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Aims and Scope

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Ferrocement an Affordable Housing Material for Low Cost Housing

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ABSTRACT

Affordable housing projects are characterized by an increasing demand mainly due to urbanization. The selection of building materials should meet the needs of local conditions to improve quality of life for the most needed ones by building new structures and/or by improving existing structures. Ferro cement as a construction material attracted considerable attention from research workers, field applicators and economists. Its property of improved homogeneity compared to R.C.C. and reduced thickness made it possible to employ the material as substitute to timber, steel and asbestos cement as material. Ferro cement is supposed to be a product of low level technology. Ferro cement is ideally suited for thin wall structures as the uniform distribution and dispersion of reinforcement provide better cracking resistance, higher tensile strength to-weight ratio, ductility and impact resistance. The applications of ferro cement structural elements are highlighted in this paper.

Keywords: ferrocement, sunscreens, Urban, demand, Life, Affordable, building Material

1. INTRODUCTION

In the early 1970's, labour intensive ferrocement construction was viewed as particularly suitable for countries, the applications of ferrocement must be viewed from a different perspective due to the competitiveness in the construction industry and the increase in labour cost coupled with shortage of skilled construction workers. In order to alleviate these problems, mechanised production and proper choice of reinforcements must be pursued to ensure the cost competitiveness and speed of construction. construction technique and to evaluate their performance in service. Ferrocement as a construction material attracted considerable attention from research workers, field applicators and economists. The simplicity of operation involved in the making of fibrocement made it popular, first in the war-affected Europe and later, now in the developing countries. Its property of improved homogeneity compared to R.C.C. and reduced thickness made it possible to employ the material as substitute to timber, steel and asbestos cement as material. Ferro cement is supposed to be a product of low level technology. As is true for all such technology, good and bad products can be made from the same set of materials, the difference being in the understanding and skill of the operatives. The salient features of the design, construction and performance of these ferrocement structural elements are discussed briefly in this paper.

2. TECHNOLOGY

Ferro cement is a type of thin reinforced concrete, commonly constructed of cement mortar reinforced with closely spaced layers of continuous and relatively small wire mesh. The mesh may be metallic or of any other suitable material. In reinforced concrete, larger diameter steel bars are placed whereas smaller diameter wire meshes are buried in cement mortar in Ferro cement. As the diameter of the bars are smaller, the bonded area increases considerably and consequently the tensile strength of Ferro cernent increases. For example One 6 mm diameter bar in concrete is replaced by four numbers of 3 mm diameter wires for equivalent area in the form of welded mesh in Ferro cement. The same area of steel is replaced by 36 numbers of GOG wires of chicken mesh. These smaller diameter bars increases the area of contact with mortar. The fundamental assumption in loaded concrete member is that at the point of bonding, the strain in steel is equal to the strain in concrete. In Ferro cement, the number of contact points is more as the bars are smaller. Hence, the Ferro cement elements behave better in pre-cracking stage, more as a homogenous material.

Multiple layers of steel welded mesh, wire mesh and small diameter steel bars embedded in a rich cement mortar and thin elements are formed. Ferro cement reinforcement can be assembled into its final desired shape and mortared. The term Ferro cement means the combination of a ferrous Product with cement. The use of non-metallic meshes (natural fabrics, jute bamboo, etc.) is being experimented in different parts of the word. There is a saving in the cost of formwork and material. Ferro cement is especially advantageous because of its lower dead weight and higher strength. Since the reinforcement is finely distributed through the section, only very fine cracks are developed under service loads. This property is utilized to the maximum in the application of Ferro cement water tanks. Ferro cement components are used in housing and this is even cheaper than timber.

The Ferro cement technology is relatively new. The product being more homogenous can replace many of the manufactured metals and natural materials like timber. Ferro cement is more efficient when subjected to direct tensile forces or in zones where tension is predominant. It is also efficient when nearly equal tensile and compressive forces are to be resisted, as in shelves, sheets, etc.

3. APPLICATION OF FERROCEMENT

Ferro cement is generally used in sunshades, cupboards, water tanks, partition walls and roofing elements. Where timber is very expensive, Ferro cement beams or trusses may be used to replace wooden structures. Ferro cement service core-units suit very well to 'sites and service' scheme. Different types of Ferro cement roofing elements have been developed for economically weaker section housing with lower thermal comforts. Ferro cement housing components can be produced as pre-fabricated elements suitable for both rural and urban housing schemes.

3.1. Ferro cement Rafters

Timber is used as rafters in trusses and other roofing elements. Ferro cement can replace these timber products in housing. Fire-resistance of Ferro cement is an excellent property for its use as a substitute for timber. Ferro cement cupboards for storage of goods in residential houses and other buildings have been developed.

3.2. Liquid Storage Structures

The properties of Ferro cement are best suited for liquid storage structures. Impermeability is the prime characteristic of Ferro cement. Small capacity tanks of 500 liters to 10,000 liters are commonly used in residential buildings. As compared to the conventional overhead water tanks made of brick, concrete and steel, Ferro cement water tanks are cheaper in cost. Moreover, it reduces the weight of the structure.

3.3. Ferro cement Core Units

Ferro cement service core units are cloisters used for toilets. They can be cast as bathroom units, toilet units or in combination. This is made up of 3 cm walls, floor and roof and needs very little formal foundation. These are best suited for the sites and services scheme where the water and sewerage distribution is assured before development of housing area.

3.4. Matrix

The mortar matrix used in Ferro cement consists of cement and well-graded sand, passing through 2.36 mm sieve. Water cement ratio in Ferro cement products vary from 0.3 to 0.55 by weight. A workable mix generally is to be achieved such that the mortar penetrates and surrounds the mesh reinforcement and will have only acceptable level of shrinkage and porosity. Standard admixtures may be used to increase plasticity and to reduce water. Such mortar used for Ferro cement is usually of high compressive strength varying from 350 to 600 Kg/cm2.

4. FABRICATION PROCEDURE

First step in making the Ferro cement is that of making reinforcement skeleton embedded with required fixtures, for application of cement mortar. The determination of the quantity of steel reinforcement is an essential part of design similar to R.C.C. During the application of mortar, reinforcement skeleton will get distorted. Suitable temporary stiffeners are to be placed in position to keep the required profile of the skeleton. These sorts of stiffeners are necessary because there is no shuttering required for Ferro cement products.

Application of mortar needs careful consideration and understanding of the behavior of the structure. When the bottom slab of a tank is cast, care is taken to spread the mortar first on the platform to get the required cover and then the steel skeleton is placed on top of the spread mortar. Then the slab is finished to the required thickness on the first casting itself. Vertical application of mortar alone is on a different method. The first coat of mortar is forced inside the skeleton and just left to be set with a rough surface. On the second day, the mortar is applied to the required thickness and cover and smooth finish is achieved.

5. PROBLEMS IN IMPLEMENTATION

While the basic principles of design are simple to follow, the freedom exercised in construction of reinforced concrete cannot be taken in Ferro cement. Essentially one is dealing with a thickness of 2 to 4 cm and steel wires of 0.5 to 3 mm diameter. The cement mortar used is of a mix not less than 1:3. Hence, in dealing with a fine material one has to be extremely careful about skill of operation. There have been instances where one could not make reinforcement element in thickness less than 4 cm whereas the specification demand 2 cm or less. This is particularly important when the skill of bar benders, masons, plasterers are not at a level as it should be handling of elements, especially the volumetric precast elements can also present problems. Reversal of stresses on thin elements is to be particularly taken care about.

6. AREAS OF RESEARCH

Ferro cement is inherently a durable material because of the micro-cracking around cement mortar, the even distribution of steel and the rich cement content. The partial galvanization of the chicken mesh employed in the skeleton may also help in durability. However, concrete structures are found to be increasingly on attack from the increasingly polluted atmosphere. The conditions will be worse in patently corrosive atmosphere of a chloride or supplied bearing environment. Experiences in the past have indicated that:

1. Mix design and fineness of sand in mortar can help durability.
2. A minimum cover of 4 mm is necessary for the outer steel.
3. A cement mortar with maximum size aggregate of 2.38 mm is desirable.
4. Galvanized steel mesh prevents corrosion.
5. Epoxy or chlorinated rubber paints are beneficial as coatings.
6. Workmanship in maintaining uniform cover for steel will help.
7. Delayed loading of the elements reduce cracking.

7. CONCLUSION

Shelter is a basic human need next only to food and clothing. At the end of the 10th Five Year Plan, the housing shortage is estimated to be 24.7 million. However, urban areas in our country are also characterized by severe shortage of basic services like potable water, well laid out drainage system, sewerage network, sanitation facilities, electricity, roads and appropriate solid waste disposal. The history of Ferro cement goes back to 1848 and many regarded it as the earliest use of reinforced concrete. Its cost is lower than conventional construction materials because one does not need shuttering, scaffolding, vibrator and mixers which cuts down infrastructures costs.

Adaptability to local conditions, unlike conventional building elements like concrete slabs etc. Ferro cement elements can be manufactured by semiskilled laborers. It is cost-efficient and can be easily maintained. It has high resistance to destruction by natural forces (rain, fire, termites) Ferro cement units being thinner than normal concrete products, a properly carried out curing procedure was very important.

Ferro cement is a versatile structural construction material possessing unique property of strength and serviceability It is made with closely- knit wire mesh and mild steel reinforcing bars filled with rich cement mortar. Welded mesh may also be used in place of reinforcing bars. The materials required for making it namely cement, sand, wire mesh and mild steel reinforcing bars.

To over come inconsistent quality and exorbitant cost of timber, an alternative substitute for making doors and window shutters with Ferro cement has been successfully developed. Ferro cement is application of rich cement sand mortar normally 1:3 or 1:2 proportions and can be made to get any shape with mild steel sections/bars and more than layer of chicken/wire mesh/expanded mesh etc. Ferro cement technique can be used for lintels shelves, doors, window frames, water tanks etc. Building center is already using this technology in manufacturing doors and water tanks in India.

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Landslide Hazard Investigation in Papua New Guinea-A Remote Sensing & GIS Approach

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ABSTRACT

Tribal communities living in the mountainous regions of Papua New Guinea (PNG), often experience frequent landslides during the rainy season. The Eastern Highlands Province (EHP) is one such landslide prone province located in the mountain regions of PNG. Landslide is classified as a natural hazard that has a critical geological process to inflict an enormous damage to civil engineering structures including other valuable assets. The research study was aimed to monitor and assess landslide hazards by remote sensing data processing and GIS spatial analysis. The occurrence of landslide is controlled by a number of morphological, geological and human factors. However, according to the availability of data, only certain principal factors are considered in the present study. The analysis focuses certain landslide contributing factors in generating landslide hazard map of the area. For this study, ranking, classification and weighted overlay analysis techniques were commonly used to generate landslide hazard map.

