 1.02% nitrogen, 0.14% sulphur and 26.30% oxygen in PPBC. The BET surface area was found to be 855.30 m^2/g and pore volume 0.188 cm^3/g. To understand the adsorption mechanism, it is utmost necessary to determine the point of zero charge (pH_{pzc}) of the adsorbent. Adsorption of cations is favored at $pH>pH_{pzc}$, while that of anions is favored at $pH<pH_{pzc}$. The pH_{pzc} of PPBC determined experimentally was 6.5, which is less than the natural *pH* (pH_0 = 7.2) of MB as found in further studies. PPBC is negatively charged for $pH>pH_{pzc}$, and an electrostatic attraction takes place between the negatively charged surface of PPBC and cationic dye, and thus favors the adsorption of cationic MB dye in the pH range of 6.5 – 12.

Scanning electron microscopy (SEM) of blank PPBC shown in Figure 2(a) reveals its morphological features and surface characteristics. The figure shows developed small circular pores on the external surface of the activated carbon. These pores have been developed due to evaporation of H_3PO_4 during the carbonization process (Hesas et al., 2013). However, the surface of PPBC becomes smooth with filled pores due to molecular cloud after loaded with MB as shown in Figure 2(b).

The Fourier transform infrared (FT-IR) spectroscopy is generally used to identify some of the characteristic functional groups that are capable of adsorbing organics. From the FT-IR analysis (Figure 3), it is clear that some organic functional groups disappeared and some new functional



(a)



(b)

Figure-2: (a) SEM of blank PPBC (b) SEM of MB loaded PPBC (500x magnification)

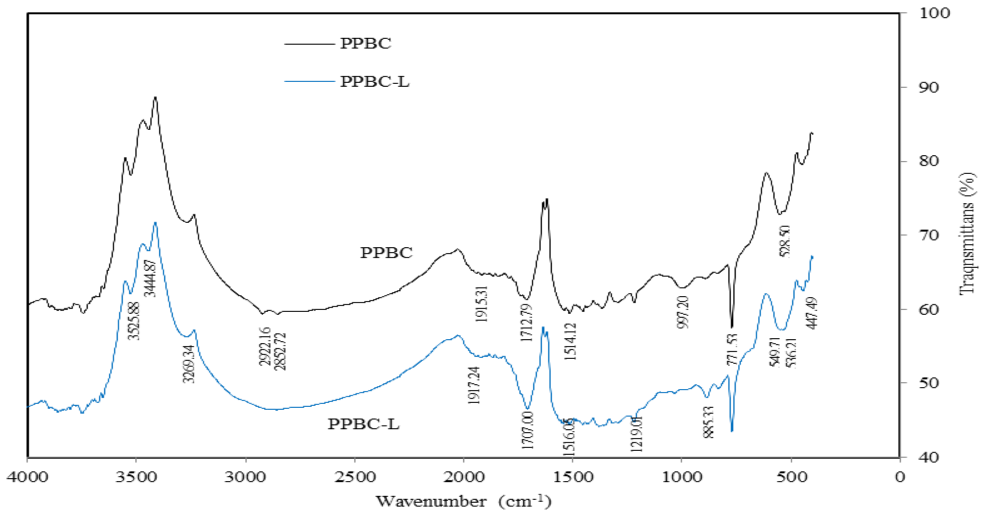


Figure-3: FT-IR spectra of PPBC in blank and MB loaded form

groups are formed after adsorption of MB. The bands around 3525.88 cm^{-1} and 3444.87 cm^{-1} can be assigned to stretching vibrations of (C=O) and (O−H) phenolic groups respectively. The peaks at 3269.34 cm^{-1} after adsorption of MB indicates the presence of stretching vibrations of (HN−H). Also, the loaded PPBC shows the complete disappearance of bands at 2922.16 cm^{-1} and 2852.72 cm^{-1} which were due to (C−H) group and (O−H) groups respectively. The peak appeared at 1917.24 cm^{-1} shows the strong stretching vibrations of (C=O) group. The bands at 1707 cm^{-1} indicates stretching vibrations of (C=N) group, and the stretching of (C−O) group is found at 1219.01cm^{-1}. The band at 997.20 cm^{-1} is disappeared which was due to (C−C) stretching. The split band can be observed at 771.53 cm^{-1}, which is due to stretching of (C−Cl) group.

X-ray diffraction technique is used to analyze the crystalline nature of the materials. If any material under investigation is crystalline, well-defined peaks are observed while non-crystalline or amorphous systems show a hallow instead of well-defined peak (Cullity, 1978). Figure 4shows the X-ray diffraction of PPBC in blank and loaded form, which shows hallow peaks indicating the amorphous nature of the adsorbent.

3.2. Effect of adsorbent dose (*m*)

The effect of *m* on adsorption of MB by PPBC at C_0 = 50 mg/L and t = 60 mins. is shown in Figure 5. It was observed that the MB removal increases with increase in the *m* and then it remains almost constant with further increase in dose. Optimum *m* was found to be 2 g/L. The available adsorption sites (surface area) increase by increasing the dose of adsorbent and hence results in the increase of the amount of adsorbed dye molecules. Later on, all the active sites get occupied and hence percent removal becomes almost constant.

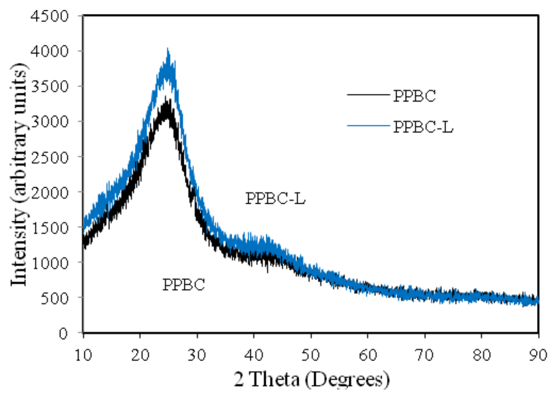


Figure-4: XRD spectra of PPBC in blank and MB loaded form

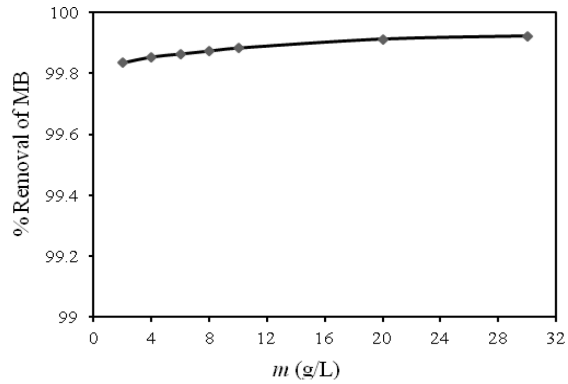


Figure-5: Effect of *m* of PPBC on removal of MB
(C_0= 50 mg/L, pH_0=7.2, t = 60 min, T = 303 K)

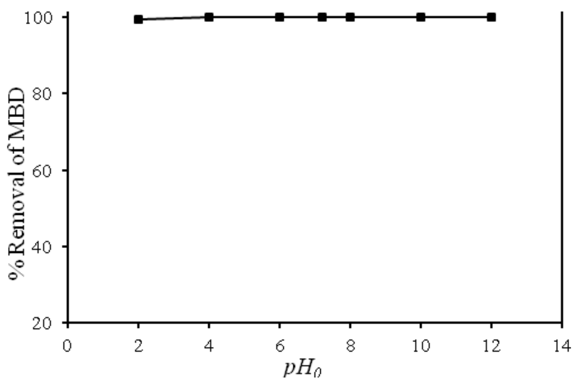


Figure-6: Effect of pH_0 on the removal of MB by PPBC
(C_0 = 50 mg/L, T = 303K, t = 60 min., m = 2 g/L)

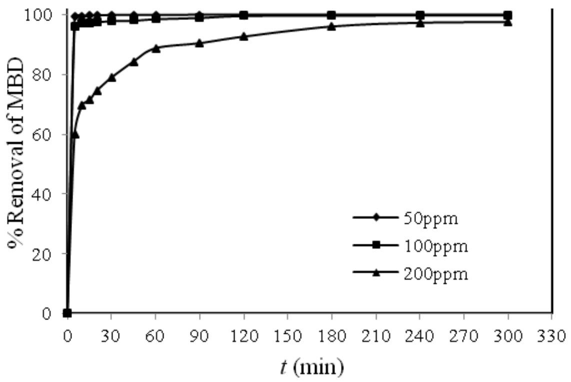


Figure-7: Effect of t and C_0on removal of MB by PPBC
(m = 2 g/L, pH_0 = 7.2, T = 303 K)

3.3. Effect of initial pH (pH_0)

The effect of varying $pH_0$of MB solutions of C_0 = 50 mg/L having natural pH_0= 7.2 was studied over a pH_0range of 2-12. Figure 6 shows the removal of MB dye with PPBC dose of 2 g/L and t = 60 mins. It can be inferred that the dye removal increased with increase in pH_0. PPBC doesn't show any significant change rather than slight increase in percent removal with increase in pH_0 value from 2 to 12. Thus, optimum pH_0 was taken as natural pH_0 = 7.2 for further studies. This can be understood by considering the electrostatic attraction that exists between negatively charged surface of adsorbent and MB, a cationic dye. Low adsorption at acidic $pH_0$was mainly due to the presence of excess H^+ ions competing with the dye cations for adsorption sites (Boumediene et al., 2015). At alkaline pH_0, the number of positively charged sites decrease and the number of negatively charged sites increase, thus favoring the removal of cationic dye. Similar results were observed for the adsorption of MB onto Fe (III) / Cr (III) hydroxide by Namasivayam and Sumithra (2005); various carbons by Kannan and Sundaram (2001); luffa cylindrica fibers by Kesraoui et al. (2017); alkali and microwave modified apricot stones by Namal and Kalipci (2019).

3.4. Effect of contact time (t) & initial dye concentration (C_0)

The effect of contact time on the removal of MB by PPBC at C_0= 50, 100 and 200 mg/L is shown in Figure 7. The figure shows that percent removal of MB increased with increase in contact time with the adsorbent, while it decreased with increase in initial concentration. Similar results were reported by Kesraoui et al. (2017) and Mabel et al. (2019) with other adsorbents.

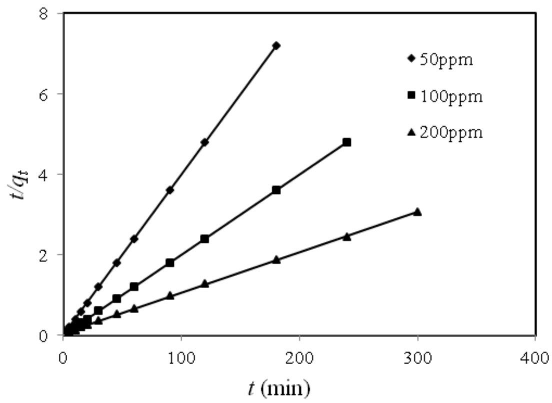


Figure-8: Pseudo second order plot for adsorption of MB on PPBC

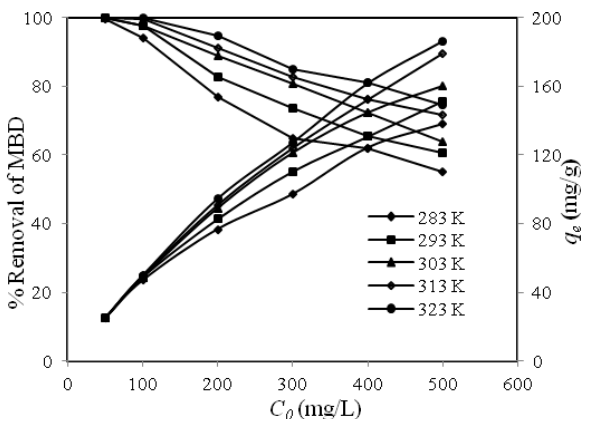


Figure-9: Effect of T and $C_0$for MB–PPBC System
(m = 2 g/L, t = 60 min, pH_0 = 7.2, C_0= 50 – 500 mg/L)

(*m* = 2 g/L, *pH₀* = 7.2, *T* = 303K)

PPBC showed rapid adsorption of MB within first 10 min. and then increased gradually attaining equilibrium after 60 min., beyond which there is no significant increase in the adsorption rate. Aggregation of dye molecules with the increase in contact time further makes it nearly impossible to diffuse deeper into the adsorbent structure at highest energy sites. This aggregation nullifies the influence of contact time as the mesopores get fully saturated and start offering resistance to diffusion of aggregated dye molecules in the PPBC. Thus, further experiments were carried out for optimum contact time i.e., t = 60 min.

3.5. Adsorption kinetic study

3.5.1. Pseudo-first order and Pseudo-second order models: The pseudo-first order equation (Lagergren 1898) is given as:

$$\frac{dq_t}{d_t} = k_f\,(q_e - q_t) \qquad (1)$$

where,

q_t= amount of adsorbate absorbed per unit weight of adsorbent at any time t (mg/g)

q_e= the adsorption capacity at equilibrium (mg/g)

k_f= pseudo-first order rate constant (min^{-1}), and

t = contact time (min.)

the integration of Eq. (1) with initial conditions,

C_0 = 0 at t = 0, leads to following equation:

$$\log(q_e - q_t) = log q_e - \frac{k_f}{2.303} t \qquad (2)$$

The $q_t$values at C_0 = 50, 100 and 200 mg/L were determined from the plot of $log\ (q_e - q_t)$ against t (not shown here). The values of $k_f$thus obtained (Table 1) for C_0 = 50, 100 and 200 mg/L are comparable to k_f values for MB sorption on modified pumice stone(Derakhshan *et al*. 2013). These values of $k_f$indicate that with increase in C_0, the adsorption rate increases.

The pseudo second order model (Ho &Mckay, 1999) is represented as:

$$\frac{dq_t}{d_t} = k_s(q_e - q_t)^2 \qquad (3)$$

Where, k_s = pseudo second order rate constant in g/mg min.

Integrating Eq. (3)and that q_t = 0 at t = 0, following equation is obtained:

$$\frac{t}{q_t} = \frac{1}{k_s {q_e}^2} + \frac{1}{q_e}\text{t} \qquad (4)$$

The initial rate of sorption, h (mg/g min) at t = 0 is defined as;

$$h = k_s {q_e}^2 \qquad (5)$$

Table-1: Kinetic parameters for the adsorption of MB onto PPBC
(*m* = 2 g/L, *pH₀* = 7.2, *T* =303K, *t* = 60 min)

Pseudo first-order model

C_0 (mg/L)	k_f (l/min)	$q_{e,cal}$ (mg/g)	R^2
50	0.016	0.094	0.792
100	0.021	2.031	0.973
200	0.026	48.139	0.945

Pseudo second-order model

C_0 (mg/L)	k_s (g/mg min)	$q_{e,exp}$ (mg/g)	$q_{e,cal}$ (mg/g)	h (mg/g min)	R^2
50	0.889	25.00	25.00	555.625	1.0
100	0.036	49.98	50.00	90.00	1.0
200	0.002	97.51	99.010	19.606	0.999

Intra particle diffusion (Weber- Morris) model

C_0 (mg/L)	k_{id} (mg/ g $min^{1/2}$)	C (mg/g)	R^2
50	0.013	4.854	0.651
100	0.136	8.136	0.917
200*	4.853	52.051	0.974
200	0.984	81.622	0.947

(*adsorption at initial stage)

The value of q_e is obtained from the slope of the plot of t/q_t versus t (Figure 8) at C_0 = 50, 100 and 200 mg/L; and h value is obtained from the intercept. As q_e is known from the slope, k_s can be determined from h value. The best fit values of k_s, q_e and h along with regression coefficients for pseudo first order and pseudo second order models are shown in Table 1. The regression coefficients (R^2) values of pseudo second order kinetics are very close to unity as compared to that for pseudo first order kinetics; hence the sorption of MB by PPBC can be approximated more appropriately by the second order kinetic model. Similar results with MB with different adsorbents have been reported by Mouni et al. (2018) and Liu et al. (2019).

3.5.2. *Weber- Morris intra particle diffusion model:* The kinetics of adsorption processmay be controlled either by one or more steps, i.e., film or external diffusion, pore diffusion, surface diffusion and pore surface adsorption, or a combination of more than one step. Weber and Morris (1963) explored the possibility of intra – particle diffusion by using intra particle diffusion model:

$$q_t = k_{id} t^{0.5} + C \qquad (6)$$

where, k_{id} is the intra-particle diffusion rate (mg/g min$^{0.5}$) and C (mg/g) is a constant. If the Weber-Morris plot (q_t versus $t^{0.5}$) satisfies the linear relationship with the experimental data, then it is found that sorption process is controlled by intra-particle diffusion only. While, the sorption process is influenced by two or more steps if the data exhibit multi-linear plots. The first steep portion is attributed to the diffusion of adsorbate through the solution to the external surface of the adsorbent or boundary layer diffusion of solute molecules. The second linear portion shows gradual equilibrium stage with the domination of intra-particle diffusion. The third linear portion features to final equilibrium stage in which intra-particle diffusion starts slowing down as very low adsorbate concentration left in the solution (Crank, 1965). Table 1 gives the best fit values of K_{id} and C along with their regression coefficients at C_0 = 50, 100 and 200 mg/L for Weber- Morris intra- particle diffusion model for the sorption of MB by PPBC. For C_0 = 50 and 100 mg/L, there is only one linear portion which depicts combined mesopore diffusion. And, for C_0 = 200 mg/L there are two linear portions, first depicting mesopore diffusion and the second representing micropore diffusion.

3.6. Effect of temperature (T) and initial concentration (C_0)

Variation in temperature gives a pronounced effect on the adsorption capacity of PPBC. The effect of C_0(50 ≤ C_0≤ 500 mg/L) and temperature T (283 ≤ T ≤ 323 K) on the sorption equilibrium of MB by PPBC at optimum conditions (m = 2 g/L, pH_0 = 7.2, t = 60 min.) was studied and a plot of C_0 versus q_e&%MB removal with temperature as a parameter is shown in Figure 9.In the present case it is found that the MB adsorption (q_e) from the aqueous solutions increased with an increase in C_0 and T, while the percent MB removal decreased with the increase in C_0. At optimum conditions, maximum 99.89 % removal is observed at C_0 = 50 mg/L &T = 323 K, and minimum 55.16 % removal at C_0 = 500 mg/L &T = 283K. And, the MB adsorption capacity (q_e) at optimum conditions is found to be minimum 24.925 mg/g at lower concentration (C_0 = 50 mg/l, T = 283 K) and maximum 186.368 mg/g at higher concentration (C_0 = 500 mg/L, T = 323 K).