Keywords: GIS, Hazard Map, Landslide, Potential Index, Remote Sensing

1. INTRODUCTION

Landslides in mountainous terrain often occur during or after heavy rainfall, human activity like indiscriminate felling of forests on steep slopes and / or natural tectonic processes inducing earthquakes result in the loss of life and damage to the natural and /or built environment [3]. When these activi- ties happen and shear stress exceeds the shear strength of the material, then the landslide occurs. The downward move- ment of surface material takes place under the influence of gravity, and the mobility of such movement is enhanced by water content in the sediment [3]. Since the early 1970s, many scientists have attempted to assess landslide hazards and produced susceptibility maps portraying their spatial distribution by applying many different GIS based methods. The results of published papers show that landslide suscepti- bility and hazard maps have become very effective tools for planners and decision makers [5].

It is understood now that in order to delineate or generate the landslide hazard maps, in addition to tectonic instability of the terrain certain geo-morphological and geological factors like lithology, slope, rainfall, land use land cover, soil type etc. are to be considered. Thus these factors are the contri- buting factors to occurrence of landslide. All the factors are processed in the GIS environment to come up with landslide hazard map. Landslide hazard (LH) defines the physical attributes of a potentially damaging landslide in terms of mechanism, volume and frequency and therefore landslide hazard assessment (LHA) estimates the probability of a landslide occurrence within a certain period of time in a giv- en area [5].

2. STUDY AREA

The area selected for the research study for landslide hazard zonation is in the Eastern highlands province, located around Latitude 60 30' S and Longitude 1450 30' E. It is in the mountainous region of PNG. Whole part of the province is assessed for landslide hazard. The total study area is approximately 11,200 sq kilometres.

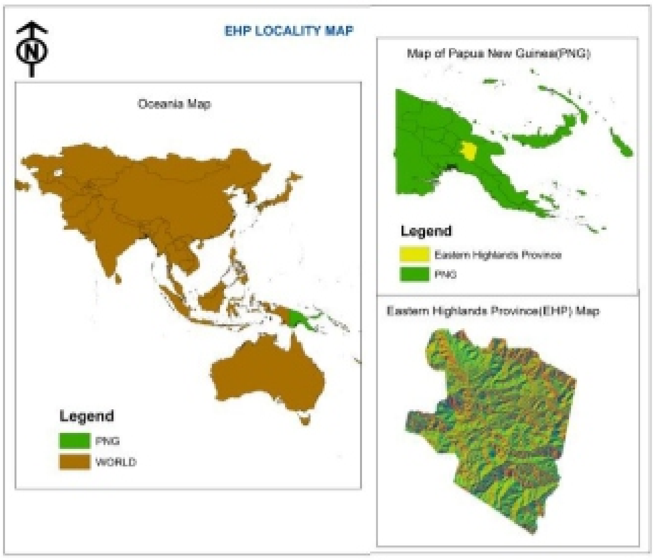

Figure 1: location map of the study area

3. DATA USED AND METHODOLOGY

Table 1: Different data layers/maps

Data Layer	Source
Soil data/map for EHP	PNGRIS metadata
Landsat8 Satellite data(28.5 spatial resolution) captured 2008 for whole PNG	Surveying and lands de- partment-PNG Unitech
Landform and Lithology data/map for EHP	PNGRIS metadata
Rainfall data for EHP	PNGRIS metadata
DEM data(SRTM) for PNG(90m spatial resolution)	Surveying and lands de- partment-PNG Unitech
Vegetation type	PNGRIS metadata
Terrain data (slope and Height)	Surveying and lands de- partment-PNG Unitech

Soil, rainfall, landform, vegetation type and lithology data for Eastern highlands province was collected from surveying and lands department at The PNG University of Technology. The data was again in the GIS environment was updated using the satellite images and according to PNGRIS data, it was again reclassified and was assigned a specific value. The metadata was rectified to WGS 1984 UTM zone 55. Land use and land cover type for the EHP were prepared from Landsat8 satellite data, captured 2008. For the slope and altitude for EHP, it was prepared using the SRTM DEM data for PNG at 90m spatial resolution by using the extraction and slope analysis tools in ArcGIS 10. The entire data bases were prepared and arranged using the ArcGIS 10 and ER- DAS Imagine 8.5 software and was all projected to the same projection system. MapInfo Professional 10.1 was used to convert tab format vector data to shape file, where it was readable by ArcGIS 10 software. From there, all vector lay- ers that is soil, rainfall, lithology and landform were raste- rized to produce the maps according to PNGRIS metadata. The entire data base were prepared and arranged for generat- ing landslide hazard zonation. The data prepared, are the common factors that can contribute to generating landslide hazard mapping.

4. RESULTS AND DISCUSSION

Soil type: Soil is one of the common factors that determine the susceptibility of landslide prone areas in a particular re- gions/province. The topsoil cover on a slope has an influence on landslide occurrence or in the steep slope area or on the hill top. The soil data for EHP was collected from Surveying and Lands department at PNG University of technology; it was then geo-referenced to match the satellite image. Ac- cording to PNGRIS metadata the soil map was reclassified and then followed by assigning weightage. It was found out from PNGRIS metadata that the soil type of the area are mainly fine to coarse loamy soil and fine loamy calca- reous/chalky. The loamy calcareous soil is highly prone to landslide. (Pareta.et al, 2014). According to that, it was given a weight. The type of soil identified or demarcate for the EHP is shown in figure 2 (A)

Land use land cover: As illustrated in figure 2(B), it is the land cover type of EHP that was extracted from Landsat8 satellite image and was classified in the ERDAS Imagine software 8.5. Thus land cover type plays an important role in determining the occurrence of land slide. For example if the pristine forests near the hill top of an extremely steep moun- tain area was once cleared for the agricultural purpose, then at that particular area, the landslide can initiate because there is no strong roots to bind the soils. Once heavy rain and / or earthquake happen, then that particular area can be prone to land slide. In the land cover map above, from classification, certain areas are shown. It was weighted in terms of vulne- rability for landslide occurrence.

Lithology: Lithology data for EHP was collected from the surveying and lands department at PNG University of tech- nology. In the GIS environment, the data was updated with satellite image and with PNGRIS metadata. Lithological data are the data about types of rocks found in the study area. It was found out that the type of rocks as illustrated in figure 2© are: limestone, metamorphic, igneous, pyroclastics and alluvial deposits. These are the rock types commonly found in EHP. Based on the rock types, weather it is strong or weak the area becomes vulnerable to landslides of varied ferocity.

Landform: The data for types of landform found in EHP was collected from surveying and lands department at PNG Uni- versity of technology. According to PNGRIS metadata, the landform map was produced by editing its attribute table in ArcGIS and was reclassified. Figure 2(D) illustrate the land- form types found in EHP. It can be confirmed that the bulk of area for landform type in EHP is covered by Mountains, hills, cliff. The hilly or mountain areas can be more prone to landslide activity, however the vulnerability will be deter- mined by types of rocks or soil or land cover out there. Therefore all the factors are to be weighted and rank accor- dingly to produce a final output map for landslide hazard zonation.

Slope and Height morphology: Slope and height play an important role in governing the stability of a terrain. As the slope increases, chances of slope failure also increase. (Pare- ta.et al, 2014). But however, there are some controlling fac- tors like soil and or rock type or land cover may also deter- mine the slope failure in a steep slope. Like for example if the soil is fine loamy chalky soil, then landslide may not occur. The shape of a slope influences the direction of and amount of surface runoff or subsurface drainage reaching a site [1]. Concentration of subsurface drainage within a con- cave slope, resulting in higher poor water pressures in the axial areas than on flanks, is one possible mechanism re- sponsible for triggering landslides [2]. Figure 3 (E) & (F) illustrate the terrain slope and height For EHP.

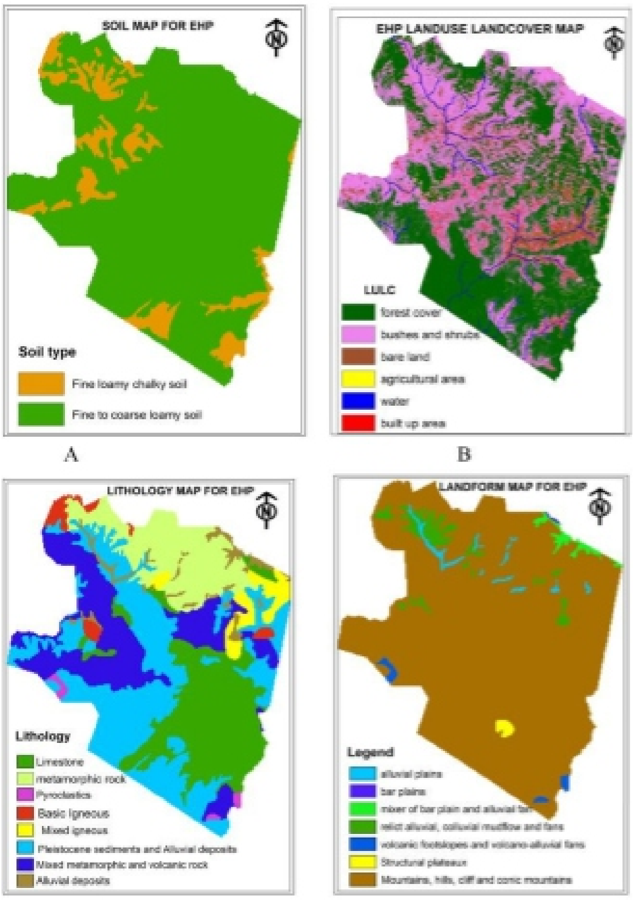

Figure 2: Thematic layer of soil, land cover, lithology and lanform

Rainfall: Rainfall is one of the main factors that lead to trig- ger landslide. Rainfall pattern of the certain locations of the study area, determines how frequent the landslides are to occur. However there are other controlling factors besidesrainfall that will combine with rainfall pattern to show the susceptibility areas for landslide. The rainfall data was col- lected from surveying and lands department at PNG Univer- sity of technology. According to PNGRIS metadata, the rain- fall pattern of EHP was edited and reclassified to produce a final map for rainfall pattern for EHP and was given rank and weightage according to the amount of rainfall. Figure 3(G) illustrates the rainfall pattern for EHP.

Vegetation: Type of vegetation like dense vegetation, sparse and mixed vegetation of the study area, can be a very helpful information or data to combine with other landslide control- ling factors to delineate landslide prone areas. Thus the type of vegetation data for EHP was collected from surveying and lands department at PNG University of technology. Accord- ing to the PNGRIS metadata and the vegetation attribute table for EHP the vegetation map was prepared. Figure 3(H) illustrate the type of vegetation found in EHP. Like dense vegetation, may not be more prone to landslide activity; however sparse vegetation or no vegetation will be more prone to landslide activity.