Generally, sorption is an exothermic process, however if the adsorption process is controlled by diffusion process (intra-particle transport pore diffusion), the sorption process will increase with an increase in temperature due to endothermicity of diffusion process. Temperature rise enhances mobility of the adsorbate and a decrease in the retarding forces acting on the diffusing adsorbates, thus results in increased sorptive capacity of PPBC, partly attributing to chemo- sorption. The increase in MB sorption

capacity with increase in temperature by other adsorbents has been also reported by Hamdaoui and Chiha (2007); Sujatha et al. (2008); Gecgel et al. (2013); Meshram and Lataye (2014); Mouni et al.(2018); Namel and Kalipci (2019).

Table-2: Isotherm parameters for the adsorption of MB onto PPBC
(m = 2 g/L, pH_0 = 7.2, C_0 = 50-500 mg/L, t = 60 min)

Isotherm	Isotherm parameters	Temperature (K)				
		283	293	303	313	323
Langmuir:	q_m (mg/g)	140.845	151.515	163.934	178.571	185.185
$q_e = \frac{q_m K_L C_e}{1+K_L C_e}$	K_L(L/mg)	0.048	0.069	0.095	0.105	0.141
	R^2	0.956	0.970	0.987	0.968	0.973
	HYBRID	21.704	26.839	24.070	31.772	35.474
Freundlich:	K_F (L/mg)	35.297	39.275	45.282	51.321	57.564
$q_e = K_F C_e^{1/n}$	n	4.333	4.161	4.227	4.237	4.310
	$1/n$	0.231	0.240	0.237	0.236	0.232
	R^2	0.970	0.992	0.990	0.986	0.970
	HYBRID	-0.804	-0.237	-0.351	-0.415	-1.110
Temkin:	B_1	14.496	16.257	16.730	17.954	18.490
$q_e = B_1 InK_T + B_1 InC_e$	K_T (L/mg)	14.862	16.266	28.545	37.379	54.714
	R^2	0.846	0.903	0.899	0.909	0.926
	HYBRID	1.401	3.196	3.882	3.828	2.230
Redlich-Peterson:	K_R (L/mg)	893.00	783.00	1521.0	2504.10	1005.56
	β	0.800	0.800	0.800	0.800	0.800
$q_e = \frac{K_R C_e}{1+a_R C_e^{\beta}}$	a_R (L/mg)	22.430	17.291	28.818	44.957	13.202
	R^2	0.996	0.998	0.997	0.999	0.998
	HYBRID	0.171	2.356	-2.485	4.604	-14.564
Toth:	*Th*	-0.218	-0.077	-0.129	-0.009	-0.001
$q_e = \frac{q_{Th} C_e}{\left[\frac{1}{K_{Th}} + C_e^{Th}\right]^{1/Th}}$	q_{Th}(mg/g)	14.340	1.580	6.816	0.000	0.000
	K_{Th}(mg/L)Th	5.130	3.620	3.822	3.267	3.315
	R^2	1.000	1.000	1.000	0.999	0.997
	HYBRID	-0.186	-0.201	-0.096	0.765	7.717
Radke-Prausnitz:	P	0.597	0.642	0.750	0.640	0.671
$q_e = \frac{K_{RP} k_{rp} C_e}{1 + K_{RP} C_e^P}$	k_{rp}[(mg/g)/(mg/L)$^{1/P}$]	15.291	22.321	44.053	29.586	37.594
	K_{RP}(L/g)	1.970	2.635	5.159	3.930	5.019
	R^2	0.996	1.000	1.000	1.000	0.998
	HYBRID	38.734	36.879	15.483	42.038	42.118

3.7. Adsorption equilibrium study

In order to optimize the adsorption system for the removal of adsorbates from the solution, it is utmost important to establish the most appropriate correlation between the equilibrium curves. Isotherm provides information on the strength by which the adsorbate is held by the adsorbent. Different isotherm equations can be used to describe equilibrium nature of sorption. Many researchers have used Langmuir, Freundlich, Temkin, Redlich & Peterson, Toth and Radke-Prausnitz isotherms (Freundlich, 1906; Langmuir, 1918; Temkin &Pyzhev, 1940; Redlich & Peterson, 1959; Toth, 1971; Radke & Prausnitz, 1972) to represent equilibrium in adsorption process for various adsorbent-adsorbate systems.

The HYBRID fractional error function has been used in this study to determine the most suitable isotherm model representing the experimental data. It is given as (Porter et al., 1999):

$$HYBRID = \frac{100}{n-p} \sum_{n-p}^{n} \left[\frac{q_{e,exp} - q_{e,cal}}{q_{e,exp}}\right]_i \quad (7)$$

The isotherm constant for Langmuir, Frendulich, Temkin, Redlich-Peterson, Toth and Radke-Prausnitz; and the correlation coefficient R^2 with the experimental data are shown in Table 2. Langmuir constant K_L indicates the affinity of the MB dye to bind with PPBC, whereas q_m is the monolayer saturation at equilibrium. Higher the value of K_L higher is the affinity. The data depicted in Table 2 indicates that the values of $q_m$and K_L increased with an increase in temperature confirming theendothermic nature of sorption process for MB-PPBC system. Freundlich constants K_F and $1/n$ indicates the adsorption capacity and intensity of adsorption respectively. Higher the value of $1/n$,higher will bethe adsorbate-adsorbent affinity, and the heterogeneity of adsorbent sites. The K_F values also showed the higher uptake of MB at higher temperatures indicating endothermic nature of sorption process. Temkin constant K_T increased with increase in temperature, thus indicating endothermic nature of sorption process. In Redlich-Peterson isotherm the value of β gives the mechanism of adsorption. If the value of β = 1, then physio-sorption is the main sorption mechanism taking place, while if β = 0, then the adsorption isotherm is linear. For β =1 – (1/n), i.e., between 0 and 1, then the adsorption process is favorable and more heterogeneous in nature. From the Table 2 it is clear that the values of β are closer to [1 – (1/n)] as compared to 1; hence the adsorption of MB onto PPBC is more heterogeneous in nature. Similarly, the constant values of Toth and Radke-Prausnitz isotherms are more or less increasing with increasing temperature. The R^2 values for Toth are closer to unity in comparison to the values obtained for other isotherms (Table 2).

The HYBRID fractional error function is lowest for Toth at all temperatures and thus can be used to represent the equilibrium adsorption of MB on PPBC. Considering R^2 and least error for HYBRID fractional error, Figure 10 presents the order of the entire six isotherms that fits to the

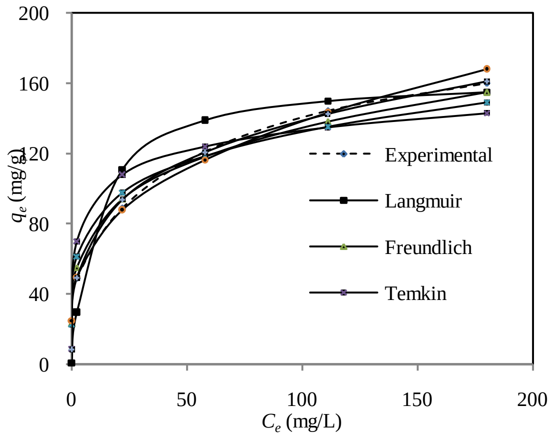


Figure-10: Experimental and Calculated q_eVs. C_e for MB – PPBC adsorption(m = 2 g/L, pH_0 = 7.2, T = 303K)

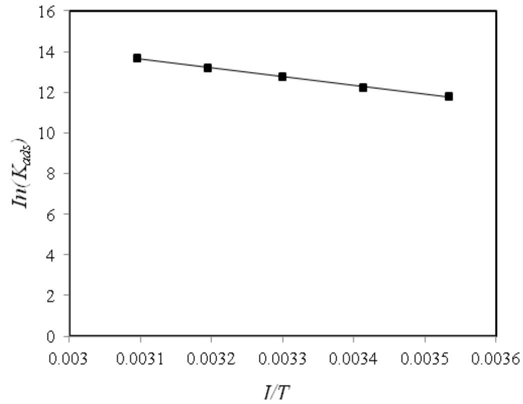


Figure-11:Van't Hoff plot for adsorption of MB onto PPBC

Table-3: Thermodynamic parameters for the adsorption of MB onto PPBC

ΔG^0 (kJ/mol)					ΔH^0 (kJ/mol)	ΔS^0 (kJ/mol K)
283	293	303	313	323		
-27.651	-29.906	-32.160	-34.414	-36.668	36.141	0.225

experimental data at 303K for MB-PPBC system. The order followed is: Toth < Radke-Prausnitz < Freundlich < Redlich-Peterson < Temkin < Langmuir.

3.8. Adsorption thermodynamic study

The thermodynamic parameters which are associated with the adsorption process, viz., standard free energy change (ΔG^0), standard enthalpy change (ΔH^0) and standard entropy change (ΔS^0) were calculated using the following equations.

$$\Delta G^0 = -R\,T\,\text{In}\,K \quad (8)$$

Where $\Delta G^0$is the free energy of sorption (kJ/mol), T is the temperature in Kelvin, R is the universal gas constant (8.314 J/mol K) and $K = (q_e/ C_e)$ is a single point / linear sorption distribution coefficient.The Gibbs free energy change is also related to the change in entropy and heat of adsorption at a constant temperature as given by the equation:

$$\Delta G^0 = \Delta H^0 - T\Delta S^0 \quad (9)$$

The above two equations give,

$$InK = \frac{-\Delta G^0}{RT} = \frac{\Delta S^0}{R} - \frac{\Delta H^0}{R}\frac{1}{T} \quad (10)$$

Where,$\Delta H^0$is the heat of sorption (kJ/mol) and $\Delta S^0$is the standard entropy change (kJ/mol K). The values of $\Delta H^0$and ΔS^0can be obtained from the slope and intercept of a plot of *InK* versus 1/*T*, using equation:

$$\Delta H^0 = \left[R\frac{d\ In\ K}{d\ (1/T)}\right] \quad (11)$$

Figure 11 shows the Van't Hoff plot (*InK* vs. 1/*T*). The thermodynamic relation between ΔG^0, $\Delta H^0$and ΔS^0implies that either (i) ΔH^0 is positive and ΔS^0 is positive and that the value of $T\Delta S^0$is much larger than ΔH^0, or (ii) ΔH^0 is negative and ΔS^0 is positive or that the value of ΔH^0 is more than $T\Delta S^0$. To occur significant adsorption, the free energy change of adsorption, ΔG^0 must be negative. The free energy change (ΔG^0) indicates the degree of spontaneity and feasibility of the adsorption process and the higher negative value speculates a more energetically favorable adsorption.

Table 3 gives the thermodynamic parameters for the adsorption of MB onto PPBC. The increase in negative value of ΔG^0 with increase of temperature showed that the adsorption of MB on prepared adsorbents increased with the rise in temperature. The positive values of ΔH^0 confirmed the endothermic nature of the adsorbents for MB adsorption in the studied temperature range 283 to 323 K. The positive values of ΔS^0 confirmed the randomness of the adsorption process. Similar results were producedby Patil et al. (2011), Pathania et al. (2017) and Basaleh et al. (2019) for the adsorption of MB with different adsorbents.

4. Conclusion

The present study reveals that Pongamia pinnata bark carbon (PPBC) is an effective adsorbent in the removal of MB from the aqueous solution. The point of zero charge for the adsorbent PPBC was found to be 6.5, and the natural initial pH_0value for cationic dye MB was maintained at 7.2 throughout the study. The optimum dose for PPBC was found to be 2 g/L; and the equilibrium time between the adsorbate in the solution and the adsorbent surface was practically achieved at 60 minutes. Pseudo-second order kinetic model fitted appropriate for the kinetic study. Increased sorption of MB onto PPBC at higher temperatures indicates endothermic adsorption process. Comparing R^2 values and HYBRID functional error values (for least error), isotherm model fitted in the order as: Toth < Radke-Prausnitz < Freundlich < Redlich-Peterson <Temkin < Langmuir at 303K for all the temperatures. Thus, adsorption of MB on PPBC is favorably influenced by increase in temperature. At optimum conditions, maximum 99.89 % removal is observed at C_0 = 50 mg/L &T = 323 K, and minimum 55.16 % removal at C_0 = 500 mg/L &T = 283K.The adsorption capacities (q_e) of PPBC for MB dye under optimum conditions was found to be minimum 24.925 mg/g at lower concentration (C_0 = 50 mg/l, T = 283 K) and maximum 186.368 mg/g at higher concentration (C_0 = 500 mg/L, T = 323 K). The negative values of ΔG^0indicates favorable and spontaneous adsorption; increased positive values of ΔH^0 shows endothermic nature of adsorption process; and positive values of ΔS^0 shows increased disorder and randomness at the solid-solution interface. This study concludes that PPBC could be effectively employed as low-cost adsorbent for the removal of MB dye from the aqueous solutions.

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EFFECT OF PORE WATER PRESSURE ON STABILITY OF SLOPES SUBJECTED TO SEISMIC LOADING

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ABSTRACT

The problems belonging to slope stability has been one of the primary concerns of the practicing geotechnical engineers across the globe. Soil behaviour becomes more complex due the presence of a water table resulting into the variation of pore water pressure. In previous studies, the consideration of increase in pore pressure due to cyclic nature of seismic forces has not been taken into the account for solving any slope stability problem. In the present study, the effect of pore water pressure on the factor of safety of both unreinforced as well as reinforced slopes, considering Janbu's method of slices for the analysis and Skempton's equation for finding the excess pore pressure. The volume of nails required to raise the factor of safety to a desired value is minimized with respect to by means of considering the location of slip surface and shape of slip surface and the orientation, location and diameter of the nails, the volume of nails needed to increase the value of factor of safety is minimized. Parametric study has been carried to investigate the effect of location, orientation, diameter, and earthquake coefficients on the location of slip surface and on the factor of safety.

Keywords: *Stability, Pore Pressure, Earthquake, Nailed Slope, Factor of Safety*

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1. Introduction

The stability of slope is one of the most challenging task of geotechnical engineers for both economic and safe design of the natural and man-made slopes (Ameen, 2018; Ansari et al. 2021). he limit equilibrium methods (LEM) have been used in such analyses, which was originally developed and refined for reinforced (Prater, 1979; Spencer, 1967) due to development in software methods using finite element and finite difference techniques, finite element method/ analysis (FEM/FEA) are extensively used in recent years. Due to the availability to predict stresses, strains and displacements within the body., the finite element analysis/difference (FEA/FD) technique score over the conventional approach of LEM (Ansari et al. 2021). In the starting phases of research, the use of ordinary method of slices (OMS) suggested for slope stability computations due to its simplicity and adaptability, which further refined by (Ansari, 2017; Prater, 1979; Spencer, 1967) assuming circular slip surface.

A generalized method for the optimum design of nailed soil slopes is carried out based on limit equilibrium method of analysis satisfying both internal and as well as external equilibrium (Janbu, 1973). A simple design method suggested to analyze the reinforced soil structure subjected to seismic forces for the internal and external stability (Basha &Basudhar, 2010; Prater, 1979). From the parametric study it is found that the design parameters like horizontal and vertical seismic acceleration, number of reinforcement layers, total length of reinforcement, angle of shearing resistance, uniformly distributed surcharge load have significant effect on the internal and external seismic stability of the wall. The influence of vertical seismic acceleration (Kv) on the factor of safety is insignificant for L≤H and is significant for L/H greater than 1 (Patra &Basudhar, 2005).Here, in this study an attempt has been made to estimate the minimum factor of safety required and corresponding critical slip surface considering the increase in pore pressure due to earthquake loading. Furthermore, a generalized optimum design of nailed slope has been given to find the optimum location, length, diameter, and orientation of the nails in order to achieve the desired factor of safety.

2. Generalized Formulation

The generalized assumptions and design constraints for both unreinforced and reinforced slopes are mentioned here.

2.1 Analysis of the Unreinforced Slopes

The assumptions, design variables, the target function and therefore the design constraints are for unreinforced slope presented below.

- The factor of safety is constant along the whole shear surface and plane strain conditions apply.
- The total resultant ΔN is assumed to act where the road of action of ΔW intersect the bottom of the slice.
- The position of the road of thrust for the entire side force E is assumed to be known.

2.2 Analysis of the Reinforced Slopes

The assumptions, design variables, the objective function and the design constraints are for reinforced slope presented below.

- Factor of safety remains same along the whole slip surface and the plane strain conditions are valid.
- The resultant of the normal force at the base of the slice is assumed to act where the resultant of weight intersects the base of the slice.
- For the no tension to develop within the slope, the position of line of thrust is assumed to act at one third of the height of the slice from the interslice base.
- At failure, the locus of maximum tension and maximum shear force in nails coincides with the failure surface developed in the soil (Juran,1993).
- The pull-out capacity of the length of the nails beyond the failure surfaces can be estimated by the relation given by Powell and Watkins (1990).

3. Unreinforced Slope under Seismic Condition

Based on the formulation a computer code in MATLAB has been developed. In the present chapter, the current formulation and code for the unreinforced slope has been validated using some standard problem available in the literature. Also, the effect of earthquake forces and increase in pore pressure due to earthquake on the slip surface and on the factor of safety has been studied.The computer code is validated by comparing the results of some standard problem given in the literature. Also, the effect of earthquake force and increase in pore water pressure due to the cyclic nature of the earthquake force has been studied.

A homogenous slope of height 16 m having slope as 1 vertical to 2 horizontal is to be analyzed. The effective shear strength parameters ϕ′ and c′ are 22⁰ and 19.5 kN/m2, pore pressure coefficient (ru) is 0.2. The unit weight (γ) of the soil is 17.6 kN/m3.

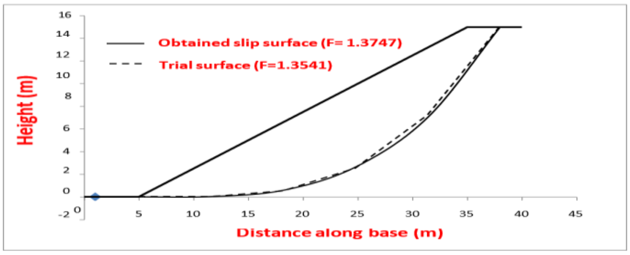

Figure 1. Assumed initial and obtained critical slip surface

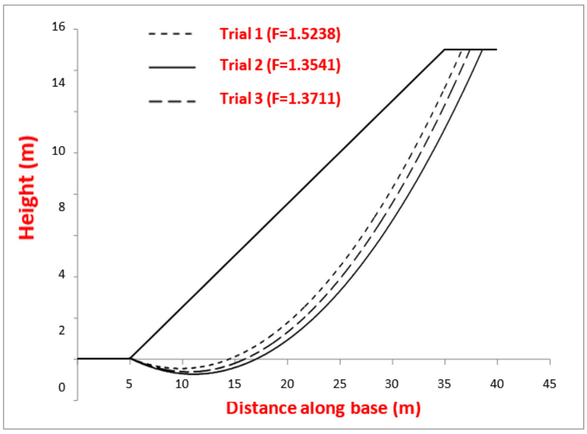

Figure 2. Obtained critical slip surface starting from different initial guess values

Figure 1 shows the critical slip surface obtained from the current analysis, minimum factor of safety obtained from the current analysis is found to be 1.3747 which is very close to factor of safety value that is obtained using Bishop and Morgenstern charts (1.37). It has been found that the critical slip surface and minimum factor of safety shows a strong dependence on the initial guess value.

1. Reinforced Slope under Seismic Condition

The formulation and code for the reinforced slope has been validated using some standard problem available in the literature. In addition, the effect of the initial values of the various parameters on the optimum design and seismic forces and the increase in pore pressure due to the earthquake on the slip surface and on safety factor has been studied.

The slope used to study the effect of different parameters on the slip surface and volume of reinforcement required to increase the factor of safety [6]. The minimum factor of safety of the unreinforced slope has been reported as 1.14.

The nails are most effective when placed horizontally having using 4 layers of reinforcement of 28 mm diameter with horizontal and vertical of 0.5m [6]. Using the same location, orientation and diameter of the nail as shown in Fig. 3, the factor of safety of slope obtained is 1.4113 and the total length of nail obtained by present method is 7.121 m which is 4.21 % less as compared to 7.41 m computed by [6] and 2.13% more compared to 6.9 m computed by [2].

In order to study the effect of initial value of diameter on the optimal design four set of diameters 23 mm, 26 mm, 29 mm and 32 mm have been considered. Following Table 1 shows the effect on optimal volume of nails, location, resistive length and total length of nails on varying the initial diameter. From the table it is seen that there is not much difference in optimal volume of nails (4.63 %), maximum difference in the optimum length of the nails is found to be 7.95%. however, it is observed that the choice of initial diameter influences the optimum orientation of nails and position of nails at the upper part of the slope.

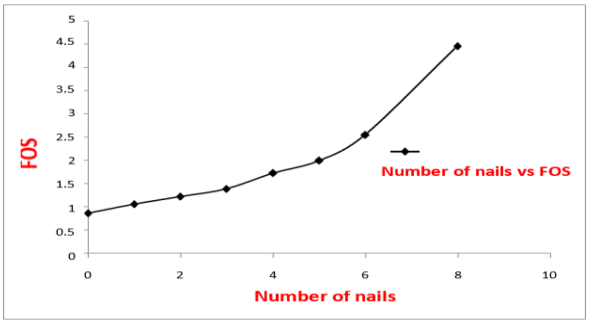

Figure 3. Variation of factor of safety with number of nails

Table 1. Optimal value of parameters for different earthquake coefficients (F_d =1.4).

K_h	K_v	Optimum dia (m)	Position of nails from top (m)	Resistive length of nails (m)	Volume of nails required (m³)
0.1	0.00	0.0232	1.7010 2.5012 3.3012 4.1014	2.2275 2.3239 1.9874 1.4178	0.0049
0.2	0.12	0.0233	1.4120 2.2120 3.0122 3.8122	2.1531 2.3047 2.1800 1.6087	0.0432

The initial orientation of the nails ranges from 0º to 25º, with an increase of 120. It has been found that the optimum volume of nails needed to achieve the optimal safety factor is highly influenced by the initial orientation of the nails, with a maximum volume difference of up to 55%. The overall difference in nail length is found to be 52%.

To research the influence of the inclination of the nails on the different parameters, the position and orientation of the nails remains constant. The nails are found to be more efficient when positioned horizontally, the volume and optimum diameter of the nails increases as the angle of inclination increases. Due to the increase in inclination from 0º to 25º, the total volume of nails may increase up to 51.32% while the optimum diameter may increase up to 34% and 37%.

The safety factor has been found to increase considerably as the number of nails increases. Earthquake forces are considered, in the present analysis, to increase the pore pressure due to the cyclic nature of the earthquake forces. Maximum increase in optimum nail diameter is found to be 30.59% when the vertical earthquake coefficient is increased from 0 to 0.2 and when the Kh value is increased from 0.1 to 0.2 and Kv = 0 is maintained, an increase in diameter is observed to increase by 13.62%. In this analysis, the increase in pore pressure due to the cyclic nature of the earthquake forces is considered.

1. Conclusion

The accuracy of the developed MATLAB computer code has been established by taking several examples of problems and comparing the results obtained. The value of the safety factor from this analysis is found to be close to that obtained by the use of other methods. The excess pore pressure generated on the slope during the earthquake plays an important role in reducing the value of the safety factor. The horizontally placed nails having longer length in the upper portion of the slope gives an optimal design while the critical slip surface is found to lie in a zone instead of occurring along a particular well-defined surface. The location of slip surface when the increase in pore pressure due to cyclic nature of earthquake forces is not same compared to the case, where increment neglected.

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GEOTEXTILE REINFORCED EMBANKMENT ON SOFT FOUNDATION

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ABSTRACT

Conventional building approaches frequently prohibit the construction of dikes or levees on very soft foundations because it is not cost-effective, operationally viable, or technically feasible. Nevertheless, geotextile-strengthened dikes had been designed and built via means of way of being made to waft on very gentle foundations. Geotextiles utilized in the ones dikes alleviated many gentle-floor basis dike construction production troubles due to the fact they allow higher device mobility, permit expedient construction, and permit production to layout elevation without failure. This paper discusses about the potential failure modes and requirements for design and selection of geotextiles for reinforced embankments.

Keywords: *Geotextile, Embankment, Foundation, Failure.*

1. Introduction

The presence of fine-grained dirt intermixed with the aggregate foundation materials destroys the structural strength of the aggregate by interfering with stone-to-stone contact, according to the majority of research into road failures built on soft soil. It be also mentioned here that unsatisfactory performance of poor sub- grade is again associated with lateral displacement of the sub-grade and the base materials under load (Ansari & Daigavane, 2020,2020a; Daigavane & Ansari, 2021a).The traditional solution for dealing with this problem is to implement a blanket strategy of using stabilized local soils as a sub-base layer instead of concrete.The flaw found with the old technique requires that the problem he addressed at its most basic level by correcting the formation sub-fundamental grade's deficiency and settling on a strategic remedy.

It is in this sense that geotextile is found to solve the problem by improving the consistency of poor soil sub-grade when added at the interface of the sub-grade (Daigavane & Ansari, 2021). This principle of integrating an additional indigenous feature at the sub-grade level, though is a new thought by way of a modern idea.

1. Modes of Potential Embankment Failure

When compared to traditional soft foundation construction methods and techniques, the design and construction of geotextile-reinforced dikes on soft foundations is technically possible, operationally viable, and cost effective. The failure modes are as follows:

- Horizontal sliding and spreading
- Rotational slope and/or foundation failure
- Excessive vertical foundation displacement

Horizontal sliding and spreading

During conventional construction, Shear forces created along the dike-foundation interface would help the dikes resist various kinds of failure. Where geotextiles are used between the soft foundation and the dike, the geotextile will increase the resisting forces of the foundation. Geotextile reinforced dikes may fail by fill material sliding off the geotextile surface, geotextile tensile failure, or excessive geotextile elongation(Nene & Daigavane, 1994).Geotextiles with the requisite tensile strength, tensile modulus, and soil-geotextile friction qualities can be specified to avoid these failures.

Rotational Slope and/or foundation failure

Dikes reinforced with geotextiles and built to a specific height and side slope will withstand conventional rotational failure if the foundation and dike shear strengths plus the geotextile tensile strength are adequate. The rotational failure mode of the dike can only occur through the foundation layer and geotextile. The dike side slopes are less than the internal angle of friction for cohesion less fill materials. Because the geotextile lacks flexural strength, it must be arranged in such a way that the critical arc determined from a conventional slope stability analysis intercepts the horizontal layer (Ansari et al. 2021; Nene & Daigavane, 1999).

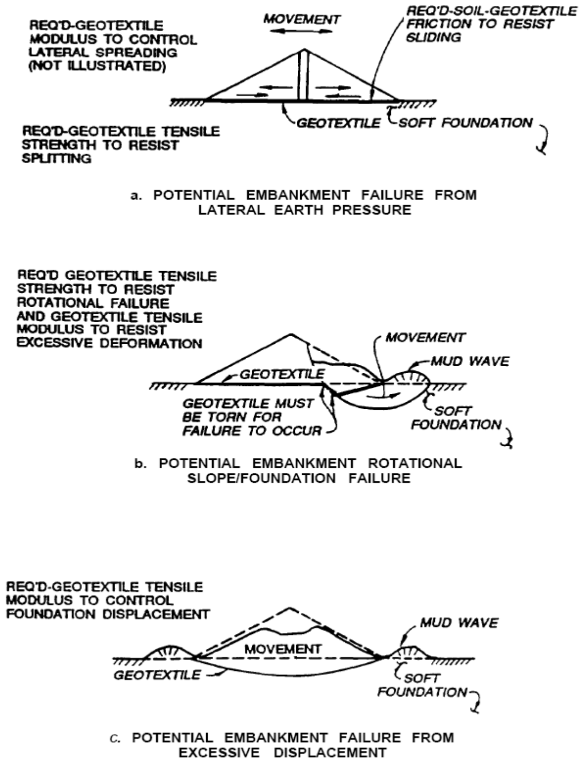

Figure1. Modes of potential embankment failure(Daigavane & Ansari, 2020)

Excessive vertical foundation displacement

Consolidation settlements of dike foundations, whether geotextile-reinforced or not, will be similar. When geotextile-reinforced dikes are consolidated, the settlements are usually more uniform than when non-reinforced dikes are consolidated. One of the goals of geotextile reinforcement is to keep the dike together until the foundation can be stabilized and strengthened. Generally, only two types of foundation bearing capacity failures may occur partial or center-section foundation failure and rotational slope stability/foundation stability.

2. Recommended Criteria

The limit equilibrium analysis is recommended for design of geotextile-reinforced embankments. These design procedures are quite like conventional bearing capacity or slope stability analysis. Despite the fact that the rotational stability study implies that ultimate tensile strength will arise quickly to resist the active moment, some geotextile strain and hence embankment displacement will be required to create tensile stress in the geotextile.

Overall bearing capacity

Whether or not geotextile reinforcement is utilized, the overall bearing capacity of an embankment must be calculated. There is no use in reinforcing the embankment if the overall stability of the embankment is not met. Standard foundation engineering textbooks include several bearing capacity procedures. Bearing capacity assessments for trip footings use assumed logarithmic spiral or circular failure surfaces and follow traditional limiting equilibrium analysis. The likelihood of lateral squeeze (plastic flow) of the underlying soils is another source of bearing capacity failure. As a result, the lateral stress and shear forces created beneath the embankment should be compared to the total of the resisting passive forces and the product of the soil failure plane area's shear strength. Stability can be addressed by adding berms or extending the base of the embankment if the total bearing capacity study shows an unsafe situation to provide a wide mat, thus spreading the load to a greater area. These berms or mats can be strengthened with suitably designed geotextiles to keep the embankment consistent and limit the possibility of lateral spreading.

Slope stability study

If the embankment's overall bearing capacity is confirmed to be adequate, the rotational failure potential should be assessed using a traditional limit equilibrium slope stability analysis or Wedgwood analysis

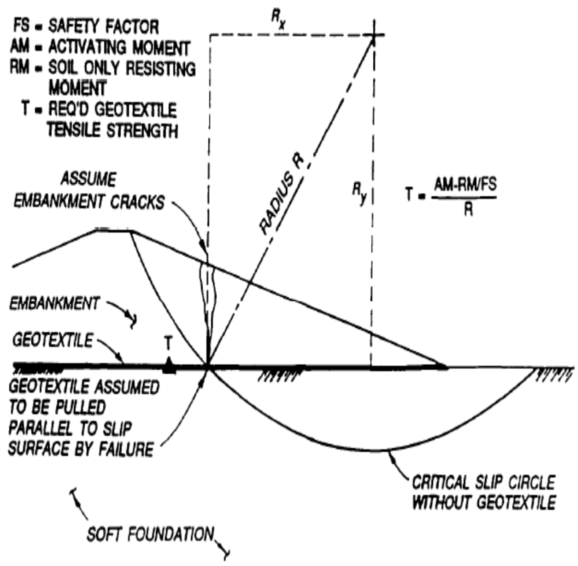

Fig. 2. Concept used for determining geotextile tensile strength necessary to prevent slope failure

Longitudinal geotextile strength requirements

For both the transverse and longitudinal directions of the embankment, geotextile strength needs must be assessed and defined. The geotextile is dragged not only longitudinally, but also laterally toward the embankment toes, by the mud wave.

Erosion of the Embankment

The reduction of vertical and horizontal deformations is one of the key goals of geotextile reinforcement in an embankment. The impact of this strengthening on horizontal movement in embankment spreading modes has already been discussed. Estimating the deformation or sinking produced by consolidation and plastic flow or creep of very soft foundation materials is one of the most difficult jobs. Elastic deformations are a function of the subgrade modulus. A strengthened embankment may result in a minor reduction in total settlement, but no major improvement. Other research suggests that high strength, high tensile modulus geotextiles can reduce foundation displacement during construction, although the methods of analysis aren't as well-established as those for stability analysis. The lateral and vertical motions induced by subsidence from consolidation settlements, plastic creep, and flow of the soft foundation materials will be avoided if the embankment is constructed for stability as mentioned previously. To determine foundation settlements, it is advised that a traditional consolidation analysis be done.

3. Conclusion

When compared to traditional soft foundation construction methods and techniques, the design and construction of geotextile-reinforced dikes on soft foundations is technically possible, operationally viable, and cost effective. The dikes would resist these kinds of failure during traditional construction by shear stresses created along the dike-foundation interface. If the foundation and dike shear strengths, as well as the geotextile tensile strength, are enough, geotextile-reinforced dikes constructed to a certain height and side slope, will withstand classic rotational failure.The overall bearing capacity of an embankment must be determined whether geotextile reinforcement is used. Wick drains can be used to quickly consolidate the soil and reach the desired strength in cases when it has a limited bearing capacity. The use of geotextile reinforcement can help speed up the construction process. Geotextile strength requirements must be evaluated and specified for both the transverse and longitudinal direction of the embankment.

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SPECIFIC APPLICATION OF GEOTEXTILE FOR REINFORCED SOIL WALLS

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ABSTRACT

Geotextile-reinforced soil walls are like similar to the common sandbag walls used for different construction applications. Geotextile-reinforced wallscan be built to large heights due to the geotextile's higher strength and a simple mechanized building process.Construction work does not necessitate the use of skilled labour or advanced machinery. Since many of the materials are prefabricated, construction can be completed in a comparatively short period of time. This paper discusses about the main design factors required to considered during the reinforcement of soil walls using geotextile.

Keywords: *Geotextile, Reinforced Soil, Backfill Soil, Wall Stability.*

1. Introduction

Granular soil is generally solid under compressive stresses. As it is reinforced, the reinforcement can withstand high tensile stresses, resulting in a composite construction with greater strength margins. Steeper slopes may be formed as a result of this greater strength. Geotextile sheets are layered in layers around compacted earth to create a strong composite basis. Geotextile-reinforced soil walls are similar to the common sandbag walls that have been used for decades. Geotextile-reinforced walls, on the other hand, can be built to large heights due to the geotextile's higher strength and a simple mechanized building process(Ansari & Daigavane, 2020; Ansari et al. 2021; Nene & Daigavane, 1994). Traditional walls can be more expensive to build than geotextile-reinforced walls. However, because geotextile application to walls is still in its early phases, long-term outcomes like as creep, ageing, and lifespan are unclear based on real-world experience. As a result, a shorter life, severe failure consequences, or expensive maintenance or replacement costs may compensate for a cheaper original cost (Daigavane & Ansari 2020).

Before being used in essential systems, careful consideration should be given. Geotextile-reinforced walls have a wide variety of applications, from temporary road embankments to permanent barriers that successfully solve slip problems and widen highways. These walls may be built as noise barriers or as abutments for secondary bridges. Because of their adaptability, these walls may be built in areas with weak foundation or in areas prone to earthquake activity.

2. Geotextile Based Reinforced Walls

Some advantages of geotextile-reinforced walls over conventional concrete walls are given below:

- Overall project becomes economical.
- Construction work does not necessitate the use of skilled labour or advanced machinery. Since many of the materials are prefabricated, construction can be completed in a comparatively short period of time (Ansari & Daigavane 2020a; Daigavane & Ansari 2021a).
- Support of the foundation is not needed during construction, regardless of the height or length of the wall, as is the case for traditional retaining walls.
- They are relatively stable and can withstand significant lateral deformations as well as massive differential vertical settlements. Because of the versatility of geotextile reinforced walls, a lower factor of protection can be used for bearing capacity construction than in traditional more stable frameworks (Daigavane & Ansari 2021; Nene & Daigavane, 1994).
- Because of the flexibility and intrinsic energy absorption ability of the coherent earth mass, they could be best suited for earthquake packing.

Following are the few disadvantages of geotextile-reinforced walls over conventional concrete walls.