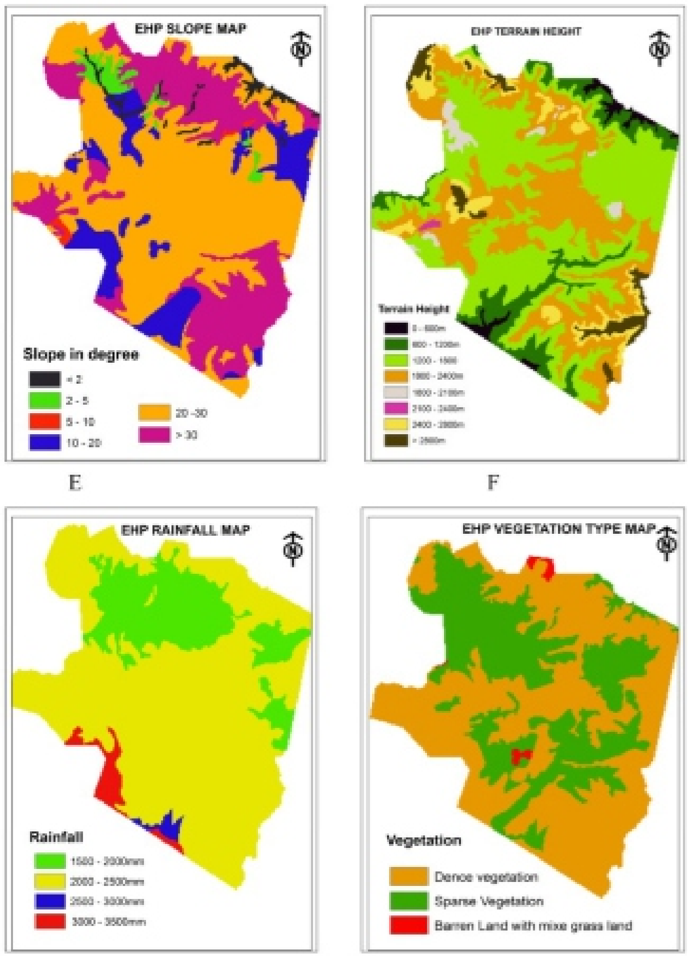

Figure 3: Thematic layer of slope Height, rainfall and vegetation

4.1 Formulations of Thematic data layers for landslide hazard zonation

The landslide examination and hazard zonation mapping study involves preparation of number of thematic databases such as terrain slope, terrain height, drainage densi- ty/drainage pattern, soil type, landform, lithology, vegetation type and land cover (Pareta.et al, 2014). When formulating and combining the thematic layers by applying weighting, ranking or applying some form of statistical calculation in ArcGIS 10 software, the landslide hazard zonation map can be produced. Thus the hazard map can be more important or useful to civil engineers for construction purpose and also to community of mountainous region, where landslide hazard map can give better idea or let them be aware of landslide prone areas in their area. Thus mitigation or adaptation measures can be put forward.

4.1.1 Numerical scheme towards preparation for landslide zonation

The identification of potential landslide areas requires that the factors considered be combined in accordance with their relative importance to landslide occurrence. This can be achieved by developing a rating scheme in which the factors and their classes are assigned numerical values [4]. The rat- ing scheme is a formulation that identifies the probability of each factor and each factor's classes that are prone to landslide activities. That is to say, each factor is assigned ranks at a scale of 1 to 8, depending on the number of factors and each class pertaining to the factors are assigned weights between 0 and 8 in order of importance. The weights and ranks are assigned according to its relative significance to- wards occurrence of landslide. Thus Ranks and Weights of causative factors (parameters) need to be assigned in order to generate a landslide hazard zonation map. The relevant factors for landslide hazard zonation mapping should include; slope, rainfall, terrain height, and vegetation type of EHP, soil type, land cover, lithology and landform. These are the factor/data for EHP that was collected and prepared for assigning ranks and weightings to generate landslide hazard map of the province. Table 2 illustrates the ranks and weight- ings of factors for landslide.

Table 2: ranks and weights for factors and their classes

Factor	*Classes*	*Ranks*	*Weights*	*remarks*
Slope	< 2	8	1	Steep slopes are more susceptible to landslide, so weight is given >30. Slope factor is highly prone to landslide, so it is rank 8
	2 – 5		2	
	5 – 10		4	
	10 – 20		6	
	20 - 30		7	
	>30		8	
Terrain Height	0 - 600	7	1	Terrain height more than 2800 highly prone to landslide activity. The rank was given to terrain height as 7.
	600 -1200		2	
	1200 - 1800		3	
	1800 - 2100		4	
	2100 - 2400		5	
	2400 - 2800		6	
	>2800		8	

Rainfall	1500 – 2000	6	2	Higher the rainfall frequency at a particular area, the landslide is more likely to happen
	2000 – 2500		5	
	2500 – 3000		6	
	3000 - 3500		8	
soil	Fine to Coarse Loamy Soil	5	4	Fine loamy chalky soil, defined by its name is highly prone to landslide. Hilly or mountain areas that have this type of soil, the
	Fine Loamy chalky Soil		8	
Vegetation type	Dense vegetation	4	1	Bare land with mixed grassland is more prone to landslide activity. The rainfall hits the soil directly causing accelerated erosion, also there is no vegetation type like thick forest to
	Sparse vegetation		5	
	Bare land with mixed grassland		8	
Lithology	Basic igneous rock	3	1	Alluvial deposits, that is; clay or silt or gravel carried by rushing streams and deposited where the stream slows down, are highly prone to landslide activity
	Mixed igneous rock		2	
	Pyroclastics		3	
	Metamorphic		4	
	Mixed metamorphic		5	
	Limestone		6	
	Pleistocene sediment		7	
	Alluvial deposits		8	
Landform	Structural plateaux	2	1	Type of landforms that was identified as mountains, hills or cliffs are more prone to landslide activities
	Alluvial plains		2	
	Bar plains		3	
	Mixer of bar plain and alluvial fans		5	
	Relict alluvial		6	
	Volcanic foot slopes		7	
	Mountains, hills, cliffs		8	
Land use land cover	Water	1	0	Bare land or built up areas like road construction, buildings, are more prone to landslide activities
	Forest cover		1	
	Bushes and shrubs		3	
	Agricultural area		5	
	Built up area		7	
	Bare land		8	

4.1.2 Landslide Susceptibility Mapping

All the thematic data layers were assigned ranks according to its potential in triggering landslide hazard. On the other hand, the weights were also assigned to each class of each factor. The numerical data layers representing weight values of the factor classes as attribute information were generated from the thematic data layers for data integration and spatial analysis in the GIS. The input data layers were multiplied by their corresponding ranks and were added up, to obtain the Landslide Potential Index (LPI) [4] i.e:

$$LPI = \sum_{i=1}^{8} (Ri * Wij)$$

(SLP * 8) + (ALT * 7) + (RN * 6) + (SL * 5) + (VEG * 4) + (litho * 3) + (lndfm * 2) + (LULC * 1)

Where Ri denotes the rank for factor i and Wij denotes the weight of class j of factor I.

SLP = slope factor, ALT = altitude (height), SL = soil, RN = rain, VEG = vegetation, LULC = land use land cover, lndfom = landform and litho = lithology

Thus this was the algebraic mathematical formula that was performed using raster calculator tool in ArcGIS 10 to gen- erate final landslide hazard zonation according to weights and ranks given.

The landslide potential index once organised and computed, ranges from 676 to 3922. Thus these values are reclassified into 5 landslide hazard susceptible zones and these are: low potential zone, medium potential zone, and medium to high potential zone, high potential zone and very high potential zone. Thus this was the final output map for landslide poten- tial zonation generated from contributing, weighting and ranking all factors that are illustrated in Figure 2 (A, B, C, D) & Figure 3 (E, F, G, H). Figure 4 illustrate the EHP landslide hazard potential zone.

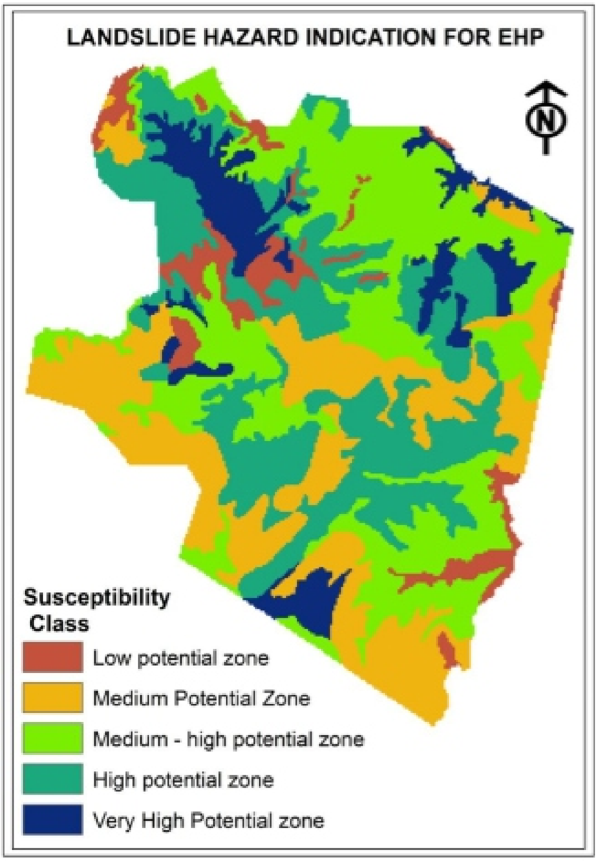

Figure 4: Landslide hazard zonation map for EHP

The landslide potential index ranging from 676 to 3922 is reclassified and arranged into 5 susceptible zones. Zones are demarcated as 5 landslide potential areas for the entire EHP as shown in figure 4. Thus table 3 shows the tabulation of Landslide potential index ranges, the susceptible zones were decided according to each ranges of LPI and finally the area covered by each susceptible classes of landslide are shown in square kilometre and percentage.

Table 3: Landslide potential index (LPI), susceptibility classes and area in percentage and km^2

Susceptibility Class	LPI	Area (km2)	Area (%)
low potential zone	676 - 1288	5211.77	5.22
medium potential zone	1288 - 1845	25843.69	25.81
medium to high potential zone	1845 - 1887	33001.67	32.96
high potential zone	1887 - 2134	26964.73	26.93
very high potential zone	2134 - 3922	9097.59	9.09
Total		100119.45	100

5. CONCLUSION

Landslide hazards are common in mountainous areas experiencing high downpour. The hazard is aggravated by defore- station and improper land use. Moreover, such hazards further being exacerbated by frequent earthquakes are thus be- coming a permanent menace to the inhabitant communities, also with respect to civil engineering construction. Events like tectonic activism, high rainfall, geology and inherent soil conditions are beyond the control of humans to manoeuvre, but pernicious human fiddling on the face of the slope by way of indiscriminate deforestation, unscientific engineering construction of building, dams etc., clearing pristine forests for agriculture should have to avoided.

In this context the research study brings out a definite relationship between the remote sensing and GIS techniques, which play a significant role in landslide zonation mapping. All the data were processed and analysed in GIS environment. The landslide hazard zonation of EHP can give clear view to the community living in EHP and civil engineers on the varied potential zones for landslide as depicted on the map. These can be a stepping stone for communities to look ahead, plan and manage their lands in a way that they can have the appropriate preparedness to mitigate the impact of landslide in such mountainous areas.