- Any reduction in geotextile strength can occur as a result of potential construction disruption.
- At constant load and soil temperature, some decrease in geotextile strength can occur over time.

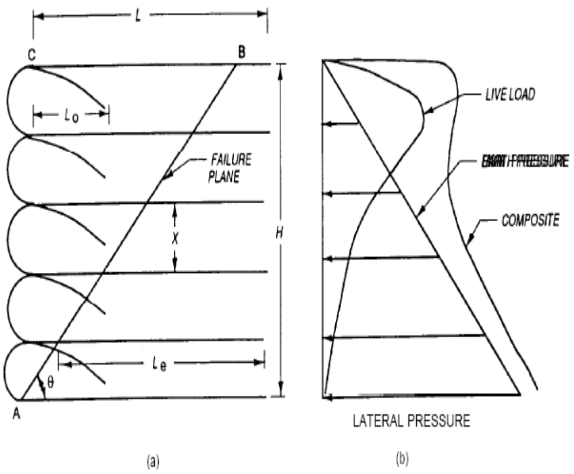

Figure 1. General Configuration of a Geotextile Retained Soil Wall and Typical Pressure Diagrams

3. Design Considerations

These are the main design factors required to considered during the reinforcement of soil walls using geotextile, we can need to consider few design factors. They are mentioned below:

- The wall face may be either upright or slanted. This may be for structural considerations, ease of construction, or architectural reasons. Since all geotextiles are evenly spaced, construction is simpler. Except for the lowest geotextile layer, all geotextile sheets usually stretch to the same vertical plane (Ansari & Daigavane 2021; Ansari et al. 2021).
- Geotextiles that are exposed to UV light will degrade quickly. A protective film should be added to the exposed face of the wall at the end of construction.
- When aesthetic appearance is significant, a low-cost solution such as a facing system made of used railroad ties or other similar materials can be used.
- It is recommended that 1 to 2 feet of natural foundation soil be replaced with a crushed-stone foundation layer to allow drainage from inside and behind the wall to ensure the rapid removal of seeping water in a permanent structure.

4. Material Specification

Retained Soil

"Retained soil" is soil that has been coated with geotextile sheets. This soil must be non-plastic and permeable. The following retained soils are graded for permanent walls using the Unified Soil Classification System: SW, SP, GW, GP, or all of these as a borderline categorization that is also denoted as GM or SM. Fines in the soil are restricted to 12% after passing through Sieve No. 200. This limitation is enforced due to the possibility of fines being washed away by seeping water. Geotextile pads can trap fines, resulting in liners with reduced permeability. Permeability of retained soil must be more than 10-3 centimeters per second in general. Gravels are not at the top of the rating list. Despite their great permeability and, most likely, great power, their deployment requires extra precaution. Gravel, which includes angular grains, has the potential to puncture geotextile sheets during construction (Nene & Daigavane, 1999).

As a result, geotextile selection must be considered in order to withstand potential damage. If a high-puncture-resistance geotextile is available, GP and GW should replace SP and SW, respectively, in their ranking order. The retained soil unit weight should be determined using standard laboratory compaction tests. A minimum of 95 percent of the complete dry unit weight, as defined by ASTM D 698, should be reached throughout construction. Because the retained soil will most likely be densified more when more layers are laid and compacted which may be exposed to transitory external sources of water, such as rainfall, the saturated unite weight should be utilized for design reasons.

Backfill Soil

As shown in the above Fig. 1, the soil to the right of L is supported by the strengthened wall and is referred to as "backfill soil." This soil has a strong impact on the exterior integrity of the wall. As a result, it should be carefully chosen. Backfill standards used for standard retaining walls can be used here as well. The materials having low permeability should be avoided next to a permanent wall.

5. Conclusion

Because the qualities of the retained soil and backfill may affect the exterior stability of the reinforced wall, the qualities of both materials are required. The unit weight should be calculated in the same manner as for the retained soil, with the maximum density at zero air spaces being used. For the permeable backfill, the strength parameters should be calculated using drained direct shear tests (ASTM D 3080).The backfill and retained soil must have a comparable gradation at their contact to reduce the possibility of soil particle lateral movement. If such a requirement is not feasible, a typical soil filter or a geotextile filter should be built and deployed along the contact.

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EROSION AND SEDIMENT CONTROL USING GEOTEXTILE MATERIALS

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ABSTRACT

Erosion is caused by a gaggle of physical and chemical processes by that the soil or rock material is untangled, detached, and transported from one place to a different by running water, waves, wind, moving ice, or different earth science sheet and bank erosion agents. Geotextiles are a good and economical various to standard hierarchic filters underneath stone riprap. Abrasion may result from movement of the duvet material as a results of wave action or currents. Strength properties usually thought of primary importance are enduringness, dimensional stability, tearing, puncture, and burst resistance. It's a decent apply to construct the silt fence across a flat space within the kind of a horseshoe. This aids within the ponding of the runoff and will increase the strength of the fence. Prefab silt fence sections containing geotextile and support posts are commercially on the market. This paper concisely discusses regarding the precise criterion similarly as construction concerns for erosion and sediment management victimisation geotextile materials.

Keywords: *Geotextile, Erosion, Sediment Control, Stability.*

1. Introduction

Erosion is caused by a bunch of physical and chemical processes by that the soil or rock material is disentangled, detached, and transported from one place to a different by running water, waves, wind, moving ice, or different earth science sheet and bank erosion agents. Clayey soils square measure less erodible than fine sands and silts. Riprap is employed as a liner for ditches and channels subjected to high-speed flow and for lake, reservoir, and channel banks subject to wave action. Geotextiles square measure a good and economical different to traditional stratified filters beneath stone riprap. The geotextiles utilized in bank protection function a filter(Ansari & Daigavane, 2020,2020a).

2. Erosion Control Using Geotextile Materials

The generalized assumptions and design constraints for both unreinforced and reinforced slopes are mentioned here.

2.1 Specific Design Considerations for Erosion Control

The assumptions, design variables, the target function and therefore the design constraints are for unreinforced slope presented below.

Durability

The term includes chemical, biological, thermal, and ultraviolet (UV) stability. All geotextile specifications should embrace a provision for covering the geotextile to limit its actinic radiation exposure to thirty days or less.

Strength and Abrasion Resistance

The required properties can depend upon the precise application- the kind of the duvet material to be used (riprap, sandbags, concrete blocks, etc.), the size, weight, and form of the armor stone, the handling placement techniques (drop height), and also the severity of the conditions (stream rate, wave height, speedy changes of water level, etc.). Abrasion may result from movement of the duvet material as a results of wave action or currents. Strength properties usually thought-about of primary importance square measure strength, dimensional stability, tearing, puncture, and burst resistance(Ansari & Daigavane, 2021; Daigavane & Ansari, 2021; Nene & Daigavane, 1999).

CoverMaterial

The cover material (gravel, rock fragments, riprap, armor stone, concrete blocks, etc.) may be a protecting covering over the geotextile that minimizes or dissipates the hydraulic forces, protects the geotextile from extended exposure to actinic radiationand keeps it in intimate contact with the soil. the duvet material should be a minimum of as pervious because the geotextile. If the duvet material isn't pervious enough, a layer of fine mixture (sand, gravel, or crushed stone) ought to be placed between it and also the geotextile(Nene & Daigavane, 1994).A very important thought in coming up with cowl material is to stay the void space between stones comparatively tiny. If the void space is overly massive, soils could move from areas weighted by stones to unweighted void areas between the stones, inflicting the geotextile to balloon or eventually rupture. the answer during this case is to position a hierarchal layer of smaller stones below the big stones that may stop the soil from moving. A layer of mixture can also be required if a significant a part of the geotextile is roofed as for instance by concrete blocks. The layer can act as a pore water dissipator.

Anchorage

At the toe of the streambank, the geotextile and canopy material ought to be placed on the bank to associate elevation below mean tide level to attenuate erosion at the toe. Placement to a vertical distance of three feet below mean tide level, or to the lowest of the bottom for streams shallower than three feet, is usually recommended at the highest of the bank, the geotextile and canopy material ought to either be placed on the highest of the bank or with two feet vertical freeboard higher than
expected most water stage. If robust water movements square measure expected, the geotextile must be anchored at the crest and toe of the streambank as shown within the Fig. 1.

2.2 Specific Construction Considerationsfor Erosion Control

The assumptions, design variables, the objective function and the design constraints are for reinforced slope presented below.

Site Preparation

The surface ought to be cleared of vegetation, giant stones, limbs, stumps, trees, brush, roots, and alternative rubbish so hierarchical to a comparatively smoothing plane freed from obstructions, depressions, and soft pockets of materials.

Placement of Geotextiles

The geotextile is unrolled directly on the swimmingly hierarchical soil surface. It shouldn't be left exposed to W deterioration for over one week just in case of untreated geotextiles, and for over thirty days just in case of W protected and low actinic radiation vulnerable compound geotextiles. The geotextile ought to be loosely arranged, freed from tension, folds, and wrinkles. once used for streambank protection, wherever currents acting parallel to the bank area unit the principal erosion forces, the geotextile ought to be placed with the longer dimension (machine direction) within the direction of anticipated water flow.Adjacent geotextile strips ought to have a minimum overlap of twelve inches on the sides and at the top of rolls. For underwater placement, minimum overlap ought to be three feet. Specific applications could need extra overlaps. Sewing, stapling, heat fastening, or gluing adjacent panels, either within the works or on website, area unit most popular to imbrication solely. stitching has proved to be the foremost reliable methodology of change of integrity adjacent panels.
Geotextiles is also control in situ on the slope with securing pins before putting the duvet material. These pins with washers ought to be inserted through each strips of the overlapped geotextile on a line through the point of the overlap. Steel securing pins, 3/16 in. in diameter, eighteen inches long, pointed at one finish, and fitted with a one.5-inch metal washer on the opposite have performed well in rather firm soils. Longer pins area unit well to be used in loose soils.The maximum slope on that geotextile is also placed are determined by the friction angles between the natural-ground and geotextile and cover- material and geotextile. the utmost allowable slope in no case is larger than all-time low friction angle between these 2 materials and therefore the geotextile.

Placement of Canopy Material on Geotextile

For slanted surfaces, placement of the duvet stone or riprap ought to begin from the bottom of the slope moving upward and ideally from the middle outward to limit any partial movement of soil as a result of slippy. In no case ought to drop heights that injury the geotextile be allowable. Testing is also necessary to ascertain a suitable drop height.

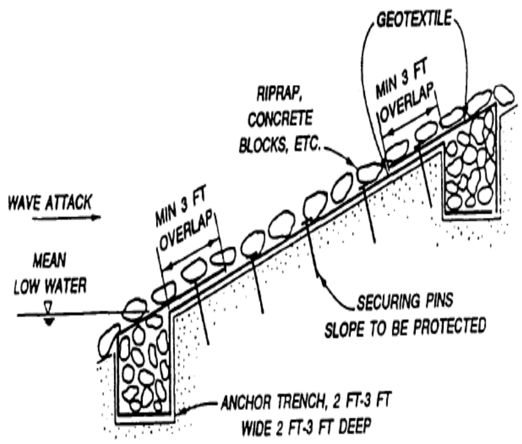

Figure 1. Pin Spacing Requirements in Erosion Control Applications

3. Sediment Control Using Geotextile Materials

Silt fences and silt curtains are sediment control systems using geotextiles. A silt fence is a temporary vertical barrier composed of a sheet of geotextile supported by fencing or simply by posts. The lower end of the geotextile is buried in a trench cut into the ground so that runoff will not flow beneath the fence. Short fences are often placed across small drainage ditches (permanent or temporary) constructed on the site. Both applications are intended to function for one or two construction seasons or until grass sod is established. The fence reduces water velocity allowing the sediment to settle out of suspension(Ansari et al. 2021; Daigavane & Ansari, 2021a).

3.1 Specific Design Considerations for Sediment Control

A silt fence consists of a sheet of geotextile and a support component. The support component may be a wire or plastic mesh support fence attached to support posts or in some cases may be support posts only (Ansari & Daigavane, 2020a;Daigavane & Ansari 2020,2020a).The designer has to determine the minimum height of silt fences, and consider the geotextile properties (tensile strength, permeability) and external factors (the slope of the surface, the volume of water and suspended particles which are delivered to the silt fence, and the size distribution of the suspended particles).

Design for Maximum Particle Retention

A minimum of 90-pound tensile strength (ASTM D 4632 Grab Test Method) is recommended for use with support posts spaced a maximum of 8 feet apart. The geotextile should be capable of filtering most of the soil particles carried in the runoff from a construction site without unduly impeding the flow. ASTM D 5141 presents the laboratory test used to determine the filtering efficiency and the flow rate of the sediment-filled water through the geotextile.

Required Geotextile Properties

The geotextile used for silt fence must also have:

- Reasonable puncture and tear resistance to prevent damage by floating debris and to limit tearing where attached to posts and fence.
- Adequate resistance to UV deterioration and biological, chemical, and thermal actions for the desired life of the fence.

3.2 Specific Construction Considerationsfor Sediment Control

- Silt fences ought to be created when the cutting of trees however before having any sod heavy construction activity within the geographic region.
- It's an honest apply to construct the silt fence across a flat space within the variety of a horseshoe. This aids within the ponding of the runoffand will increase the strength of the fence. ready-made silt fence sections containing geotextile and support posts square measure commercially obtainable.

4. Conclusion

Geotextiles are an effective and economical alternative to conventional graded filters beneath stone riprap. However, for aesthetic or economic reasons, articulated concrete mattresses, gabions, and precast cellular blocks have additionally been used to cover the geotextile. The type, size, and weight of cover material placed over the geotextile depends on the mechanical energy of water. Cover material that is lightweight as compared with the hydraulic forces acting on it may be moved. By removing the weight holding the geotextile down, the ground-water pressure may be able to separate the geotextile from the soil. When no longer constrained, the soil erodes. It is a good practice to construct the silt fence across a flat area in the form of a horseshoe. This aids in the ponding of the runoff, and increases the strength of the fence. Prefabricated silt fence sections containing geotextile and support posts are commercially available. They are generally manufactured in heights of 18 and 36 inches. Anchor lines hold the curtain in a configuration that is usually U shaped, circular, or elliptical. The design criteria and properties needed for silt fences additionally apply to silt curtains.

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REHABILITATION AND CONSTRUCTION OF RAILROAD TRACK: A CHALLENGE FOR RAILWAY ENGINEERS

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ABSTRACT

In railroad applications, geotextiles are primarily wont to perform the functions of separation, filtration, and lateral drainage. supported current knowledge,little is understood of any reinforcement effect geotextiles wear soft subgrades under railroad. Test installations have shown that woven geotextiles tend to clog with time and act almost as a plastic sheet preventing water from draining out of the sub grade. In some locations, the elevation of the track structure could also be such the geotextile is placed below the extent of the natural ground. Where the natural ground surface is elevated above the geotextile, steps should be taken to stop the inflow of water. A French drain installed along the sting of the track and lined or completely encapsulated during a geotextile to filter the inflow of surface water could also be wont to direct water far away from the track structure. This paper briefly discusses about the precise criterion also as construction considerations for rehabilitation of railway track using geotextile materials.

Keywords: *Rehabilitation, Railroad, Geotextile, Construction, Railway.*

1. Introduction

The use of geotextiles during a railroad structure depends upon many factors including the traffic, track structure, subgrade conditions, drainage conditions, and maintenance requirements (Ansari & Daigavane 2020a; Nene & Daigavane 1999). In railroad applications, geotextiles are primarily wont to perform the functions of separation, filtration, and lateral drainage. supported current knowledge, little is understood of any reinforcement effect geotextiles wear soft subgrades under railroad. Therefore, geotextiles shouldn't be wont to reduce the ballast or sub ballast design thickness. Geotextiles have found their greatest railroad use in those areas where an outsized amount of track maintenance has been required on an existing right-of-way as a results of poor drainage conditions, soft conditions, and/or high-impact loadings. Geotextiles are normally placed between the subgrade and ballast layer or between the sub grade and sub ballast layers if one is present. a standard geotextile application is found in what's commonly referred to as “pumping track” and “ballast pocket areas.” Both are related to fine grained sub grade soil and difficult drainage conditions. Under traffic, transient vertical stresses are sufficient to cause the sub grade and ballast or sub ballast materials to intermix if the sub grade is weak. because the intermixing continues, the ballast becomes fouled by excessive fines contamination, and a loss of free drainage through the ballast occurs also as a loss of shear strength. The ballast is pulled down into the subgrade. As this process continues, ballast is forced deeper and deeper into the subgrade, forming a pocket of fouled and ineffective ballast and loss of track grade control.

2. Material Selection

Ballast pockets tend to gather water, further reducing the strength of the roadbed around them and end in continual track maintenance problems. Installation of geotextiles during rehabilitation of those areas provides separation, filtration, and drainage functions and may prevent the reoccurrence of pumping track. Common locations for the installation of a geotextile in railroad are locations of excessive track maintenance resulting from poor subgrade/drainage conditions, highway-railroad level crossing, diamonds (railroad crossings), turnouts, and bridge approaches

(Nene & Daigavane, 1994). If a geotextile is installed in track without provisions made for adequate drainage, water are going to be retained within the track structure and therefore the instability of the track are going to be worsened. In any track construction or rehabilitation project, adequate drainage must be incorporated within the project design.

3. Application of Geotextile for Rehabilitation and Construction of Railroad Track

Geotextiles should be wont to separate the ballast or sub ballast from the sub grade (or ballast from sub ballast) during a railroad in cut sections where the sub grade soil contains quite 25 percent by weight of particles passing the No. 200 sieve. Geotextiles also are utilized in embankment sections consisting of such material where there's but 4 feet from rock bottom of the tie to the ditch invert or original ground surface.

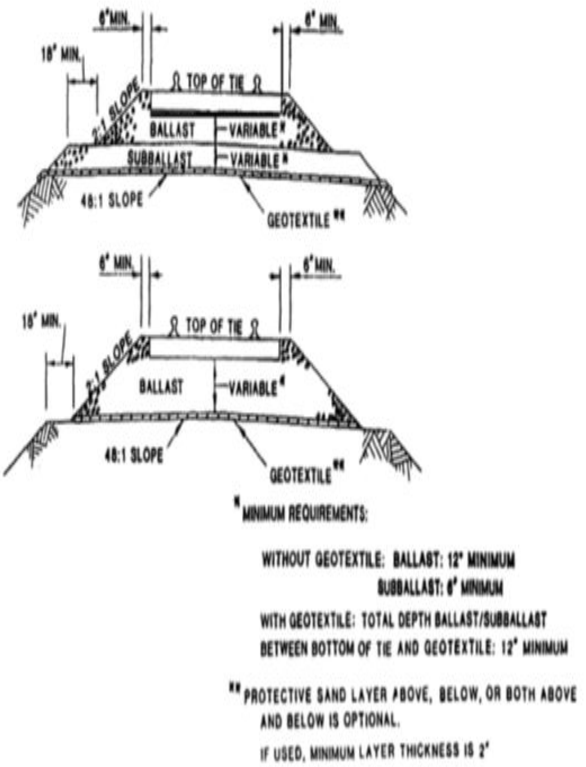

Figure 1. Typical Sections of Railroad Track with Geotextile

3.1 Depth of Placement

Technical Manual TM 5-850- 2/AFM 88-7, chap. 2 specifies a minimum ballast thickness of 12 inches. a further minimum of 6 inches of sub ballast could also be utilized in areas where drainage is difficult. the particular total ballast/ sub ballast thickness required may be a function of the utmost wheel load, rail weight, size, tie spacing, and allowable sub grade bearing pressure.

3.2 Protective Sand Layer

- In track rehabilitation where undercutting of ballast removal operation is employed, there could also be many large aggregate pieces remaining on the surface of the sub grade before the location of the geotextile. A 2-inch-thick layer of sand placed on the sub grade provides a smooth surface for the location of the geotextile and protects the geotextile from punctures and abrasion thanks to the massive aggregate pieces that are on the sub grade.
- While the utilization of protective clean sand (less than 5 percent passing the No. 200 sieve) extends service lifetime of a geotextile, there also are several disadvantages. These disadvantages include the additional cost of the sand, the rise in rail height (which results from the additional thickness within the track structure), and therefore the difficulty and price of placing the sand layer during construction or rehabilitation.

3.3 Drainage

Adequate drainage is that the key to a stable railroad structure. During the planning of a replacement track or a track rehabilitation project, provisions for improving both internal and external track drainage should be included. Drainage provisions that ought to be considered include adequate (deep) side ditches to handle surface runoff, sufficient crown in both the sub grade and sub ballast layers to stop water from ponding on the highest of the sub ballast or sub grade, installation of perpendicular drains to stop water accumulation within the track, and French drains where required to help within the removal of water from the track structure. During track rehabilitation, the creation of bath or canal effects should be avoided by having the shoulders of the track below the extent of the ballast/geotextile/subgrade interface (Daigavane & Ansari, 2021).Geotextiles shouldn't be placed during a railroad structure until existing drainage problems are corrected. Proper maintenance of railroad drainage facilities is described in TM 5-627.

4. Special Applications

Installation of Geotextiles Below Natural Ground Level

In some locations, the elevation of the track structure could also be such the geotextile is placed below the extent of the natural ground. Where the natural ground surface is elevated above the geotextile, steps should be taken to stop the inflow of water. A French drain installed along the sting of the track and lined or completely encapsulated during a geotextile to filter the inflow of surface water could also be wont to direct water faraway from the track structure. In extremely flat areas it's going to be necessary to construct perpendicular side ditches and soak-away pits from the track structure to permit the water to empty out of the French drains. Slotted drainpipes are often placed within the trenches to facilitate movement of the water from the track.

Highway Grade Crossings

- Drainage during a level crossing is usually parallel to the rails until the pavement and roadshoulder are cleared. Once beyond the crossing itself, the drainage should be turned perpendicular to the track and discharged faraway from the track structure. A perforated drain pipe either wrapped with a geotextile during installation or prewrapped, could also be placed within the trench to help the flow of water from within the crossing to the ditches outside of the crossing area. Such drainpipes should be placed within the trench with the road of perforations facing downward (Ansari & Daigavane, 2020; Ansari et al. 2021).
- The ends of the perforated drainpipes and therefore the geotextile under the crossing should be laid with sufficient fall toward the side ditches to stop water from ponding within the crossing area. Whether perforated pipes are used or not, the shoulders at the corner of the crossing should be removed, and therefore the ends of the geotextile turned down in order that the geotextile facilitates drainage under gravity toward the side ditches.
- In cold climates it's common to salt and sand highways, including grade crossings, which may cause ballast fouling within the level crossing. One method of preventing or minimizing this ballast fouling is to encapsulate the ballast during a geotextile. the supply for drainage during this sort of installation would be an equivalent as discussed above.

Turnout Applications

- The installation of a geotextile under a turnout is essentially an equivalent as installation in the other segment of track. within the vicinity of a switch, drainage of ballast or subballast to ditches is harder to realize because horizontal distances for subsurface flow are about doubled and gradients are about halved. Thus, there are reasons for using geotextiles to market lateral drainage under a turnout where none is employed in adjacent straight sections(Daigavane & Ansari, 2021a). If this is often done, it should extend a minimum of 25 feet far away from the turnout itself to supply a transition section. like road crossings, particular attention should tend to the removal of surface water from the turnout area.
- Many geotextile manufacturers produce specially packaged units ready-made for quick

5. Conclusion

The use of geotextiles during a railroad structure depends upon many factors including the traffic, track structure, subgrade conditions, drainage conditions, and maintenance requirements. If a geotextile is installed in track without provisions made for adequate drainage, water are going to be retained within the track structure and therefore the instability of the track are going to be worsened. In any track construction or rehabilitation project, adequate drainage must be incorporated within the project design. Adequate drainage is that the key to a stable railroad structure. During the planning of a replacement track or a track rehabilitation project, provisions for improving both internal and external track drainage should be included. Drainage provisions that ought to be considered include adequate (deep) side ditches to handle surface runoff, sufficient crown in both the sub grade and sub ballast layers to stop water from ponding on the highest of the sub ballast or sub grade, installation of perpendicular drains to stop water accumulation within the track, and French drains where required to help within the removal of water from the track structure. the utilization of a geotextile within the track under a rail crossing is extremely almost like the road crossing application. the planning and installation process must provide adequate drainage.

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SOIL-CEMENT BASED EFFECTIVE METHOD OF SOIL STABILIZATION

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ABSTRACT

Soil cement may be a mixture of soil, hydraulic cement and water that, once compacted and cured, forms a robust and sturdy pavement base. Construction practices and variance among core strength data have led to questions concerning proper internal control practices and testing protocol regarding soil cement. To satisfy of these rising questions, various sorts of structures made from soil cement analyzed and concluded some results based out of it, which incorporates grouting by soil cement in several structures. The small print of properties of cement also as soils also are explained in short. The applications and therefore the future scope of our paper is additionally explained intimately.

Keywords: *Stabilization, Grouting, Red Soil, Cement Mortar.*

1. Introduction

Soil-cement may be a mixture of pulverized soil material and measured amounts of hydraulic cement and water, compacted to high density. because the cement hydrates, the mixture becomes a tough, durable artifact . A bituminous wearing course is placed on the soil-cement base to finish the pavement. Only three basic ingredients are needed for soil-cement: soil material, hydraulic cement, and water. The soil in soil cement are often a good sort of materials. Either in-place or borrow material are often used (Ansari & Daigavane, 2021; Spencer, 1967). Old granular-base roads, with or without their bituminous surfaces, are often recycled to form soil-cement. Soil-cement is usually called cement-treated base or cement-stabilized-aggregate base. no matter what it's called, the principles governing its composition and construction are an equivalent. Before construction with soil-cement starts, the soil materials which will be treated with cement should are identified and representative samples of every type tested. These tests determine the minimum cement content required to harden each material adequately and therefore the approximate optimum moisture content and density values to be used in construction. Soil-cement construction involves two steps—preparation and processing. Variations in these steps are dictated by the sort of blending equipment used.

2. Literature Review

Soil Stabilization

General Soil stabilization may be a method of improving soil properties by blending and mixing other materials. There are various soil stabilization methods and there are various materials used for soil stabilization. the subsequent are the few methods described in literature.

- Soil Stabilization with Cement
- Soil Stabilization by Grouting

1. Clay grouting
2. Chemical grouting
3. Chrome lignin grouting
4. Polymer grouting, and
5. Bituminous grouting

Red Soil Treatment

Red soil may be a porous and friable structure. Red soil may be a fine soil which holds great deal of water than the coarse soil. thanks to its 0-permeability it are often used for building high rise building (multi-storied building). Red soil are often utilized in RCC also as (prestressed concrete. If this concrete is employed in RCC, then there will be no corrosion in steel.

Soil Cement Mortar

The supply of sand is declining in need of meeting the demand, it becomes imperative to seek out a special alternative. Mud mortar was generally used for low-rise masonry buildings within the past. When the soil used for the mortar consists of clay, difficulties like volume instability thanks to its high affinity towards water are faced (Daigavane & Ansari, 2021a; Patra &Basudhar, 2005). To negate this action, stabilization of the clay is important. Cement is employed as binding agent. This paper address on an experimental study to know the varied inclination of soil-cement mortars. Workability and compressive strength of soil-cement mortars are studied. Flow table tests are conducted to measure the workability of the mortars. during this paper, the vitality of replacing river sand with locally available red soil is studied(Daigavane & Ansari, 2021).

3. Methodology

3.1 Pressed Soil Cement Blocks

Three distinct operations can be recognized in the process of soil-cement block production using manually operated machines. They are (a) soil preparation (b) block pressing, and (c) stacking and curing.

Figure 1. Constructed DSMW used in a subway project in Tianjin, China

3.2 Grouting

Grouting also can be categorized by either grouting method or the aim. The jet grout is advanced to the treatment depth, where grout jets (cement grout with optional water and air) are sprayed with high velocity from nozzles under high within the side of the drill chamber counting on the appliance and kinds of soils, jet grouting can use the only fluid system (slurry grout jet), the double fluid system (slurry grout jet surrounded by an air jet) or the triple fluid system (water jet surrounded by an air jet, with a separate grout port).

4. Materials

Soil Cement Base (SCB)

It contains relatively high proportion of hydraulic cement. It is used as pavement base in streets, parking lots, airports, roads and material handling areas. Equipment used are mechanical cement spreader and stabilizer. To lock the moisture and to stop the moisture out a seal coat is provided.

Cement-Modified Soil(CMS):

A cement modified soil contains low proportions of hydraulic cement as compared to soil cement base. the ultimate result's sort of a soil cake, but with improved properties like lower plasticity, increased bearing ratio and shearing strength and decreased volume change(Ansari et al. 2021; Prater, 1979).

Cement-Treated Base

A cement treated base may be a mixture of granular soil mixed with hydraulic cement and water. Its uses are same as that of soil cement base.

Conclusion

In pressed block, characteristics of soil cement blocks having three different cement contents (6%, 8% and 12%) are examined. White cement is that the most usual stabilized added 5 to 10% by weight to the soil. In red soil, compressive strength, for plain concrete the values are 13.6-16.8 N/mm2but in red soil mixed concrete, there is significant improvement. In split lastingness, for plain concrete the particular value stops at 7.11-7.42 N/mm2 but in red soil mixed concrete, there is significant improvement in strength. The values of red soil mixed concretes split lastingness is 8.48-9.2 N/mm2. Soil-cement mixture may be a product of cement grouting or mixing with soils. Chemicalslike soluble glass are frequently utilized in combination to satisfy specific needs. The proportion of cement required in soil decides supported the sort of soil. hydraulic cement widely used as a soil stabilizer, due to its easy handling and internal control properties. With the rise in cement quantity within the strength of the cement stabilized soil increases. In most cases of blending 5.5% organic clay with cement content of 300 kg/m3and more, the extent of strength reached 3.0 MPa.

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GREEN BUILDING: A METHOD FOR UTILIZING NATURAL ENERGY RESOURCES

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ABSTRACT

Green building technology is one of the most popular themes worldwide, with the goal of reducing the construction industry's enormous influence on the environment, society, and economy. As pollution and global warming become more prevalent throughout the planet, the world urgently requires sustainable and intelligent development. Climate change has also had a major impact. Due to an increase in Green House Gases (GHGs), dramatic climate shifts have been observed and experienced all over the world. This paper discusses the importance of sustainable development around the world, particularly in developing countries such as India and China, which have large land masses and are fast developing, with the potential to become new world superpowers in the near future. It also covers sustainability and economic research with connections to Indian contexts, as well as a case study of a newly designed and built magnificent residential bungalow in a small town in India. The case study is a residential bungalow in a small town in the state of Maharashtra that was designed and built as a sustainable and green structure as India is also recognized as a country of villages, with the world's second largest population.

Keywords: *GRIHA (Green Ratings for Integrated Habitat Assessment); IEQ (Indoor Environmental Quality, LEED (Leadership in Energy andEnvironmental design).*

1. Introduction

There are many definitions of a Green building as per different researchers. It is also worth noting that the term green building is now days used as an interchangeable word with the high-performance buildings or a sustainable buildings or structures. The concept of Green Building basically stands on four main points which are Reduction of the effects or rather the side effects of the structure on the environment (Daigavane & Ansari, 2021, 2021a). Improving and strengthening the health of the people who live in a building. Investors and the society benefit from savings and investment returns. Considering the life cycle within the planning and development process. The construction sector is one of the fastest growing industries on the planet. Simultaneously, the construction sector has substantial economic, environmental, and social consequences for society (Ansari & Daigavane, 2021). These effects are most noticeable over the lives of built structures. Construction operations also have both beneficial and harmful effects on society. Some of the beneficial efforts include providing structures and habitats, as well as facilities, to meet human needs, providing jobs for the people of the country, and contributing to the country's economy. Waste disposal during construction activities, dust, noise pollution, water pollution, traffic congestion, and other negative effects are also included. Furthermore, the unfavourable effects persist throughout their entire life cycle. According to the World Business Council for Sustainable Development, a building block consumes 40% of overall energy use.

2. Material Characteristics

Compressed Earth Block:

A compressed mix of dirt, non-expansive clay and aggregate. It is fire resistant, sound resistant and non-toxic in nature.

Piezoelectric Sensor:

A piezoelectric sensor is a device that uses the piezoelectric effect to measure changes in pressure, acceleration, temperature, strain, or force by converting them to an electrical charge.

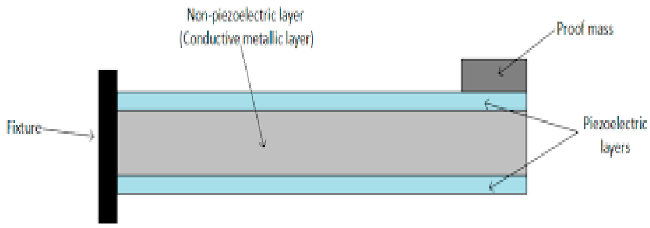

Figure 1. Piezoelectric sensor for green building(modified after Li &Strezov, 2014)

Fly Ash Block

Mixture of fly ash and lime. It possess high strength, good finishing and uniformity in size which reduced quantity of plastering.

Low VOC Paints

Low VOC stands for low Volatile Organic Compounds. It provides better indoor air quality, protects ozone layer, less allergic, quick drying and low odour.

Daylight Harvesting System

Daylight harvesting systems use daylight to offset the amount of electric lighting needed to properly light a space, in order to reduce energyconsumption. This is accomplished using lighting control systems that can dim or switch electric lighting in response to changing daylight availability.

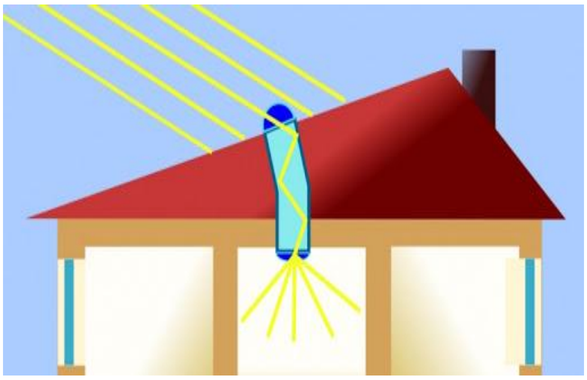

Fig. 2Daylight harvesting system for green building (modified after Lim et al. 2017)

3. Methodology

Three distinct operations can be recognized in the process of soil-cement block production using manually operated machines. They are (a) soil preparation (b) block pressing, and (c) stacking and curing.

This study is aimed at research, study and development of the green building construction techniques in order to save our planet from pollution and global temperature rise. Also, it aims at spreading awareness among the people all over the world, about the advantages and also the long term cost savings from green buildings.

- Plan is oriented facing east for maximum utilization of natural light and ventilation.
- Larger opening of windows.
- Onsite rainwater harvesting and compost generation is proposed in the plan.
- Onsite generation of Renewable Energy through Solar power, Wind power, Hydro power can be considered to minimize dependency on fossil fuels.
- Proper ventilations and air filtrations can be included to ensure sufficient flow of fresh and clean air.

4. Conclusion

This paper study reported all the technical and also the economic aspects related to green buildings worldwide. Also, through this live case study of a small residential bungalow in a small town of India it is expected to attract at least the researchers all over the world, particularly in India, and to all readers in developing their own homes or retrofitting their odd ones with simple adjustments and converting them into a green or sustainable structure for future long-term savings (economic aspects) and for environmental preservation (environmental aspects). The research conclusions can be divided into three categories: affirmative, negative, and neutral. Most literature evaluations, it has been found, focus on environmental aspects of sustainability, such as energy consumption, water efficiency, and greenhouse gas emissions, as well as technical solutions. Also, the life cycle assessment approach, which is widely used in green building's environmental elements, might be a beneficial tool for social sustainability. New rating tools are rapidly emerging all around the world. However, further research in these disciplines is needed to support these new rating methods and to aid investors and developers in their decision-making. Also, public knowledge of green construction concepts and their long-term benefits should be spread. People in nations such as India are currently ignorant of this notion, and there is also a lack of awareness. The government's initiative will go a long way toward raising awareness.