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Land Suitability Assessment for Cocoa Cultivation in Ife Central Local Government Area, Osun State

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ABSTRACT

Cocoa is a major cash crop in Nigeria making the country the leading exporter and second largest producer of cocoa in the world in the 1960's. However, cocoa production has dropped significantly due to inadequate land information resulting to poor utilization of land and marginal crop yield. Thus, land suitability assessment based on the FAO Land Framework was carried out for cocoa in Ife Central Local Government Area using Geospatial techniques, soil diagnostics survey, and Multi-Criteria Evaluation (MCE). Soil samples were collected and analysed using standard methods; while other ancillary data with spatial attributes were prepared and analysed using appropriate geospatial techniques. All the data was integrated into a work geo-database from which spatial queries and multi-criteria analysis were carried out. The result of the analysis revealed that 19.44% (28.26 km2) and 25.67% (36.45 km2) are moderately and marginally suitable respectively while 54.38% (77.29 km2) of the study area is not suitable. Some of the constraints affecting the crop suitability are unsuitable soil textures, low organic matter, nitrogen, phosphorus and cation exchange capacity (C.E.C). Therefore, this study recommends effective soil management and nutrient enrichment to increase yield and promote sustainable cocoa production.

Keywords: Cocoa, Land Suitability, Geospatial Techniques, MCE, Soil Management

1. INTRODUCTION

Land suitability assessment provides information on constraints and opportunities for land use and hence serves as guide for decisions on optimal utilizations of the land resources, whose knowledge is an essential prerequisite for land use planning and development. This kind of assessment identifies the main limiting factors for the agricultural production and enables decisions makers such as land users, land use planners, and agricultural support services to develop crop management that can overcome such constraints, thereby increasing crop yield[19]. Geospatial technologies like Remote sensing and Geographical Information System (GIS),which incorporate database systems for spatial data, can be designed and developed to enable the acquisition, compilations, analyzing and displaying topological interrelations of different spatial information for land suitability assessment[20]. The conventional method for land suitability analysis rely more on field data and soil analysis but this can be very costly, time consuming and not feasible for very large and tortuous terrain [3]. Since land suitability analysis requires both spatial and attributes data of land in many layers, GIS can be used to combine the biophysical and socio-economic characteristics for land evaluation and multi-criteria evaluation tool can be developed for its suitability for crop production. Hence, the integration of GIS and AHP into a multi-criteria land suitability assessment for cocoa cultivation in Nigeria can greatly improve the crop yield. Nigeria was a leading exporter of cocoa and also the second largest producer of cocoa in the world earning over 20 million dollars annually as foreign exchange from the export of cocoa beans alone, besides revenue from cocoa by- products [1]. However, the country has lost its former status as major exporter of cocoa to Cote de voir and Ghana [14]. This decline in production has been attributed to the discovery of oil and consequent neglect of the sector by government [2]. Some research also identified inadequate agriculture practices such lack of fertilizers, poor cropping system and poor site selection as factors that has contributed to decreased production of cocoa [11,18]. Hence, information on land capability and suitability and input requirement for the cultivation of cocoa is necessary to increase the current yield of the crop and restore the country back to its former status. This research focuses on utilizing the integration of geospatial technologies with multi-criteria evaluation in identifying areas suitable for cocoa cultivation in Ife Central Local Government Area (L.G.A). This is aimed at providing agriculture policy makers, cocoa investors; stakeholders and farmers in particular with necessary information to ensure optimal and sustainable cocoa production in the Ife Central L.G.A.

2. STUDY AREA

Ife Central Local Government Area is bounded in the south by Ife East Local Government Area, in the west by Ife North Local Government, in the east by Ondo State and in the north by Ilesha. It is located between latitudes 7°28' 43.5"N and 7°34' 51.41"N and longitudes 4°27' 22.5"E and 4°35' 40.61"E and an altitude of 256m above sea level (Fig 1). The rainy season starts from mid-March to late October with mean annual rainfall of about 1400mm, relative humidity is about 75.8% and 86% while the dry season runs from November to March with temperature ranging between 280C to 340C. The population of the area is about 167,254 persons consisting of 88,403 males and 78,801 females based on the National Population Commission 2006 census result. The study area is characterized by two types of soil: deep clay soil formed on the lower smooth hill crests and upper slopes; and sandy (hill wash) soil on the lower slopes. The mixture of clay and sandy soil forms loamy soil and this helps water retention from seepage. The natural vegetation of the area is under tropical rainforest belt characterized with multiple canopies and lianas which can sustain cocoa production. The people are mostly farmers producing suchfood crops as yam, maize, cassava, cocoyam and cash crops which include cocoa, tobacco and oil palm produce.

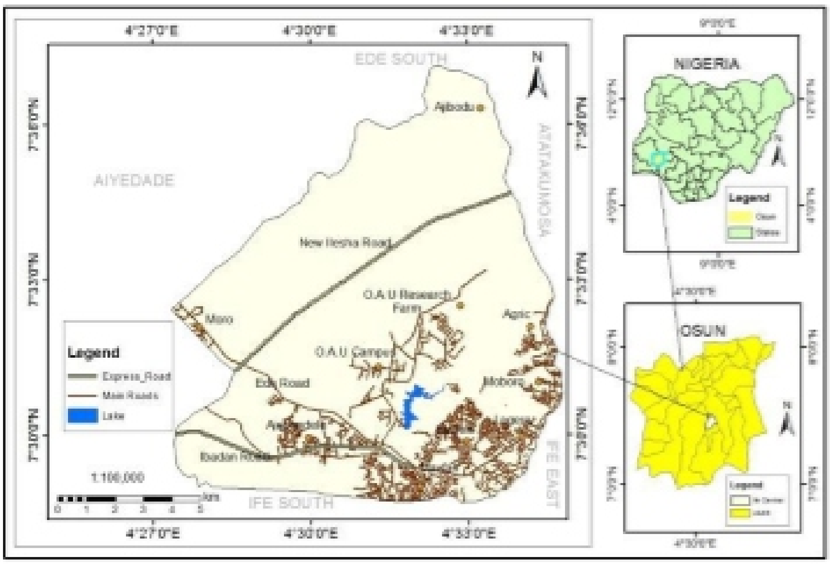

Figure 1: Study Area

3. METHODOLOGY

The methodology followed in the study can be classified into five steps namely: extraction of study area, soil sample collection and analysis, generation of thematic maps, image processing and multi-criteria evaluation. The workflow diagram is shown in Figure 2 below and Table 1 summarizes the data sets used in the study.

Table 1: Secondary Data and their Sources

Sr.No.	Data	Year	Source
1	Mean Annual Temperature, Rainfall and Relative Humidity of Ife Central Local Government Area	2009 to 2012	Nigerian Mesoscale Experiment (NIMEX), Ile – Ife
2	Existing Shapefile of Ife Central Local Government Area	2012	Office of the Surveyor General of the Federation (OSGOF), Nigeria
3	SRTM Image covering Ife Central Local Government Area.	2008	Global Land Cover Facility (GLCF)
4	NigeriaSat 1 Image covering Ife Central Local Government Area.	2007	National Space Research and Development Agency, Abuja.

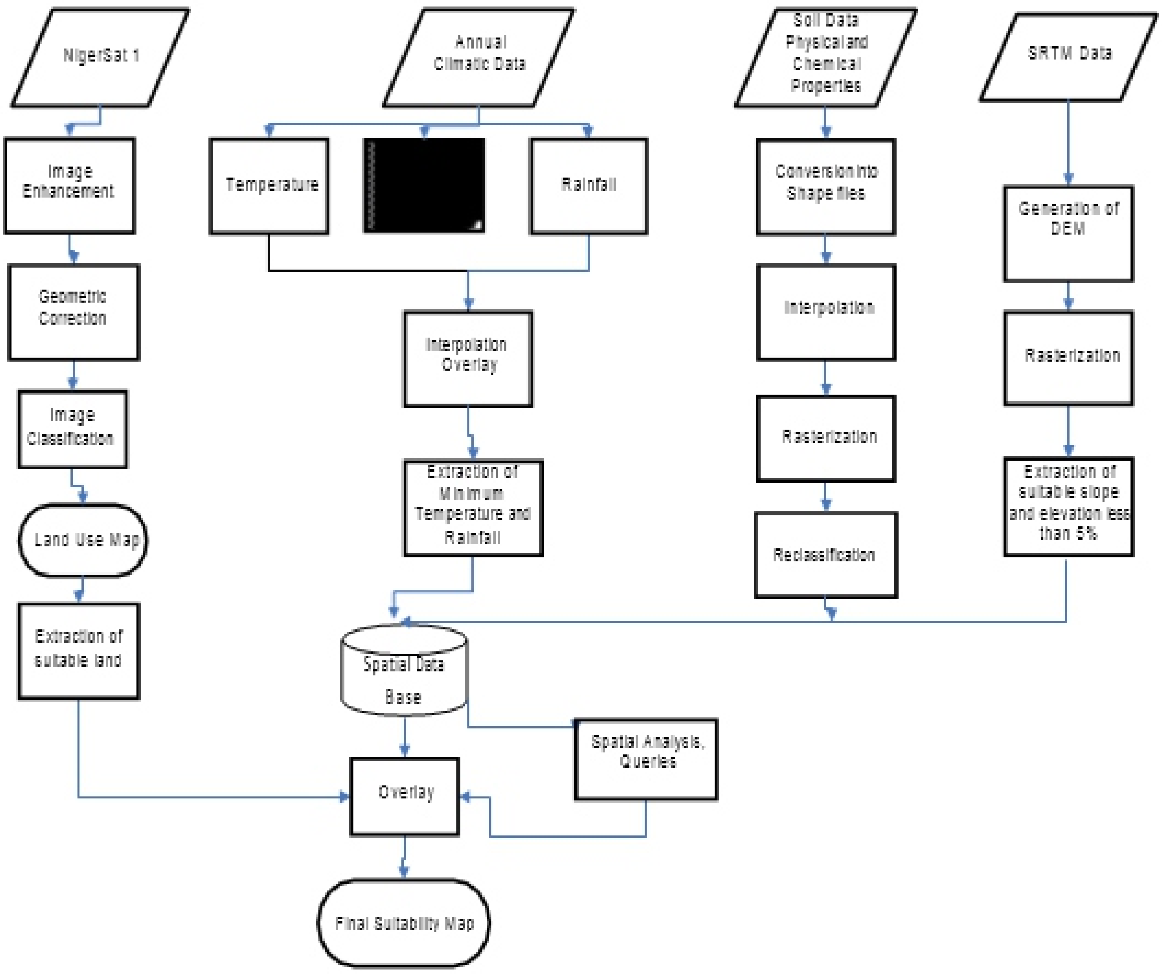

Figure 2: Flow Chart

3.1 : Extraction of Study Area: The existing shapefile of the Ife Central Local Government Area was used to carve out the study area from the satellite image using the clip extract function in ArcGIS 10.1 version.

3.2 : Soil Samples Collection and Analysis: Based on the soil types identified in the area, the study area was divided into twenty homogenous land units using a 3km by 3km grid system that ensured adequate coverage of all the soil types in the area. This conformed [7] recommendation for a large scale intensive in forested area such as the tropical rain forest zone where the study area is located. The grid was used as guide in the field survey, soil sampling and also used to develop a more detailed soil map using interpolation of soil analysis. Soil classification was made based on FAO [8]. Twenty composite soil samples were obtained using soil auger from the demarcated horizons of the four profile pits and their coordinates recorded using a GPS hand receiver. The soil samples were taken for physico-chemical analysis of the following parameters: Soil texture, Organic Matter, pH, Cation Exchange Capacity (C.E.C), Base Saturation, Nitrogen and Phosphorus. These soil parameters were determined using methods described by [4-5,23, 27].

3.3 : Generation of Thematic Maps: The thematic map of each of the soil properties and climatic data was generated using inverse direct weighted (IDW) method of interpolation in the ArcGIS 10.1 software. The weight is a function of inverse distance and IDW lets the user control the significance of known points on the interpolated values, based on their distance from the output point. The thematic maps were rasterized and reclassified into five suitability classes based on the crop requirement using the spatial analyst tool in ArcGIS 10.1. The topography and slope information were obtained from Digital Elevation Model (DEM) using GIS software package Arc GIS 10.1. The source of DEM was SRTM (Shuttle Radar Topographic Mission) which was 30m spatial resolution. The DEM and slope was rasterized and reclassified into five suitability classes based on the crop requirement.

3.4 Image Processing: The land use land cover information was generated using the NigerSat 1 image acquired in 2007 with a spatial resolution of 32m pixel size and processed using ERDAS Imagine version 9.2. The image was checked to conform to UTM Zone 31N of WGS 1984 and geometric correction carried out to enhance the image. Supervised classification was done using the maximum likelihood algorithm for 3 spectral bands corresponding to 432 combination green, red and near infrared (G, R, NIR). The kappa statistics indicating the accuracy of the land use/cover classification was determined in ERDAS Imagine 9.2 by using the samples points collected from the field survey. The land use /cover classes identified in the image was classified into six (6) basic features such as forest, vegetation, riparian forest, settlement, water bodies and rockout crop using the land classification scheme described by [3].

3.5 : Multi Criteria Evaluation: The objective of weighting is to express the importance of each factor relative to other factor effects on crop yield and growth rate [15]. The factors were established based on the expert opinions of local agronomists and researchers who have identified the following variables as relevant to suitable growing areas for cocoa: soil texture, organic matter, pH, organic matter, C.E.C, base saturation, nitrogen, phosphorus, slope, rainfall, temperature and relative humidity as the relevant criterion set. Suitability levels for each factors was defined and these levels were used as basis for constructing the criteria maps for each factor. The suitability levels were: Highly suitable- S1, Moderately suitable-S2, Marginally suitable-S3, Not suitable-N based on the FAO 1976 framework for land suitability classification. Specific suitability level of each facto was defined with respect to the crop requirement as shown in table 2. The Analytic Hierarchical Process (A.H.P) was used to generate weights and criteria as described by [21]. The weight and criteria of each factor was used to produce the standardized thematic layer (Table 3) and the weighted overlay function in ArcGIS 10.1 was used to produce the soil and topography suitability maps. These maps were then overlaid on the land use land cover to generate the final suitability map for cocoa in the study area.

Table 2: Climatic, Soil and Land Requirement for Cocoa

<table>
<tr><th>Land use / Land characteristics</th><th>S1</th><th>S2</th><th>S3</th><th>N1</th><th>N2</th></tr>
<tr><td rowspan="2">Average annual temperature (^{0}C)</td><td rowspan="2">25 – 28</td><td>22 – 25</td><td>20 – 22</td><td>16 – 20</td><td><20</td></tr>
<tr><td>28 – 32</td><td>32 – 35</td><td>35 – 37</td><td>>37</td></tr>
<tr><td rowspan="2">Average annual rainfall (mm)</td><td rowspan="2">1600 – 2500</td><td rowspan="2">1400 – 1600</td><td>1200 – 1400</td><td rowspan="2">1000 – 1200</td><td rowspan="2"><1000</td></tr>
<tr><td>3000 – 4000</td></tr>
<tr><td rowspan="2">Average annual relative humidity</td><td rowspan="2">40 – 65</td><td>65 – 75</td><td>75 – 85</td><td>85 – 95</td><td rowspan="2">>95</td></tr>
<tr><td>35 – 40</td><td>30 – 35</td><td>25 – 30</td></tr>
<tr><td>Soil texture</td><td>Fine, Slightly fine, medium</td><td>-</td><td>Slightly coarse</td><td>Coarse</td><td></td></tr>
<tr><td>Coarse materials %</td><td><15</td><td>15 – 35</td><td>35 - 55</td><td>>55</td><td></td></tr>
<tr><td>Nitrogen</td><td>>1.8</td><td>1.5</td><td>1</td><td>0.5</td><td><0.5</td></tr>
<tr><td>Phosphorus</td><td></td><td></td><td></td><td><0.02</td><td></td></tr>
<tr><td>C.E.C-clay (cmol/kg)</td><td>>24</td><td>20 – 24</td><td>16 – 20</td><td>12 – 16</td><td><12</td></tr>
<tr><td>Base saturation %</td><td>>50</td><td>45 – 50</td><td>40 – 45</td><td>35 – 40</td><td><35</td></tr>
<tr><td>Ph</td><td>6.0 – 7.0</td><td>5.5 – 6.0</td><td><5.5</td><td></td><td></td></tr>
<tr><td>Organic matter %</td><td>2.5 – 3.5</td><td>2.0 – 2.5</td><td>1.5 – 2.0</td><td>1.0 – 1.5</td><td><1.0</td></tr>
<tr><td>Slope %</td><td><4</td><td>4 – 8</td><td>Aug-16</td><td>16 – 20</td><td>>20</td></tr>
</table>

Table 3: Factors and Weights for Cocoa

	COCOA	
Factor	***Weight***	***Weight (%)***
Soil		
Physical Property		
Texture	0.2572	25.72
Chemical Properties		
pH	0.0514	5.14
Organic matter	0.0171	1.72
Cation Exchange Capacity	0.0342	3.43
Base Saturation	0.0342	3.43
Nitrogen	0.0172	1.72
Sulphur	0.0172	1.72
Climate		
Rainfall	0.1143	11.43
Temperature	0.0857	8.57
Relative humidity	0.0857	8.57
Topography		
Slope	0.0857	8.57
Elevation	0.0571	5.71
Land use		
Vegetation	0.0999	10
Forest	428	4.28
Total	**1**	**100**

4. RESULTS AND DISCUSSION

4.1 Soil Properties Variability: Land suitability assessment, on the basis of soil properties requires criterion from the soil attributes and the result of the various physio-chemical properties of the soil analyzed are presented below. Soil texture is most useful in land suitability assessment and management as it provides information about the porosity of the soil and bulk density thus indicating possible limitation to root growth and penetration. Sandy loamy was most dominant soil while clay loamy had the smallest coverage in the study area. The result of the analysis shows that just 1.5% of the study area was highly suitable for cocoa production; 32.4% is moderately suitable while 25.1% is marginally suitable. The remaining 22.29% are not suitable for cocoa production. The suitable soil texture identified for the crop was clay loamy, sandy clay loamy, sandy loamy and silt loamy. The result of the soil texture obtained is in tandem the findings of [22] and [17] who also identified similar soil texture in the study area.. The Soil pH is useful in soil suitability evaluation as it provides information about the solubility and phyto-toxicity of elements for specific crops. The soil pH of the study area ranged from 5.5 to 7.2 representing different level of suitability for crop indicating that the soils are slightly acidic. The result of the analysis shows that 26.7% of the study area is highly suitable; 46.8% is moderately suitable; 23.4% marginally suitable while just 1.3% is not suitable. The pH range is in agreement with [17] who observed pH values of 6.5 and below tend to be found in regions such as rain forest with abundant rainfall and moderate to high temperature like the study area.. Soil organic matter exert major influence on the soil properties such water-holding capacity, retention, infiltration, pH, exchangeable capacity of the soil and source of nitrogen. Generally the organic matter of soil ranges from 0.13 to 3.3 with 12.5% of the study area highly suitable; 24.27% moderately suitable; 9.1% marginally suitable while the remaining 54.2% is not suitable. The area with high organic matter confirms the result of [26] who observed that soil with high pH have corresponding high organic matter. The areas with suitable organic matter may be due to the high clay content and it is in tandem with the findings of [10] that organic matter increases corresponding with clay content. The cation exchangeable capacity ranges from ranges from 0.31 to 3.3 and just 31.2% of the whole study area is marginally suitable for cocoa production while the remaining 68.8% is unsuitable for cocoa production. Studies by [11] obtained low CEC in cocoa soils and attributed this to low clay and organic matter of the soil. The base saturation ranges from 45.6 to 99% showing that most the study area (94.7%) is highly suitable for cocoa production while the remaining 5.3% is moderately suitable. The nitrogen content of soil ranges from 0.04 to 1.5 indicating that over half of the study area (74.5%) is highly suitable for cocoa production; 10.4% is moderately suitable; 8.8% is marginally suitable and just 4.3% unsuitable. The phosphorus content of soil ranges from 1.7 to 8.8 in the study area showing that 18.3% of the study area is highly suitable for cocoa production; 2.4% is moderately suitable; 7.5% is marginally suitable and over half of the study area (71.8%) unsuitable. Thus, less than one third of the study area is suitable for cocoa production. The soil suitability map of the study area for cocoa was produced (Figure 3) showing that 21.4% of the soil is moderately suitable, 56% marginally suitable while 23.6% is unsuitable. None of the soils in the study area is rated as highly suitable thus confirming the [10] findings that over 48 % of the Nigerian soils fall into class 4 and 5.