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LLC RESONANT CONVERTER DESIGN ALONG WITH SOLAR PV ARRAY USING MAXIMUM POWER POINT TRACKING ALGORITHM FOR INDUCTION MOTOR DRIVE

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ABSTRACT

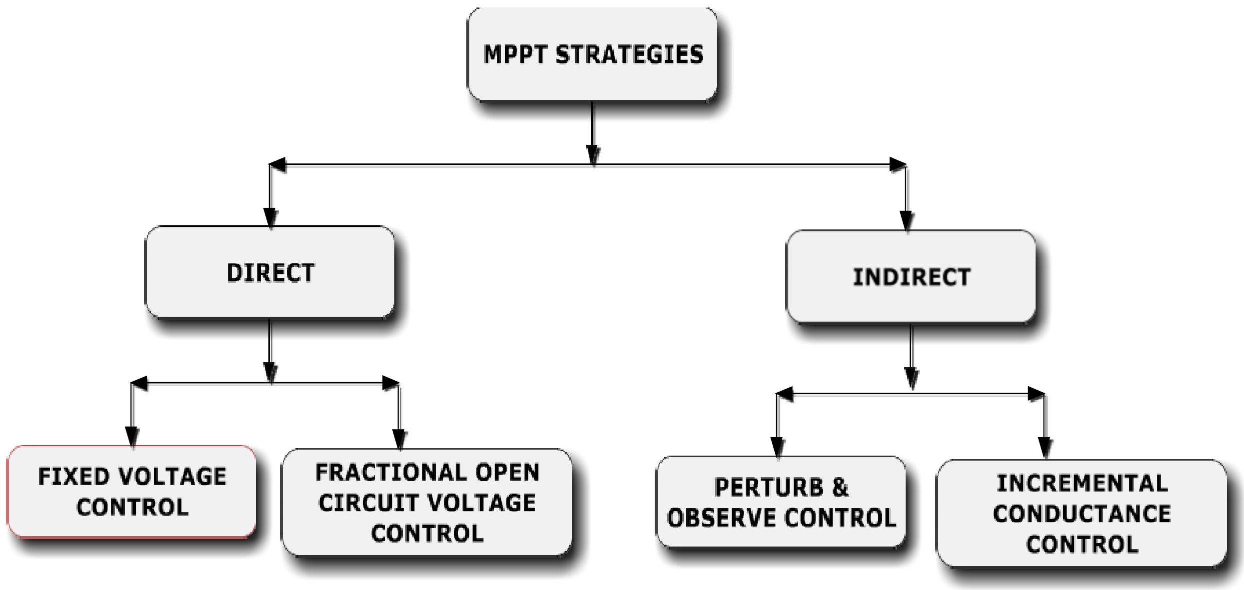
Due to high Switching Frequency rage, Resonant Converter (RC) is proven to be highly effective one. Solar Photovoltaic (SPV) is used as a renewable energy source to provide input supply voltage to this converter. For getting Maximum efficiency and power output, method of Maximum Power Point Tracking (MPPT) is employed. This is achieved by various methods like Direct (Perturb and Observe (PnO), Incremental Conductance (IC)), and Indirect methods. In this paper, Direct method of PnO is used to simulate model suing MATLAB Simulink. Corresponding simulation results are presented in this paper.

Keywords: *LLC RC, SPV, MPPT, PnO, IC.*

1. Introduction

As a Renewable energy source, Solar Photovoltaic systems are widely used to fulfill electrical power demand. Solar Photovoltaic systems have less output efficiency of about 30-35%. Because of this, use of Maximum Power Point Tracking technique is adopted. This makes solar PV to operate at its Maximum Power Operating Point region. There are two different ways of getting Maximum Power Point. They are called Direct and Indirect Methods. MPPT classification is as given below –

Figure 1. Various MPPT Methods



In Indirect MPPT, simple assumptions and periodic estimations of MPPT are made with easy measurements just to fix the operating voltage of Solar PV module on seasonal variations. This is not a very accurate method.
Direct methods evolve direct measurements of Voltage, Current or Power and provides more faster accurate response. These are also called Hill Climbing algorithms.
In P&O method, Perturbation is provided to PV module or array voltage (Salman Salman, Xin AI, Zhouyang WU, 2018). This will translate increase or decrease in power. The flowchart of this P&Oalgorithm is shown below in figure 2.

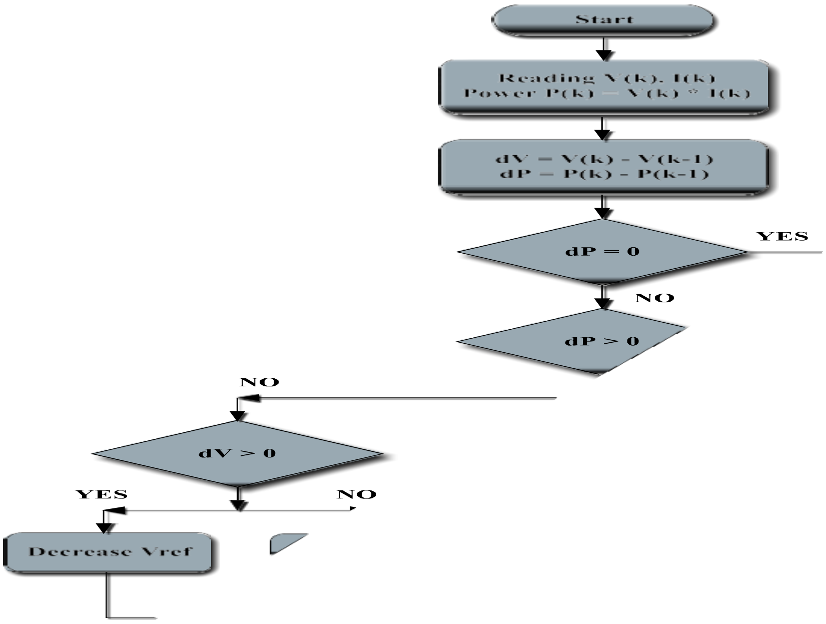


Figure 2. P & O Algorithm Flowchart

In case of Incremental Conductance method, algorithm imposes voltage on PV module at every iteration and measures the incremental change in conductance and compares it with instantaneous conductance and decides if the operating point is to the left or right of maximum power point (Adrian S.T. Tan and S. Iqbal, 2018). The flowchart of this P&O algorithm is shown below in figure 3 below.

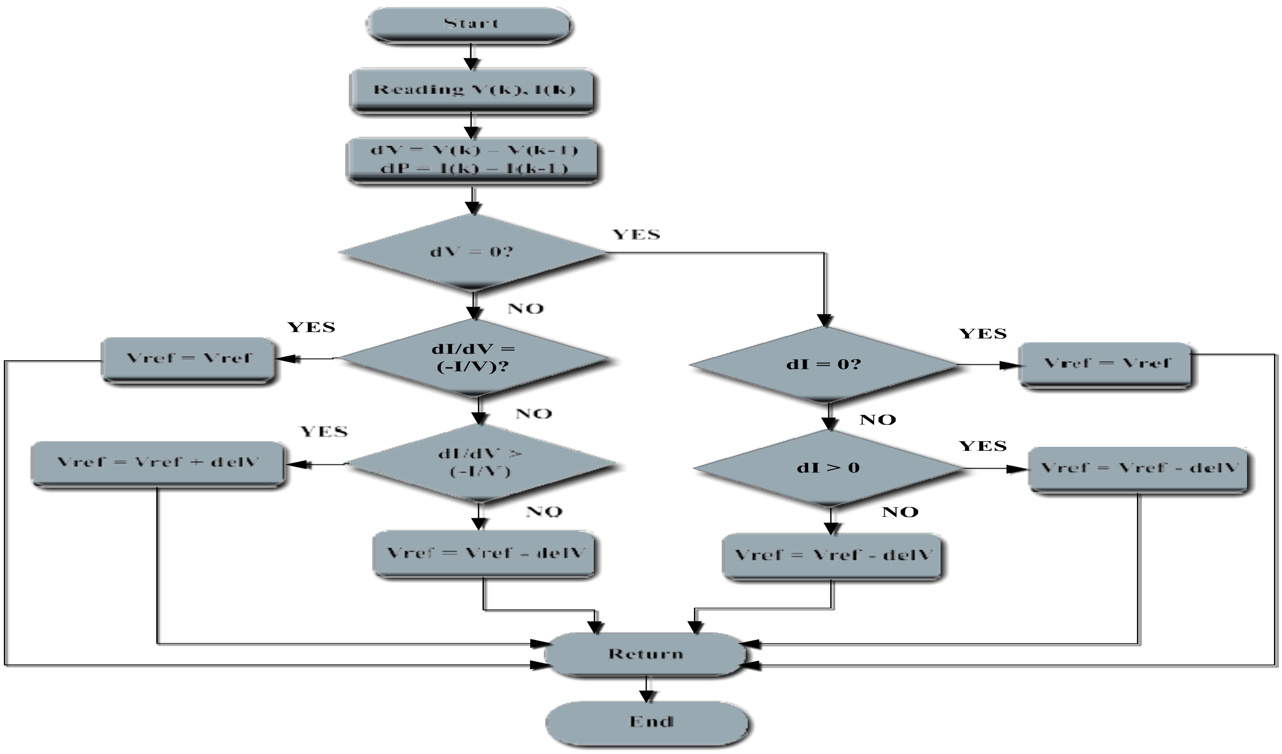


Figure 3. Incremental Conductance Algorithm Flowchart

Resonant converters are mostly used converters now a day because of their output impedance can be regulated from zero to infinite. This is achieved using frequency modulation control. They can operate at very high efficiency since the switching losses are very less (turn ON and OFF of the switch occurs near the natural current zero instant). Circulating energy is very less in these LLC resonant converters compared to Series Resonant Converters (SRC), Parallel Resonant Converters (PRC) and Series Parallel Resonant Converters (SPRC). Hence LLC type Resonant Converter is proposed here for Solar Array system to achieve high efficiency. High frequency transformer is used here for boosting output of LLC Resonant converter and also to provide isolation for Safety requirements.

In this paper, LLC Resonant Converter model and its design is proposed to be used along withSolar PV Array. Simulation study of design and associated results are verified using MATLAB SIMULINK.

2. Design of an LLC Resonant Converter

Figure 4 below shows the block diagram of a proposed LLC Resonant Converter for Induction Motor Drive application. Here MOSFET's are used as switches and are operating at high frequencyrange (100 kHz).

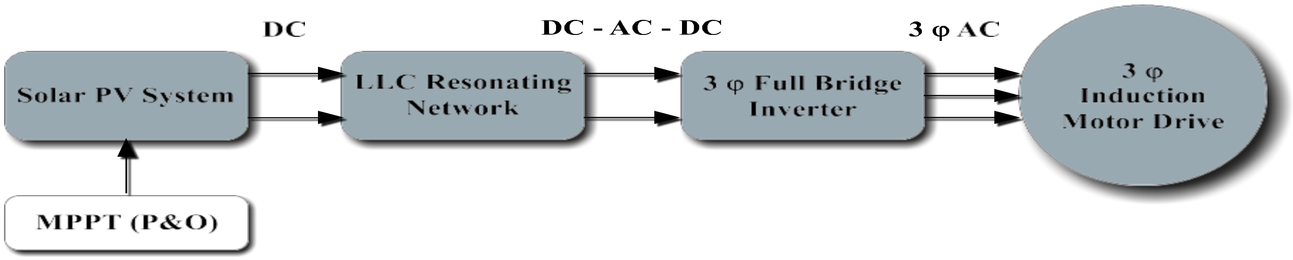


Figure 4. Block Diagram of a Proposed LLC Resonant converter System

Figure 5 below shows the proposed LLC Resonant Converter circuit. The Resonating Tank design consists of Resonant Capacitor Cr, the Leakage Inductance Lr, and the Magnetizing Inductance Lm of a Transformer (Chien – Hsuan Chang, Chun – An Cheng and Hung – Liang Cheng, 2014; Yu – Lung Ke, Ying – Chun Chuang, Mei – Sung Kang, Yuan – Kang Wu, Ching – Ming Lai, Chien – Chih Yu, 2011; Valter S. Costa, M. S. Perdiago, A. S. Mendes, Dhaker Abbes, Abdel Aitouche, 2017). The voltage output is regulated by controlling the switching frequency fs. Switches Q1, Q2, Q3 and Q4 are MOSFET's. D1 – D4 forms the Diode Bridge FW Rectifier (Adrian Soon Theam Tan, Shahid Iqbal, Dahaman Ishak and Syalruddin Bin Masri, 2017; Md. Saif Iftekhar, Md. Rabiul Hasan, Rana Banik, Rubaeat Umar, Chinmoy Barua, 2015). Transformer used here is having ratio of n = 1:10. It not only steps up the voltage level but also provides necessary isolation to the output and input circuit (Wardah Inam, Khurran K. Afridi, David J. Perreault, 2014). The inductance of transformer is a part of this LLC RC network (Hangseok Choi, 2007).

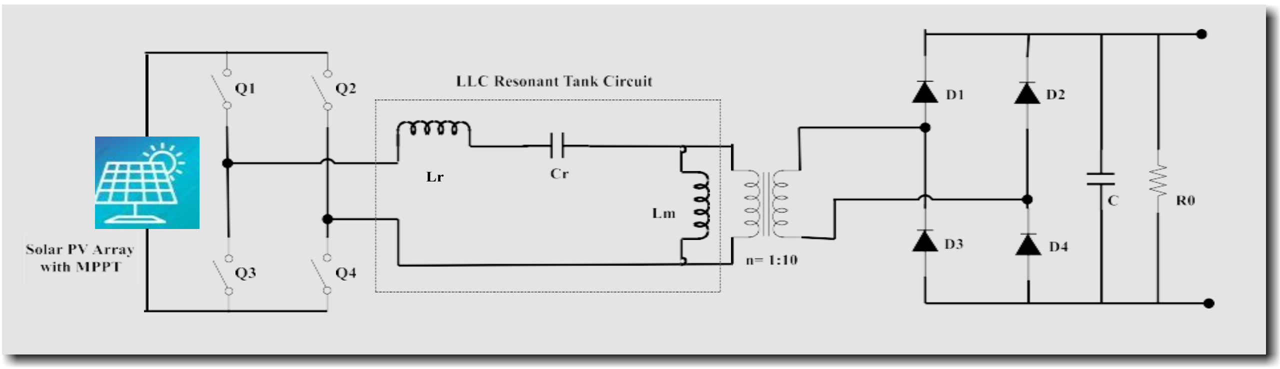


Figure 5. Proposed LLC Resonant Converter Model

The MPPT Algorithm proposed here takes care of maintaining stable output voltage corresponding to Maximum Power Point of the Solar PV. Perturb and Observe (PnO) algorithm is used to achieve Maximum Power Point (Ahmed Saidi, Chellali Benachaiba, 2016; M. Lamnadi, M. Trithi, Badre Bossoufi, A. Boulezhar, 2016). The Solar PV Array used as a source is having following parameters as shown in table 1 below. The Maximum Power Point is achieved using Perturb and Observe Algorithm. Duty ratio control is achieved using the same so that Solar PV array should give stable output voltage corresponding to Maximum Power operating point. The below mentioned parameters are given for a single PV Module. Hence accordingly, as per requirement series – parallel combination of Solar PV Modules is used toobtain desired output.

Table 1: Parameters of Solar PV Array used

Parameter	***Abbreviations***	***Value***
Maximum Power Output	*Pmax*	*180 Watts*
Open circuit voltage	*Voc*	*63.3 Volts*
Short Circuit Current	*Isc*	*7.6 Amp*
Irradiance	*Q*	*1000 W/m^2*
Temperature	*T*	*25 ^{0}C*

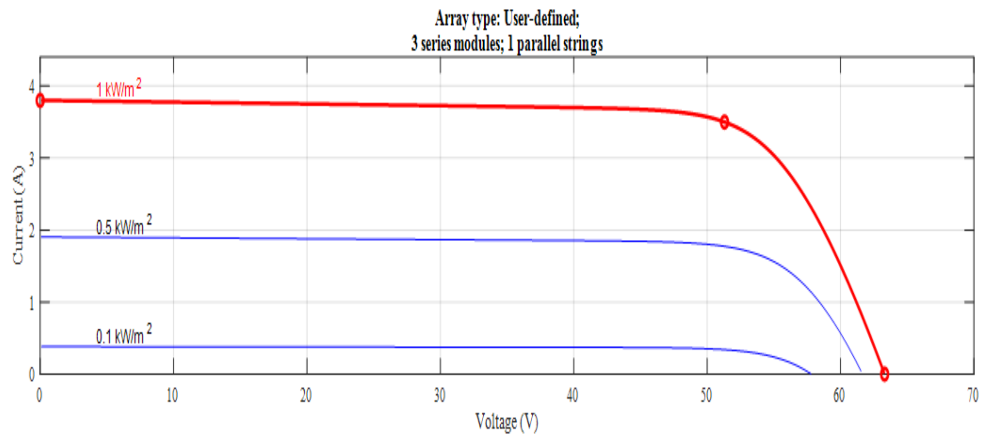


Figure 6. I – V Characteristics of Solar PV Module

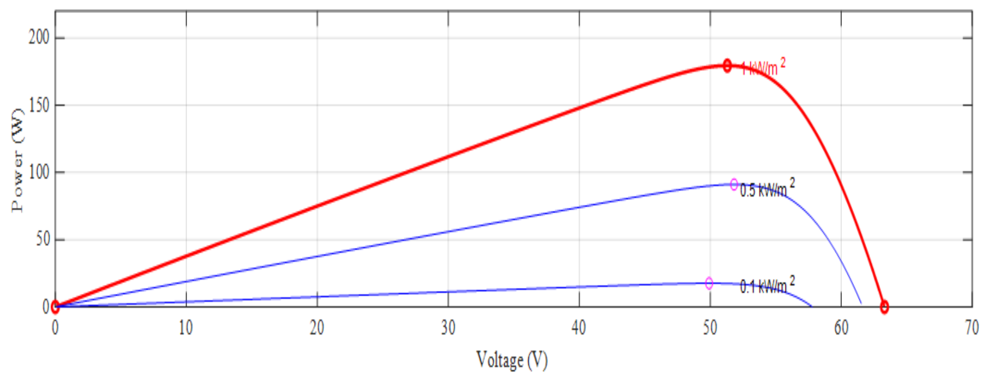


Figure 7. P – V Characteristics of Solar PV Module

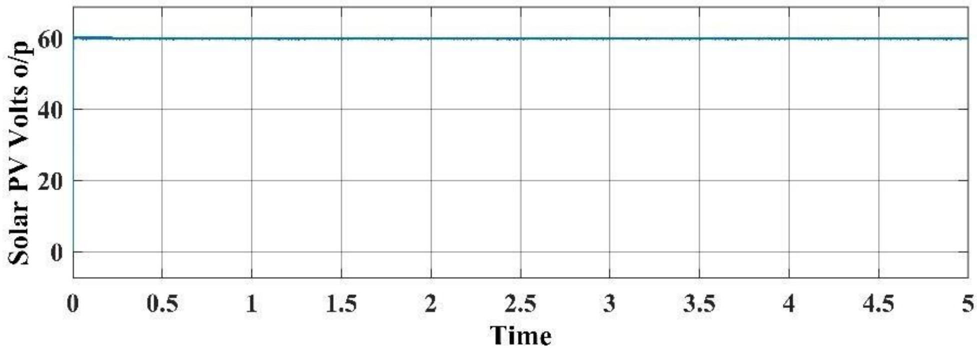


Figure 8. Voltage Output of a Solar PV Module

LLC Resonant Converter Design Considerations

The design of a proposed LLC Resonant Tank circuit, Priyesh Pandey, Prashant Agnihotri, 2019; M. Shanthi and R. Seyezhai, 2015; Yu Tang, Dekai Kong, Chenxu Duan and Hao Sun, 2020) is based on calculations as given in equations (1) to (8).