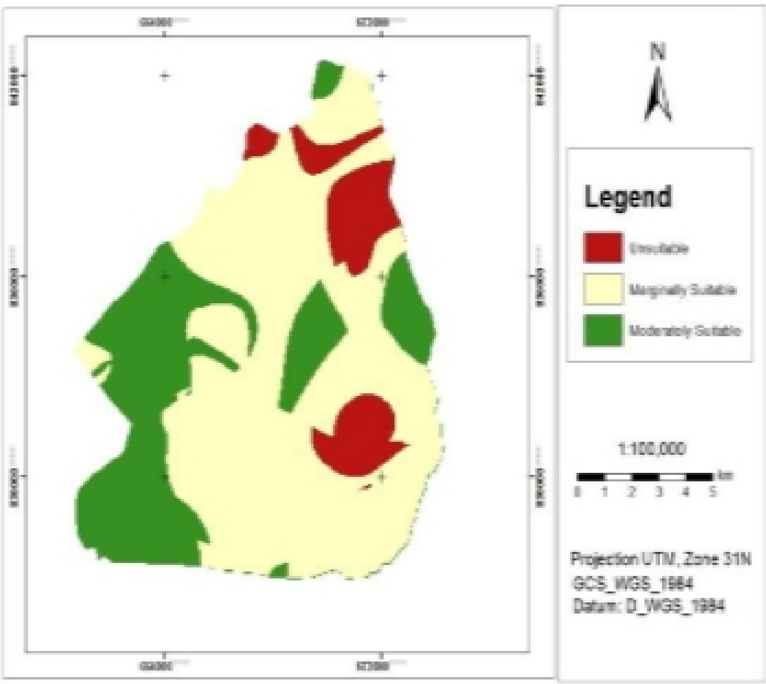

Figure 3: Soil Suitability for Cocoa

4.2 : Climatic Data and Topography

The annual temperature ranged from 24 – 28.320C with a mean value of 26.150C; the annual rainfall ranged from 1250 -1300mm with a mean value of 1300mm while annual relative humidity ranged from 64.86 to 85.60% with mean value of 77.82%. The mean annual temperature and relative humidity of the study area are suitable for cocoa cultivation; however the mean annual rainfall of 1,300m is insufficient when compared to the rainfall requirement of the crop as described by [25]. In terms of elevation, the Digital Elevation Model (DEM) varies from 216m to 440m above mean sea level with an average of 283m above mean sea level. The analysis of the slope, indicate that the area has a slope range of 10 to 16% which is marginally suitable for the crop. The reclassified DEM analysis shows that reveals that the majority of the study area is flat with 137.7km2 (96.34%) of its total area under 300m, which is characterized mainly by flat and gently sloping lowlands and suitable for cocoa production (Fig 4). The remaining 5.2km2 (3.66%) is above 300m is characterized by mountains and hills.

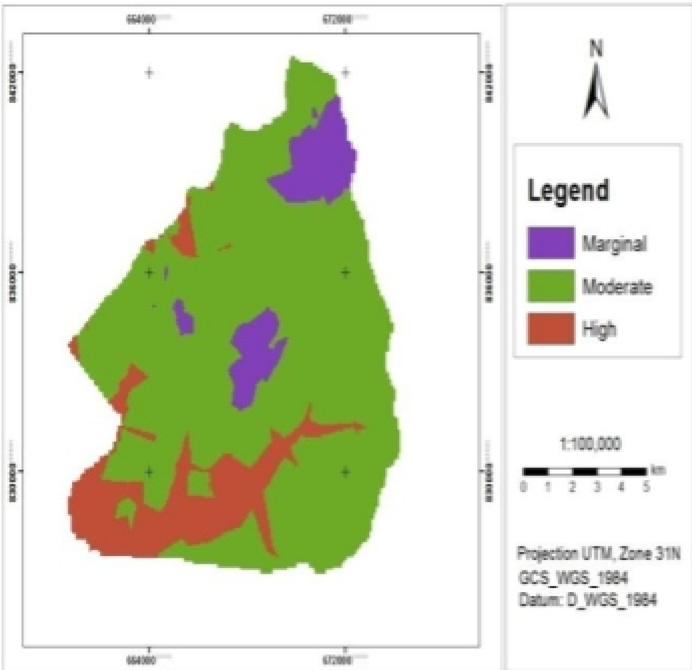

Figure 4: Reclassified Elevation

4.3 : Land Use/ Land Cover Map

The result of the supervised classification performed on the Land Use/ Land Cover Map (Figure 5) showed forest as constituting 46.83km2 which represent the highest share of 33.0% followed by vegetation which had 39.15km2 (27.59%). Riparian forest constitutes 32.17km2 (22.68%) and settlement 17.58km2 (12.39%) of the study area. Water body constitutes0.78km2 (0.26%) representing the least while rockout crop was 5.79km2 (4.08%). The result of the Kappa statistics indicates 81.1% accuracy showing that the classification is a fair representation of the features in the study area.

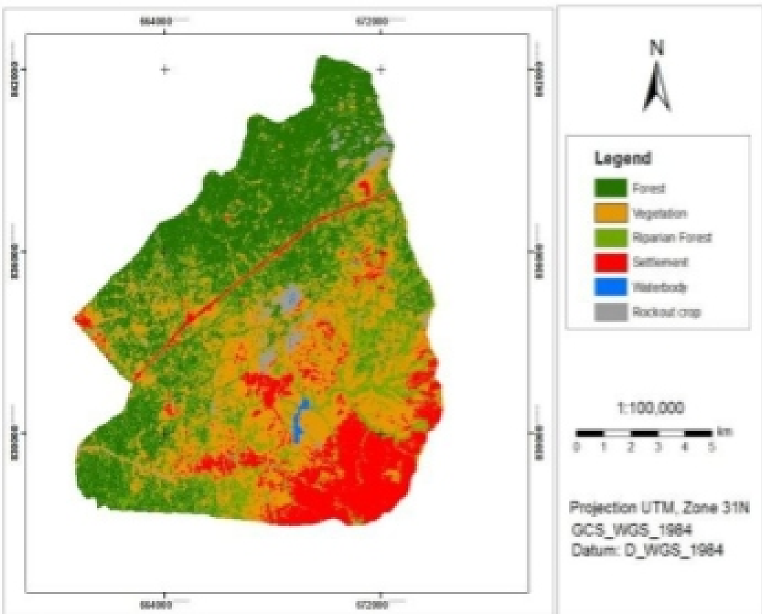

Figure 5: Classified Image of Ile-Ife Local Government Area

4.4 : Final Land Suitability

The final weighted overlay land suitability analysis for cocoa production in the study area showed that the 16.32km2 (11.51%) of the study area is moderately for cocoa production while 26.45km2 (18.09%) is marginally suitable for cocoa production (Table 4). The study area was classified as having moderately climatic suitable. This finding is in agreement with other result obtained by [13]. The areas mapped as moderately suitable are having all the necessary requirements with minor limitations. The integration of land cover map with the crops suitability map was used to extract the suitable land cover and restrict the unsuitable ones as earlier described (Fig 5). The final suitability was overlaid on the Ikonos satellite image to validate it and the suitable areas identified were in conformity with existing cocoa plantations in the study area (Fig 6).Various studies have produced land suitability maps for agricultural crops using GIS to identify different suitability classes of land for the crops [6, 12] illustrating that GIS is power tool in land suitability analysis. This research has also demonstrated the effectiveness of geospatial technologies like GIS in land suitability assessment of agricultural crops like cocoa.

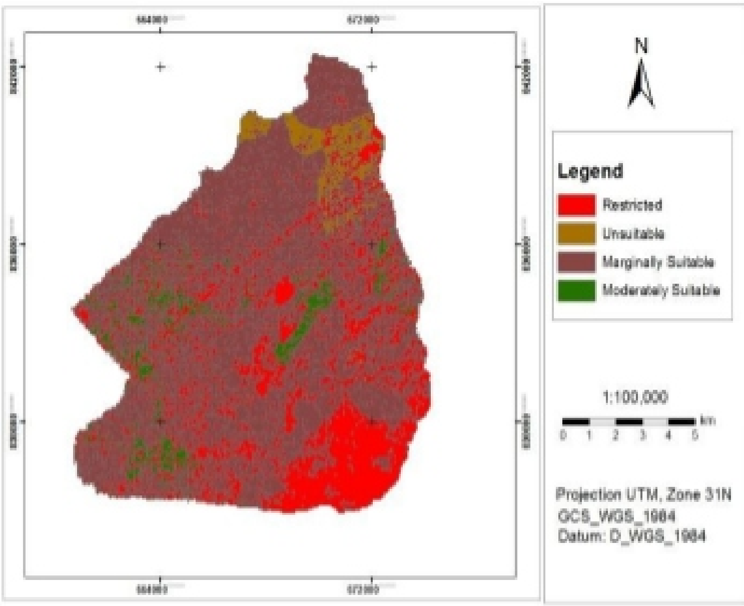

Figure 6: Final Land Suitability for Cocoa Production in the Study Area

Table 4: Land Suitability of Cocoa

Suitability Class	***Area (km ^{2})***	***Area (%)***
Moderately Suitable	28.26	19.44
Marginally Suitable	36.45	25.67
Unsuitable	77.29	54.38
Total	**142**	**100**

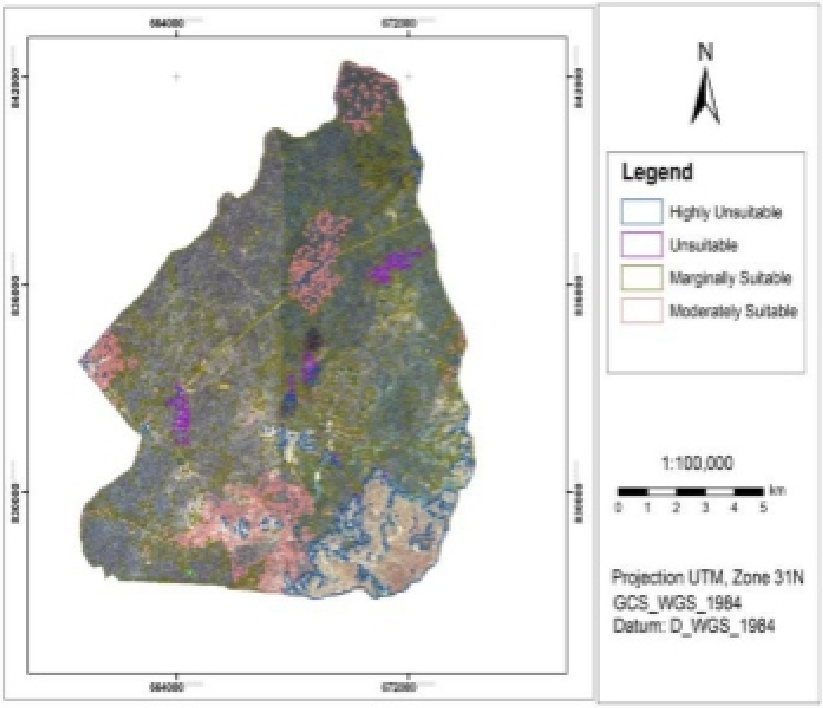

Figure 7: Validation of Land Suitability of Cocoa

5. CONCLUSION

This study identified sandy loamy, sandy clay loamy, silt loamy and loamy soil as the major types in the study area. Some of the physio-chemical properties of these soils and other land suitability parameters such as the climatic condition and topography affect the suitability of the land for cocoa cultivation. The major limiting land qualities for cocoa cultivation identified include soil texture, organic matter, nitrogen and phosphorus. The integration of the existing land use land cover map showed that over one third of the study area is moderate and marginally suitable for cocoa production. Consequently, this study recommends that: (I) sustainable cocoa cultivation be carried in areas categorized as suitable. (II) mitigating some of the limiting soil nutrients through application of nitrogen rich and phosphatic fertilizers; increasing the soil organic matter through effective crop residue management and increased use of leguminous crops. Further research should be carried out considering other parameters such as socio-economics factors in determining the land suitability. This study concludes that use of geospatial technologies is power tool in land suitability assessment for cocoa cultivation and ensuring sustainable land usage.

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An Experimental Study on Behaviour of Square Footing Resting on Reinforced Sand Bed under Static and Repeated Loading Using Geosynthetic Material

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ABSTRACT

In several structures in addition to static loads the foundations are subjected to dynamic loads like machine loads, seismic loads and moving wheel loads, petroleum tanks and ship repair tracks. In this study an attempt is made to evaluate the static and cyclic behavior of square footing resting on sand sub grade by conducting plate bearing and cyclic plate load tests in model box. The load- displacement characteristics were found from static plate bearing tests from which modulus of sub grade reaction (K) was found which is used in pavement design and evaluation. Also from cyclic plate load tests from which cyclic parameters (Cu, Cϕ, Cτ, Cψ) was evaluated which is a parameter used in the design of machine foundations. To implement this objective, a cyclic plate load tests were performed to study the of reinforced soil foundation. The sand bed consists of horizontally placed polyester geogrid reinforcement in different layers and observed the effect of number of reinforced layers, effect of loading on bearing capacity, effect of width of reinforcement, effect of top layer spacing of reinforcement on dynamic properties.

Keywords: Cyclic loading, Geogrid, Coefficient of Elastic Uniform Compression, Coefficient of Non Uniform Compression, Coefficient of Uniform Shear, Coefficient of elastic non uniform shear, Modulus of Sub Grade Reaction.

1. INTRODUCTION

The sub grade of highway or foundation of structures require the special attention of the civil engineer when subjected to weight of machine or vehicle and the foundation loads are dynamic nature in addition to static loads. Dynamic analysis to evaluate the response of earth structures to dynamic stress applications, such as those produced by machine loads, seismic loads and moving wheel loads are finding increased application in civil engineering practice. As it is well established that a foundation weighs several times as much as a machine, a dynamic load associated with the moving parts of a machine is generally small as compared to its static load.

In this type of foundation a dynamic load applies repetitively over a large period of time but its magnitude is small, and it is therefore necessary that the soil behavior be elastic, or else deformation will increase with each cycle of loading until the soil becomes practically unacceptable. Similar type of loading can be expected on pavement, the moving wheel loads are dynamic in nature due to repeated application of moving wheel loads the settlement of soil sub grade will increase with each application and finally leads to the sub grade failure. In dealing with these types of loads the coefficient of elastic uniform compression of soil Cu is the most Important parameter to be determined which can calculate by cyclic plate load test in the model box. An Attempt has been made in this paper to study a point of this phenomenon. In the current research, two types of tests on circular plate subjected to cyclic and static loads are performed. However, the main objective of the present study is to evaluate the dynamic elastic constants of locally available sand with geogrid reinforcement using large scale model box.

2. BACKGROUND

Since N. Hataf, A.H. Boushehrian and A. Ghahramani ,(2010) conducted that by use of grid-anchor increasing the number of their layers in the same proportion as that of the cyclic load applied, the amounts of permanent settlements are reduced and the numbers of loading cycles to reach it are decreased, A.Asakereh1, S.N. Moghaddas Tafreshi2, M. Ghazavi2, (2011); J S Vinod, B. Indraratna, B. Indraratna,(2011); M. V. S. Sreedhar, A. Pradeep Kumar Goud, (2012); Asakereh, M. Ghazavi, S. N. Moghaddastafreshi, (2013).

3. MATERIALS AND EXPERIMENTAL SETUP

The sand use for the investigation is brought from a Bhugao river 10Km from Rajkot City, Gujarat (State), the relative density of sand is used 50% for all the tests and the geogrid use a polymer uniaxial geogrid. The properties of the sand in unreinforced condition are determined by different soil test as per relevant Indian Standards shown in Table 1. The salient features and properties of geogrid are listed in Table 2.

Table 1: Properties of Sand

Sr.No	*Properties of sand*	*Value*
1	D10	0.35 mm
2	D30	0.58 mm
3	D60	1.1 mm
4	Coefficent of Uniformity, C_u	3.14
5	Coefficent of Curvature, C_c	0.87
6	Types of Soil	SP
7	Ymax	1.83 gm/cm^3
8	Ymin	1.61 gm/cm^3
9	Specific Gravity G	2.58
10	Angle of Friction ϕ	32^o
11	Relative Density	50%
12	Dry Density	1.71 gm/cm^3

Table 2: Properties of geogrid Reinforcement used

Sr.No	*Properties*	*Value*
1	**Peak tensile strength**	
	Machine direction	250 KN/m
	Cross machine	30 KN/m
2	**Physical Properties**	
	Colour	Black
	Coating	PVC
	Aperture Size	15x15 mm

3.1 Test-set-up

A tank of size 750X750X750 mm is use in the present study. Hand operating jack is used and having a capacity of 2 tonn for performing static and cyclic plate load tests. A 150mmX150mm square steel plate is use to exert pressure on the prepared sand bed, the experimental test set up is shown in figure.

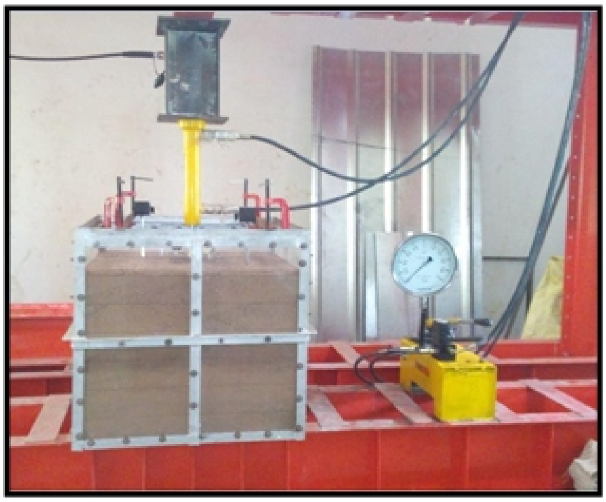

Figure 1: Experimental setup

Table 3: u/B ratio corresponding first reinforcement depth

u/B Ratio	*First reinforcement depth(u)*
0.2	3.2cm
0.4	6.4cm
0.6	9.6cm

4. RESULTS AND DISCUSSION

4.1. Static Loading on Un-Reinforced and Reinforced Sand:

The load-settlement curve for plate load test on unreinforced sand and reinforced sand bed plotted and shown in the fig.2. From the Fig.2 it is observed that (a) The settlement of footing was decreases with increases No of layer of Geogrids (N) and increases in width of geogrid (B'). Settlement of footing without geogrids which was 33.93mm, decreased to 22.13mm at u/B=0.2, B'=4B and N=4 showing 34.77% decreased. (b) The ultimate bearing capacity of sand without geogrids which was 63kN/m2, increased to 118kN/m2 with using geogrid reinforcement at u/B=0.2, B'=4B and N=4 showing 87.30% increased.

4.2. Cyclic plate load test with reinforcement sand

The experimental results of the applied cyclic loads, incrementally (loading, unloading and reloading) with footing settlement rested on reinforced sand with B'/B = 1, B'/B = 2, B'/B = 3, B'/B = 4 for u/B = 0.2, 0.4 and 0.6 are shown in Fig.3-4-5-6 and the following observations were made. It indicates that in each stage due to unloading, a small amount of settlement rebounds which named elastic or recoverable settlement (the amount of elastic rebound of the soil increases with increase in the stress level) while a major part of the settlement is plastic settlement and remains in the system.

It can be seen that, the load v/s footing settlement response of reinforced sand bed is far better than the un- reinforced case. This is due to the frictional resistance at the interface of the sand and reinforcement which would have prevented the soil mass from shearing under vertical applied load.

The footing resting on the soil-reinforcement composite will carry more loads. This shows that settlement of sand improvement is totally depends on the position of the reinforcement and density within the sand bed. The response of the reinforced sand bed is seen to improve as the depth ratio u/B= 0.2 and thereafter shows a increasing trend. As the increase in the width of the geogrid reinforcement settlement of sand is decrease. For B'/B = 4 and U/B=0.2 there is a maximum value of settlement 26.83mm is observed when compared with other width of reinforcement B'/B = 1, B'/B = 2, B'/B = 3 the values are, 35.52mm, 33.34mm, 29.95mm respectively. The value of settlement of the sand for different width of reinforcement and u/B ratios is exclusively given in table 4.

Table 4: Settlement of sand for different width of reinforcement and u/B ratio

	Settlement (mm)		
	N=1, u/B=0.2	**N=1, u/B=0.4**	**N=1, u/B=0.6**
B?/B=1	35.52	37.53	39.41
B?/B=2	33.33	35.43	37.47
B?/B=3	29.95	32.84	35.52
B?/B=4	26.83	29.91	33.94

4.3 Effect of Reinforcement Top Layer Spacing (u)

Fig-11-12-13-14, shows the coefficient of uniform compression of the footing with B'/B = 1, B'/B = 2, B'/B = 3, B'/B = 4, corresponding to number of reinforcement layers for different u/B ratio 0.2, 0.4 and 0.6, respectively. Fig-11-12-13-14 shows that with increases width of reinforcement and u/B ratio also increase coefficient of uniform compression. In fig.11 obtained maximum value of coefficient uniform compression for B'/B=4 and u/B=0.2 Cu is 15.42x104kN/m3 is observed when compared with other width of reinforcement B'/B = 1, B'/B = 2, B'/B = 3 the values are, 9.88x104kN/m3, 11x104kN/m3, 13.25x104kN/m3 respectively.

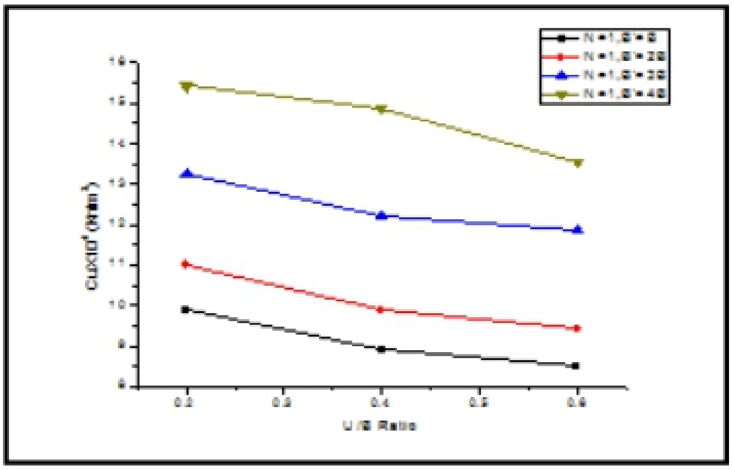

Figure 2: Top layer spacing (u/B) vs. Cu for N=1 and different width of geogrid.