Table 2: Design Parameters of an LLC Resonant Converter

Parameter	*Abbreviations*	*Value*
Input Voltage	*(VDC)*	*60 Volts*
Output Voltage	*(Vo)*	*415 Volts*
Output Power	*(Po)*	*2.32 kW*
Switching Frequency	*(fs)*	*100 kHz*
Resonating Frequency	*(fr)*	*5 kHz*
Resonating Capacitor	*(Cr)*	*4.1733e-6 F*
Leakage Inductance	*(Lr)*	*0.10116e-6 H*
Magnetizing Inductance	*(Lm)*	*0.5058e-6 H*
Transformer Ratio	*(n)*	1:10

Equations

$$Cr = \frac{1}{2*\pi*Q*fo*Rac} \quad (1)$$

$$Lr = \frac{1}{(2*\pi*fo)^2*Cr} \quad (2)$$

$$Rac = \frac{8*n^2*RL}{\pi^2} \quad (3)$$

$$= \frac{RL}{2\pi fr} \quad (4)$$

Magnetizing Inductance, L_m

$$n = \frac{Np}{Ns} = \frac{Vinmax}{2*(Vo+Vf)} * Mmin \quad (5)$$

$$Mmin = \sqrt{\frac{m}{m-1}} \quad (6)$$

$$Resonant\ Frequency,\ f = \frac{1}{2\pi\sqrt{Lr\,Cr}} \quad (7)$$

$$m = Inductance\ Ratio = \frac{Lm}{Lr} \quad (8)$$

Selecting m=5 and quality factor corresponding to m chosen as 0.4, the calculated parameters of LLC Resonant Converter are as given in table 2 (Neemi Altin, Saban Ozdemir, Adel Nasiri, 2019; Junhao Luo, Junhua Wang, Zhijian Fang, Jianwei Shao, Jiangui Li, 2018; Kirlampalli Harija Rani, Ch Venkateswara Rao, 2016; Wardah Inam, Khurran K. Afridi, David J. Perreault, 2014).

The Induction motor load is considered to check the proposed system. The parameters of Induction Motor drive load is given below in table 3.

Table 3: Parameters of Induction Motor Drive

Parameter	*Abbreviations*	*Value*
Input Voltage L-L, rms	*(Vin)*	*415Volts*
Output Power	*(Po)*	*2.3 kW*
Frequency	*(f)*	*50 Hz*

1. Results

The proposed design and model are simulated using MATLAB / Simulink. The simulation results for respective LLC Resonant converter voltage output, Induction Motor Outputs for Stator Current, Stator Voltage L-L, Speed, Torque, are shown below in figure (10) to figure (13) respectively.

The stator current is stabilized at a final RMS value of 4.57 Amps. The Stator Voltage is obtained to be equals to 415 Volts (RMS). Induction motor stabilizes its speed after 3.5 seconds and the same can be also seen for Electromagnetic torque developed by an Induction Motor. Looking at these values and waveforms of various parameters of Induction motor, this proposed system is giving better results compared to plain Induction motor drive supplied from direct AC source. Some harmonic contents are there which can be further taken care by designing proper filter circuit. The respective resulted values of different Induction Motor Parameters are also listed below in table 4.

Table 4: Induction Motor Simulation Output Results

Parameter	Abbreviations	Value
Stator Voltage, rms	*(VL-L)*	*415 volts*
Stator Current, rms	*(IFL)*	*4.57 amps*
Full Load Speed	*(NFL)*	*1431 rpm*
Electromagnetic Torque	*(Te)*	*14.42 N*m*

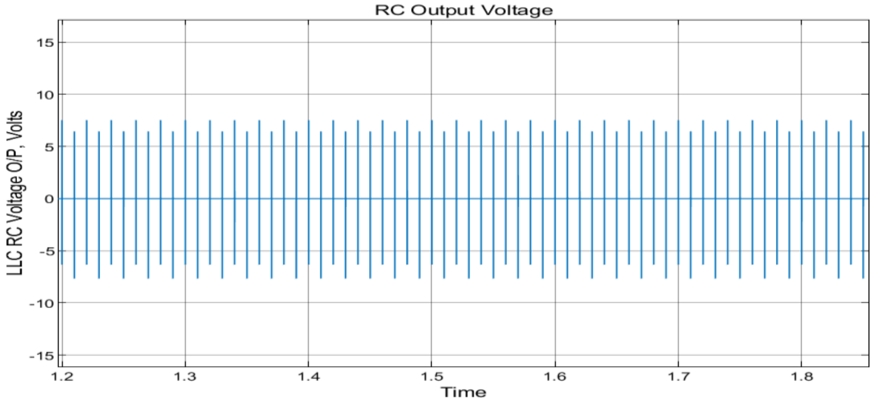


Figure 9. LLC Resonant converter O/P voltage waveform

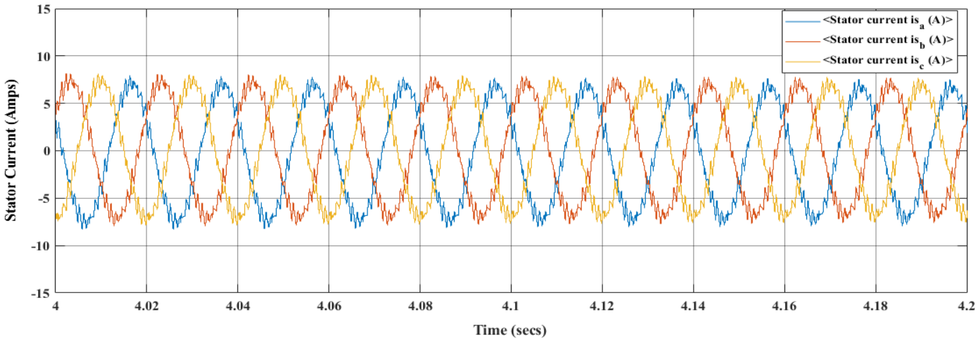


Figure 10. Induction Motor stator current waveform

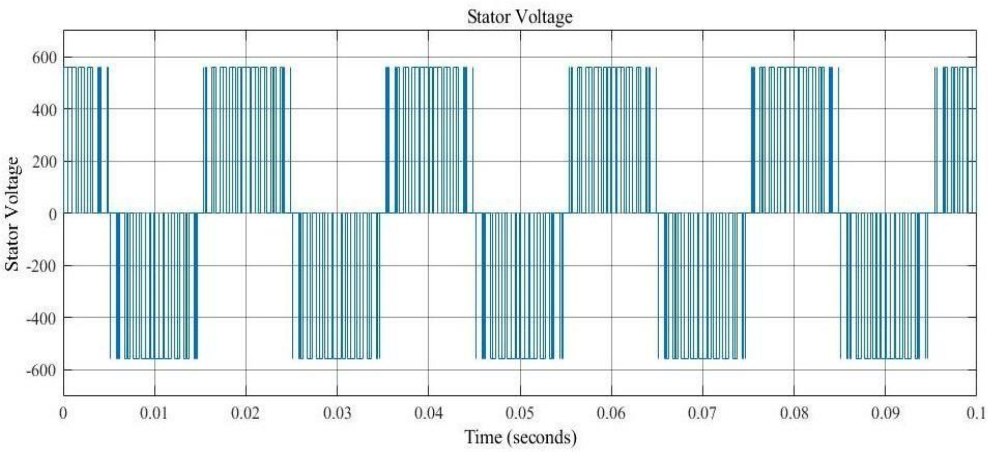


Figure 11. Induction Motor Stator Voltage Waveform

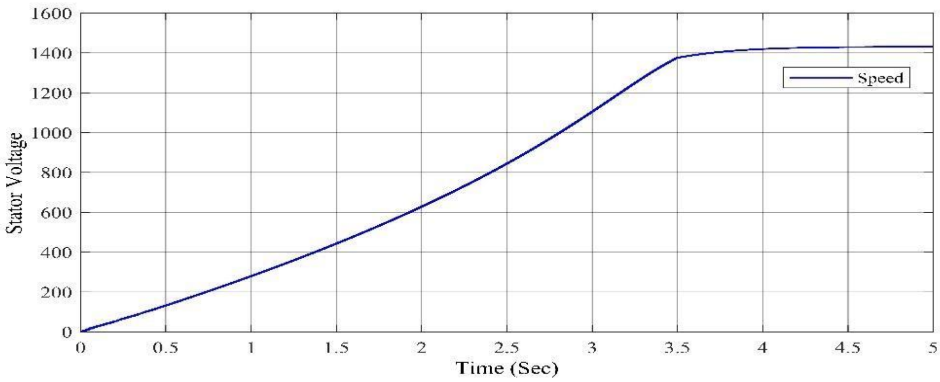


Figure 12. Speed Curve of Induction Motor Drive

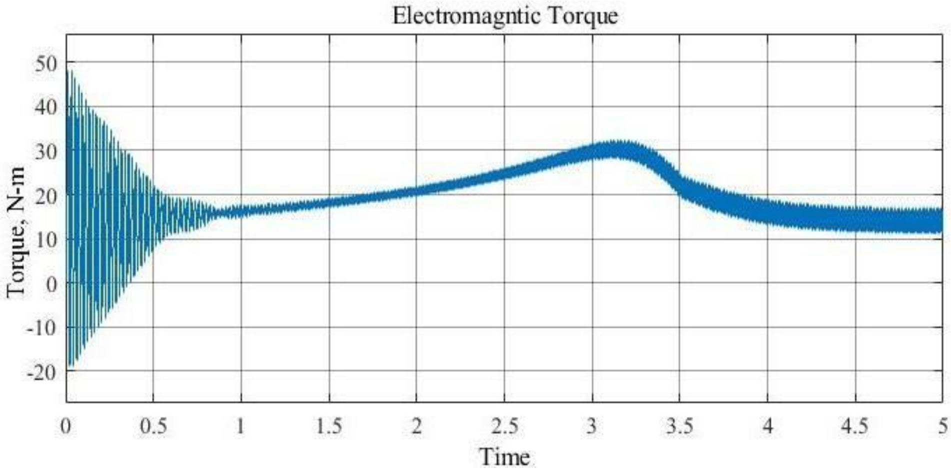


Figure 13. Electromagnetic Torque curve for Induction Motor Drive

3. Conclusion

The Perturb and Observe algorithm based MPPT based system is simulated. The duty ratio control method is used for stabilizing Solar PV output voltage corresponding to Maximum Power Point. The LLC tank network is providing necessary voltage value to drive the Induction Motor. The simulated resultant values for Induction Motor drive are satisfactory. MATLAB/SIMULINK is used to obtain corresponding resulted values. Overall, the Proposed LLC Resonant Converter Model for Induction Motor Drive along with Solar PV using MPPT is showing satisfactory performance in terms of output parameters

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GEOTECHNICAL PROPERTIES OF RANDOMLY REINFORCED FIBERS MASS: A CRITICAL REVIEW

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ABSTRACT

Random Reinforcement of soil by fibers is a process in which appropriate amount of fibers are randomly blended into a soil mass to improve the certain behavior of soil. It helps to increase tensile strength, ductility, reduce differential settlement and improve stability of construction. Diameter, length, orientation and percentage of fibers are varies and depends on the soil behavior. This technique has been used to improve certain properties of soil like ductility, tensile strength, bearing capacity, swell-shrinkage behavior and shear strength (c &ϕ) characteristics in the present and past years by different technologist. It's the cost effective nature, easy adaptability, usability of waste fibers is again attracting the interest of Geotechnical scientists to work on different fibers reinforced composites. Finally, review will help to proceeds the future direction of random reinforced soil mass through published papers. This paper critically reviewed the geotechnical properties, failure pattern and mechanism of gaining strength of random reinforced soil mass.

Keywords: *Bearing capacity, Random reinforcement, Shear strength, Tensile strength.*

Introduction

Nessecity of Ground Improvement Technique

Increasing population growth and urbanization made high demand of unstable and erosive lands with poor geotechnical properties. Therefore, development of effective ground improvement techniques for soils has been focused in past few years [10, 11]. Ground improvement techniques like vibro stone columns and prefabricated vertical drains are the new trends and used widely on soft clay. However engineers and scientists are still finding the new techniques which are faster and cheaper than the traditional methods [12]. Use of random reinforced fibers in soft soils is a new and widely used technique for many geotechnical applications. Random reinforcement of fibers is one of the important methods of ground improvement to reduce shrinkage cracks and improve flexibility in soft clays [1].

Methods of Soil Stabilisation

The soil stabilisation methods mainly divided into physical, mechanical and chemical methods. These methods are subdivided into number of groups as follows [3].

1. Physical Methods-These are in-situ ground improvements techniques without addition of any other admixture.
   I. Compaction- Static, Dynamic, Vibration
   II. Preloading -With drains, without drains
   III. Thermo-electrical
   IV. Freeze and thaw

The other methods are mechanical and chemical methods where additives are used for improvement of soil [3].

2. Mechanical Methods
   I. Using Fibrous material
      a) Geosynthetics material- Geogrid, Geotextile,Geonet, Geocomposite, Geocell
      b) Random reinforced soil-Natural fibres, Man-made fibres, Mineral fibres
3. Chemical Methods
   I. Conventional
      a) Cement
      b) Lime
      c) Bitumen
   II. Enzymes
   III. Polymeric Resin
      a) Polyvinyl alcohal
      b) Polyvinyl Acetate
      c) Polyvinyl Acrylic
      d) Urea formeldehyde
      e) Poly methyl mehta acrylate (PMMA) etc.

To achieve the better results, two of more methods are combined together. Use of lime/cement/bitumen with fibres improve strength characteristics in multiple times rather than using alone. There are many more combination can be used to get the better results with minimum effert.[3]

Facter affecting the ground improvement techniques

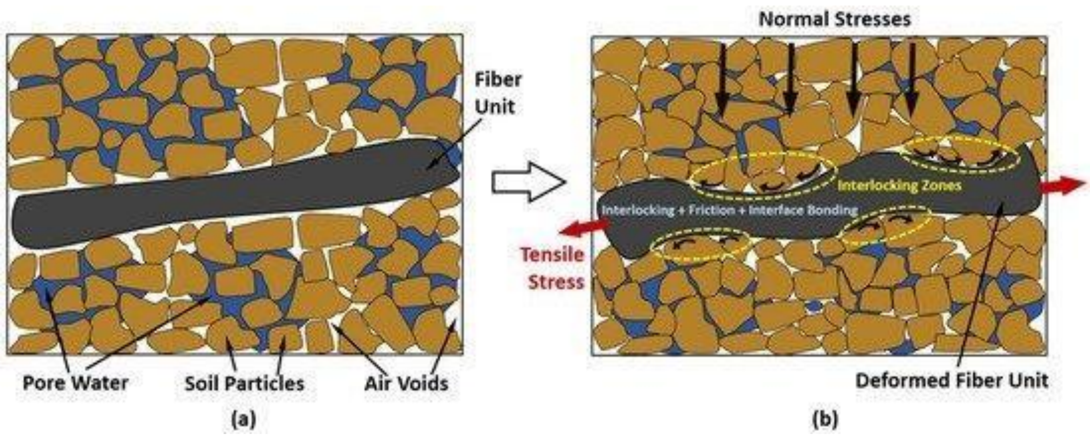
There are number of factors affects the gorund improvement techniques in which soil type and properties of soil is the main. Soil gradation, presence of mineral, organic matter and moisture content changes behaviour of soil drastically and affect ground conditions. Some other facters to influence the ground improvement techniques such as area and depth at which treatment are required, type of structure constructed, load distribution on soil, permessible total and differential settlement, availability of material, skills, equipments and funds.

Fibre reinforced soil

The fibre reinforcement soil mass is a compacted soil composite which contain randomly distributed discrete fibres that can be different diameter and length. Reinforced fibres helps to improve geotechnical behaviour of soil. Distributed fibres in soil mass subjected to tension which provides strength of soil mass. When the load is applied to soil mass initially the volume of soil mass decreases and soil particles get densify, which cause deformation on fibre surface. Forces are induced on fibre surface because of rotation and direct impact of soil particles. Along this, frictional forces are generated where soil particle get contact with fibre [26]. The interlocking forces and frictional forces are combined induced tensile stress on fibre material. In case of random distributed fibre soil mass, fibres mobilize fibre soil adhesion bonding which provide additional composite strength. The interaction of flexible fibres behaves as a structural mesh that holds soil particle together and increases soil structural integrity [26, 27].

Figure -1: Randomly Reinforced fibers soil mass unit at: (a) Initial Stage without loading and (b) Fiber behavior due to applied loading, where the effect of interlocking, friction and interface bonding induces mobilization of the tensile stress on the fiber unit [21].

II. History of fibre reinforced soil mass



The concept of reinforcing soil with fibres is not new, it was practiced with early civilisation. Construction of clay bricks using straw and natural fibres are known and used from 4th and 5th century B.C. It has found that reinforced soil improves durability and strength of the dried bricks. There is a evidence of using tamarisk branches of the Great wall of China. AGAR-QUR ZIGGURAT (tower temple of Babylon) is the ancient monument constructed in late 14th or early 15th century B.C. and situated 5 km off from Baghdad. The original height of the structure is about 80 m. high. Now it is 45 m. tall structure. In the structure clay bricks reinforced with woven mats of reed ropes in 100 mm. length and 0.5 to 2.0 metre spaceing horizontal on layer of sand and garvel. Measurement of improvement in the geotechnical properties of soil using fibre reinforcement is a new concept. In the modern history the strengthening of soil mass using fibre reinforcement was presented by Vidal during the 1960s for composite material framed from flat reinforcing strips laid horizontally in a frictional soil. He explained that there is friction between soil and reinforced material and because of this friction when load is applied to soil stresses get transferred to reinforced material. It will behave as a composite material and get better tensile strength as compared to soil without reinforcing material. He described composite material named as ‘Reinforced Earth’ [9]. Initially synthetic fibres are used with concrete to reduce the shrinkage cracks. Later on the same concept is used in soils to reduce the shrinkage cracks especially in clays [2].

From the history of fiber reinforced soil mass, it can be concluded that the use of fibers in soil is started from early civilization but the use of natural and synthetic fibers in soils with geotechnical concepts and principles are new field where improvements in soils are measured, optimized and critically analyzed [3].

Fibres used in Soil Reinforcement

a. Natural fibres _ Natural fibres obtained from plant, animal and mineral origin. These fibres are available worldwide. Natural fibres provide high strength, high modulus, low breaking extension and low elasticity. In certain soil reinforcement applications geotextile have to serve for more than 100 years. Biodegradable natural geotextiles are deliberately manufactured to have relatively short period of life. They are generally used for prevention to soil erosion until vegetation can become properly established on the ground surface.

b. Synthetic fibre _ Synthetic or manmade fibres are the major raw materials for the production of all types of geotextile. Polyester, polyamide, polyethylene and polypropylene are the most commonly used fibres for soil reinforcement.

c. High performance Geotextile _ Expansion of the application of geotextiles and the complexity of the environment, high strength, multifunctional and high performance geotextile have become the development direction of geotextiles. At present, the main methods to improve the performance of geotextiles are additives, chemical modification and composite geotextiles

Functional Requirements of Geotextile for soil reinforcement

Property of geotextiles	Performance requirements
Tensile strength	A
Elongation	C
Chemical resistance	B-C
Biodegradability	C
Flexibility	A
Frictional property	A
Interlock	A
Tear resistance	A
Penetration	A
Puncture resistance	A
Creep	C
Resistance of flow	A
Properties of soil	C
Water	C
Burial	C
UV light	B
Quality assurance and Control	C
Cost	C

A= highly important, B = important, C = least important[29]

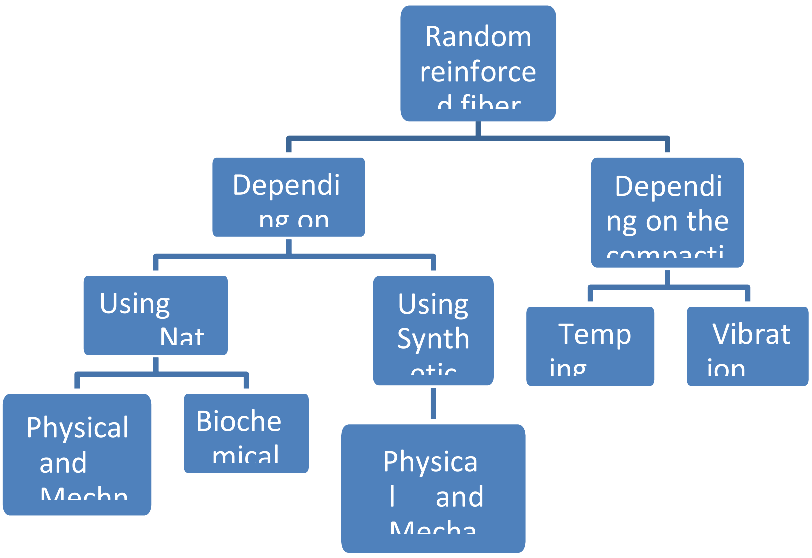
Characteristics of Fibers used in Reinforcement

Detailed characterization is the main concern before use of fibers in reinforced soil mass. Lots of literature summarized that fibre characteristics (orientation, type, length, thickness, dosage and geometry), nature of soil and type of stabilizers effect on the resultant behavior of fiber-reinforced soils [3, 13, 14, 15, 16].

Uses of synthetic fibers are dominating natural fibers for soil reinforcement because of their specific characteristics. Diameter of reinforcement fibers are very fine ranging from 3µm to 60µm. Hence the single fiber mechanical properties determination is difficult and good results only in tensile strength of fiber. ASTM D3379 and ASTM D4018 describe the tensile strength and Young's modulus test on reinforcing fibers under static loading for single filament material and resin-impregnated fibers respectively [17]. Compressive strength testing and flexural strength is performed as per the standards ASTM D 695 and ASTM D 790 respectively. The Barcol hardness tester as per the standard ASTM D 2583 are used to conduct the hardness test and also the Impact test has been conducted as per ASTM D 256 standard, by using impact testing machine [18]. Analysis of reviews of compaction test results shows that the inclusion of fibers in soil increase the porosity of soil fiber mix. The synthetic fibers are offers resistance to compaction which causes lesser dry density.

Maximum mechanical properties of reinforced fibers are calculated indirectly. Firstly the composite properties are calculated and that retrieve to the fiber properties by using some relation [17].

Classification of fiber reinforced soil mass is shown below



Eco-friendly Non-eco-friendly

Table - 1:Properties of Fibers which makes it preferable soil reinforced material are:

1.	They are good alternative of natural raw material sources like lime, cement, aggregates.
2.	They are an alternative of conventional ground improvement techniques.
3.	They are sometimes the only way to construct.
4.	They can boost textile industries.
5.	It takes less time to use it and least impact on environment.
6.	Various site constraints like space, alignment can be achieved easily.
7.	They ensure maximum usage of local materials and least maintenance cost, hence reduces the construction cost.
8.	They provide long term performance and higher cost benefit ratio over a large period of time.
9.	Use of fibers solve the problems or reduce the problem up to a certain extend.

Table - 2:Different properties of soils which will improve by the fiber reinforcement are:

1.	Increase shear strength and maintain strength isotropy
2.	Increase the tensile strength of soil
3.	Reduced Post peak strength loss
4.	Increased flexibility
5.	Reduce shrinkage and swelling quantities of far reaching soils
6.	No cataclysmic disappointment
7.	Provide disintegration control and encourage vegetation improvement
8.	Not extraordinarily influenced by climate conditions
9.	No noticeable change in permeability [4]

Degradation of the natural fibres due to micro-organisms is a major challenge in fibre reinforced technique [22, 23]. Such biodegradation of fibres cause depletion of strength of fibre reinforced soil mass due to breakdown of cell wall polymers (cellulose, lignin and hemicelluloses etc). Fibres absorb moisture present in soil mass resulted by holocellulosic content which provides favourable conditions for microorganism to live on the fibre material [24]. Lignin content which exists in the outer layer of fibre matrix resists the bacterial intrusion up to certain extent [25].

The biodegradation happens in both aerobic and anaerobic conditions. In the reaction lignocelluloses breaks down into residue carbon polymer [24].

$$C_{polymer} + O_2 \xrightarrow{aerobic} C_{residue} + C_{biomass} + CO_2 + H_2O$$

$$C_{polymer} + O_2 \xrightarrow{anaerobic} C_{residue} + C_{biomass} + CO_2 + CH_4 + H_2O$$

Biodegradability can be adequately overwhelmed by heat treatment, coating by bitumen or water based paint, alkali treatment, ultrasonic impact, applying substance coatings on filaments utilizing polymer mixes etc. [21]. Natural fibres are poorer in mostly mechanical properties than the synthetic fibres. The possible solution of this is to use of natural/synthetic fibre combination in polymer hybrid composites. The biodegradability effects of natural fibres are compromised by synthetic fibres in hybrid composites. Hybrid composites are multiple fibres in the same matrix. The properties of hybrid composites are the synergistic effect of the properties of both fibres [19]. Natural fibres are appropriate just for shallow foundation in light of their constraints. For the development top to bottom and long life, manufactured polypropylene fibres have been utilized [5].

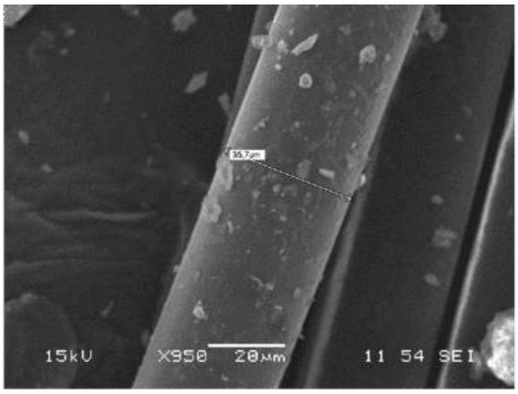
Table - 3:Properties of fibre reinforced soil are depends on:

1.	Properties of soil (particle shape, size and gradation)
2.	Mechanical properties of fibre (weight ratio, modulus)
3.	Surface roughness of fibre
4.	Compaction of soil fibre mixture and soil-fibre interlocking
5.	Moisture content and other environmental conditions
6.	Orientation of fibres along the failure plane
7.	Length and aspect ratio of fibre
8.	Fibre soil surface friction
9.	Dosages of fibre in terms of dry weight of soil [6]

It has been seen that use of fibres for reinforceing soil there is no change in the cohesion. Only the friction between soil and fibre increases the strength properties and angle of internal friction. Due to this the rough surface texture fibres gave better results as compared to smooth surface fibres. All the fibre (natural and synthetic) have varying surface roughness.

Scanning Electron Microscope (SEM) image shows the texture of fibre which is indicated the roughness of fibre surface. Surface roughness of fibre is cause friction between soil and fibre. Higher roughness will cause higher bonding between them. Fig. 1 shows the SEM image of polypropylene fibre.

(a) Polypropylene fibers with 12mm length



(b) SEM image of polypropylene fiber [28]

Figure - 2

Random reinforcement of soil using fibres is better than any other soil improvement techniques in many ways:-

- Random reinforcement minimizes the tensile cracks in soil surface and at depth [7].
- Random reinforcement provides uniformity in soil and eliminates the weaker plane [8].
- Fibre reinforcement is cost effective, eco-friendly, requires minimal machinery and diverse materials can be used to reinforce the majority of soils [8].
- There are number of natural and synthetic fibre available and synthetic fibre can be produced according to the unique specification which is needed for a particular project [8].

Use of fibres in the construction industry has been increased tremendously due to its several benefits. It is encouraging the fibre manufacturing and treating industries to develop many more kinds of fibre according to the specific properties and requirements. This paper reviewed the discrete and random reinforced soil mass including wide range of applications. The object of the paper is to summarize the past researches, present status of work done and the future scope of the research in the topic. The paper has discussed the numerous studies related to experimental, analytical and field performance. A concluding statement is in the past studies indicated that the fibres used as an application for increasing the strength of soil. In future the fibre applications are dams, embankments, slope protection, railways, earth retaining structures, foundations etc.

2.2 Method of mixing fibers in the soil

To achieve the best results from random reinforcement of fiber reinforced soil, it is important that the soil and fiber mixed uniformly. Several methods adopted by researchers to get the proper mix of fiber and soil. It is important that soil is at its optimum moisture content before adding fibers. Stir fibers and soil with different movements to achieve most homogenous mix. For large amount of fiber soil mixing concrete mixer can be used.

III. Behaviour of Fibre reinforced soil Mass

Number of studies has been carried out to study the behaviour of fibre reinforced soil mass (FRSM). Maximum experimental studies are summaried in the following tests:

- Compaction test
- Permeability test
- California Bearing Retio (CBR) test
- Direct Shear test
- Triaxial test
- Unconfined Compression (UCS) test
- Splitting Tensile test [20]

The effect of fibre reinforcement on the above properties have been repoted by number of researchers. They have found variation in the properties depending on the variation in parameters, but in some cases the observations appers to be contraductory. Variation in orientation cause the variation in results. The fibres are most effective when fibres are oriented in soil mass in such a way that the tensile stains caused by applied loading and orientation of fibres will be same direction. The orientation of fibres in soil mass in the laboratory and fields are depending on the method of mixing of soil with fibres. Initially required amount of water is added to soil mass and mixed uniformly, followed by adding the fibres in the wet soil till to get the uniform mix. The soil fibre mix is filled in the desired mould with specified layers and compaction. There are two methods of compaction, tamping and vibration. It has been observed that use tamping and vibretion methods in the moist fibre reinforced soil leads to preffered nearly horizontal orientation of fibres. In both the techniques at least 80 % of fibres oriented between ±30˚ of horizontal.

Bandaru Ramarao et. al. (2011) compared falling head test (FHT), pressure head test (PFT), mid scale hanging bag test (HBT) and geotextile tube dewatering test (GDT) method adopted for analyzing dewatering performance. The tests were performed using woven geotextile and silt slurry at 33% of solids concentration. The study proposed a theoretical model using Darcy's law and Kozeny – Carmon equation which help to estimate dewatering time. Results indicate that the dewatering efficiency is almost same for the PFT, HBT and GDT. While filtration efficiency is similar for the HBT and GDT. The FHT was determined to be a poor indicator of performance parameters relative to other test methods. PFT is more suitable due to its simplicity, ease to use and cost. It is an alternative to the GDT and HBT especially for application where dewatering efficiency is the controlling criteria. [32]

Grzelak et. al. (2011) used different methods for assessing geotextile tube dewatering performance. A new test setup has developed for filtration test to simulate vacuum condition in the field. Geofelt 200 G1, polyprop 300 G2, polyprop 700 G3, cocos G4, typar 3337 G5 nonwowen are used to evaluate the clogging potential and retention capacity. Results for the test are compared and concluded that G3, G4 and G5 performed well in terms of clogging potential and soil retention and permeability loss compared to G1 and G2 systems. G3 and G4 systems are not suitable due to piping behaviour. G1 and G2 are not suitable due to low steady state permeability. The pattern of the flow across the sludge geotextile system follow the three distinct stages. In first stage the permeability decrease because of the consolidation of sludge layer. After 200 hours k exhibiting a steady state behavior. From the test it is concluded that sludge - G5 is most efficient.[31]

S. K. Ghosh et. al. (2013) suggested uniform test procedure for jute Geotextile for global acceptance. ASTM standard for testing is summarized. The paper clearly discussed the problem of using existing testing standards.[30]

IV. Future prospects

Discrete and randomly distributed fiber reinforced soil (DRDFRS) is a new concept while use in earth retaining structures, dams, embankments and slope protection etc. Future scopes of the DRDFRS are following:

- Durability is a very important factor in natural fibres which has not been investigated in detail up to now. Use of fibres at different possible subsoil conditions including cyclic stress-strain, wetting-drying and freezing-thawing responses can be considered as future work.
- Surface roughness plays a very important role in fibre-soil friction. Study the surface roughness of fibres and evaluate the effect of surface roughness in the tensile strength of fibre reinforced soil mass is the future prospect of fibre reinforced soil mass.
- Review clearly revealed that studies related to pullout frictional investigation and failure mechanism of reinforced soil have not done.
- A lot of scope in the large-scale investigation on fibre-soil reinforcing technology, as most of the investigation studies only for small-scale laboratory studies. It is recommends to scale-up the future investigation to promote reinforcing

mechanism.

Studies to evaluate the cost of product developments, field applications, monitoring and performance evaluation in order to quantify the economic benefits of different men made fibres, natural fibres and waste fibres has to be done

V. Conclusion

From the previous studies it can be concluded that the behaviour of fibre reinforced soil mass is function of fibre content, aspect ratio, skin friction between soil particle and fibre surface, soil index and strength characteristics and fibre strength characteristics. Fibres (natural and synthetic) are better option as stabilizers for almost all type of soils and environmental conditions. The fibre provide flexible behavior in fibre reinforced soil mass which able to withstand a large differential settlement without any major distress. Uses of fibre, moderate the swelling-shrinkage behavior and ductility of fibre reinforced soils. It provides tensile strength to soils. In some cases reinforcement is only the valid technical solution. The soil reinforcement is based on the friction/adhesion of soil particles and fibres surface. The increment in the strength of soil is reflected by either cohesion C_R (failure due to rupture of reinforcement) or by increased friction angle ϕ_R (failure due to slippage). The increase in strength is a function of shear strength of soil, tensile strength and distribution of reinforcement in soil mass. Geosynthetics improves strength, settlement characteristics of the reinforced soil mass by shear stress reduction effect, confinement effect, membrane effect, and interlocking effect. Extra care is required to obtain reasonably uniform distributed fibres within the soil mass in the field. Since the scale effect on the stress-strain behavior of fibre reinforced soil mass has not been investigated fully on a large scale, the actual behavior of fibre reinforced soil mass is not well defined. Use of fibres will likewise improve the CBR and UCS of soils up to certain extend. The properties of fibre reinforced soil mass will improve by addition of fibres up to a certain limit after that addition of fibre will reduce the strength and increases the permeability. The percentage of fibre suitable for maximum improvement called as optimum percentage of fibre. The optimum percentage of fibres for maximum strength is depends upon the soil type, fibre type, fibre length and diameter, admixtures if added, moisture content and compaction energy given to the fibre reinforced soil. Prediction of optimum percentage of fibre and behavior of the fibre reinforced soil can be achieved by Regression analysis (linear and non-linear), Target Reliability analysis, Constitutive models based on the Critical State Soil Mechanics and the Modified Cam Clay model etc. Use of fibres will not change any chemical composition in soils. Uses of lime, cement, fly ash or any other admixture with the fibres improve the strength properties tremendously. Improvements of strength will always more than the addition of improvement of strength when added individually. It's easy to understand the concept of fibre reinforced soil mass by using the four phase diagram for fibre reinforced soil.

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