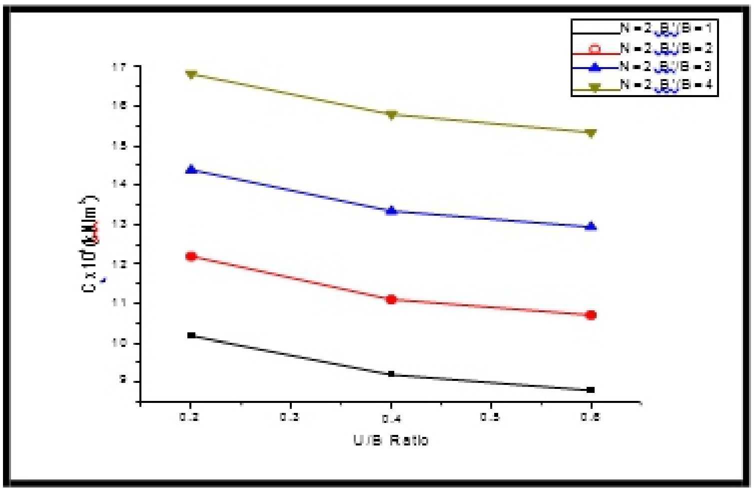

Figure 3: Top layer spacing (u/B) vs. Cu for N=2 and different width of geogrid

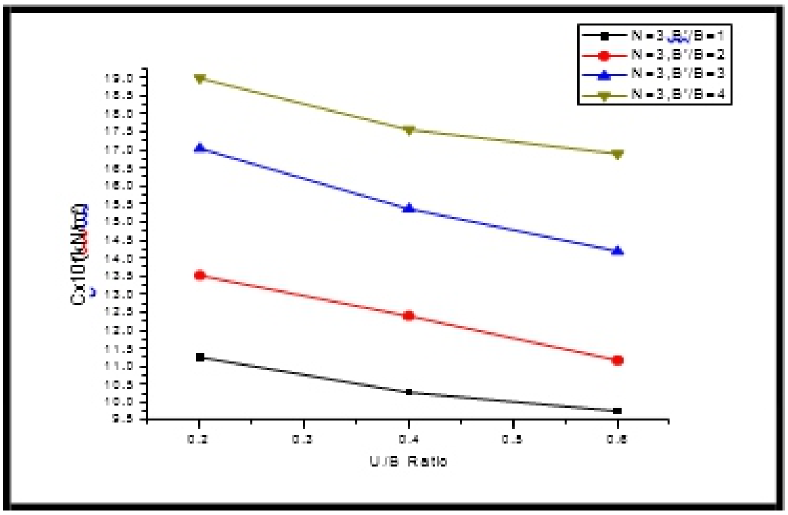

Figure 4: Top layer spacing (u/B) vs. Cu for N=3 and different width of geogrid

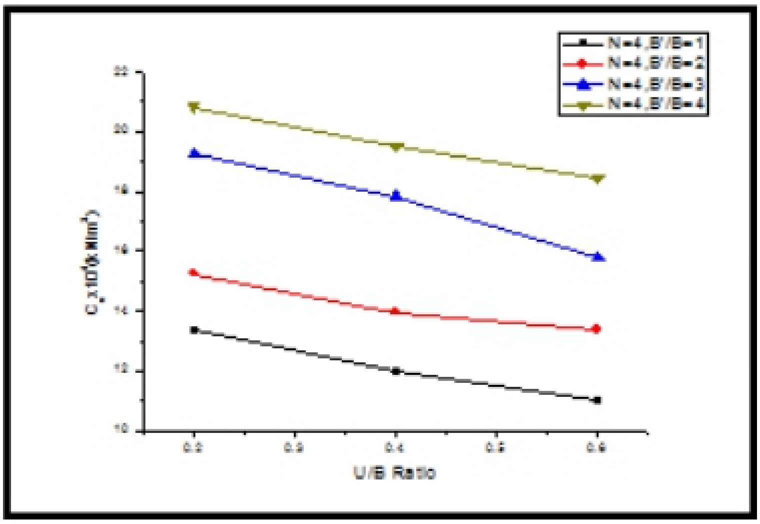

Figure 5: Top layer spacing (u/B) vs. Cu for N=4 and different width of geogrid.

4.3 Effect of Numbers of Reinforcement Layer (N)

Fig-15-16-17-18, shows the coefficient of uniform compression of the footing with B'/B = 1, B'/B = 2, B'/B = 3, B'/B = 4 correspond to u/B ratio 0.2, 0.4, 0.6, for different numbers of reinforcement layer N=1, N=2, N=3, N=4, respectively.

Fig-15-12-13-14 shows that with u/B ratio and Numbers of reinforcement layer also increase coefficient of uniform compression. In fig.18 obtained maximum value of coefficient uniform compression for N=4 and u/B=0.2 Cu is 20.83x10 kN/m is observed when compared with other Numbers of reinforcement layer N = 1, N = 2, N = 3 the values are, 9.88x10 kN/m , 12.20x10 kN/m , 17.04x104kN/m3 respectively.

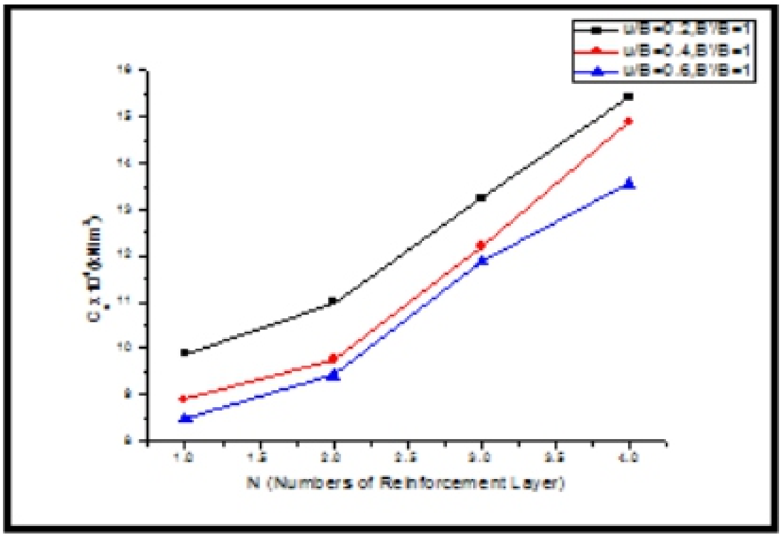

Figure 6: Numbers of Reinforcement (N) vs. Cu for B'/B=1 and different top layer spacing of geogrid

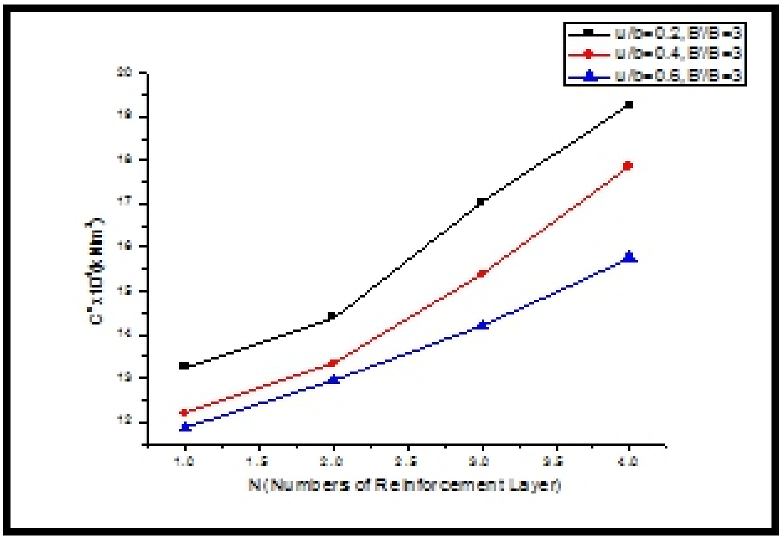

Figure 8: Numbers of Reinforcement (N) vs. Cu for B'/B=3 and different top layer spacing of geogrid

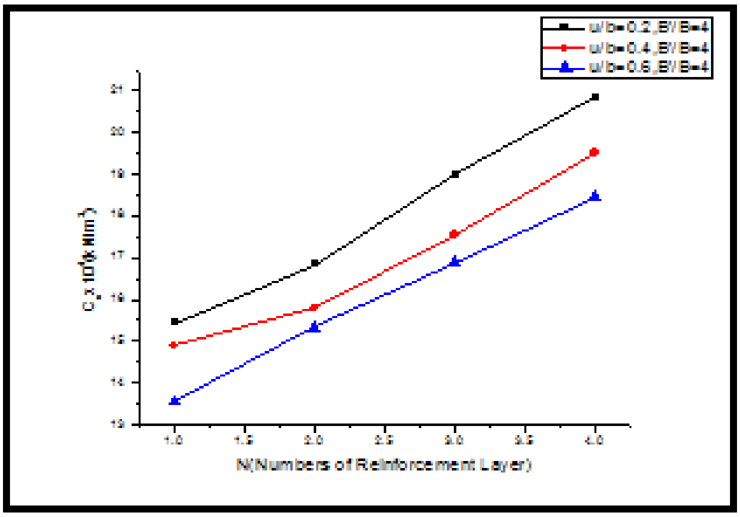

Figure 9: Width of geogrid (B'/B) vs. Cu for N=2 and different top layer spacing of geogrid.

4.5. Effect of Width of Reinforcement (B'/B)

Fig-19-20-21-22, shows the coefficient of uniform compression of the footing with N = 1, N= 2, N = 3, N = 4, correspond to u/B ratio 0.2, 0.4 and 0.6, for different width of reinforcement layer B'/B = 1, B'/B = 2, B'/B = 3, B'/B = 4 respectively.

Fig-19-20-21-22 shows that with u/B ratio and different width of reinforcement layer also increase coefficient of uniform compression. In fig.22 obtained maximum value of coefficient uniform compression for B'/B=4 and u/B=0.2 Cu is 20.83x104kN/m3 is observed when compared with other width of reinforcement layer B'/B = 1, B'/B = 2, B'/B = 3 the values are, 9.88x104kN/m3, 12.20x104kN/m3, 17.04x104kN/m3 respectively.

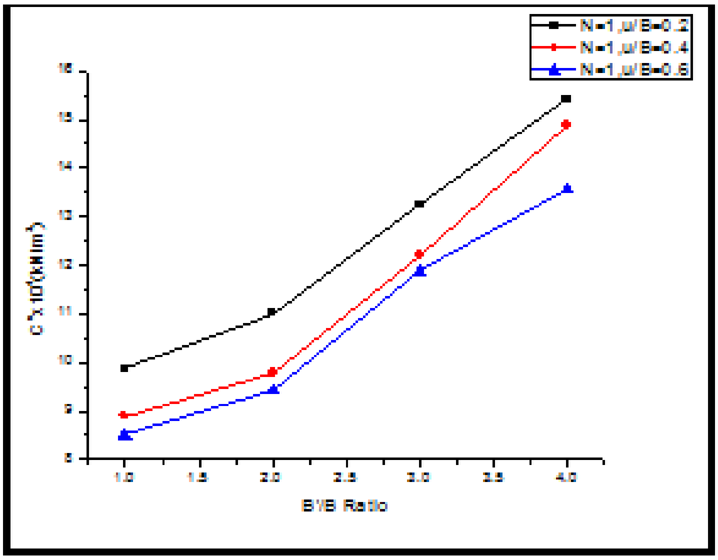

Figure 10: Width of geogrid (B'/B) vs. Cu for N=1 and different top layer spacing of geogrid

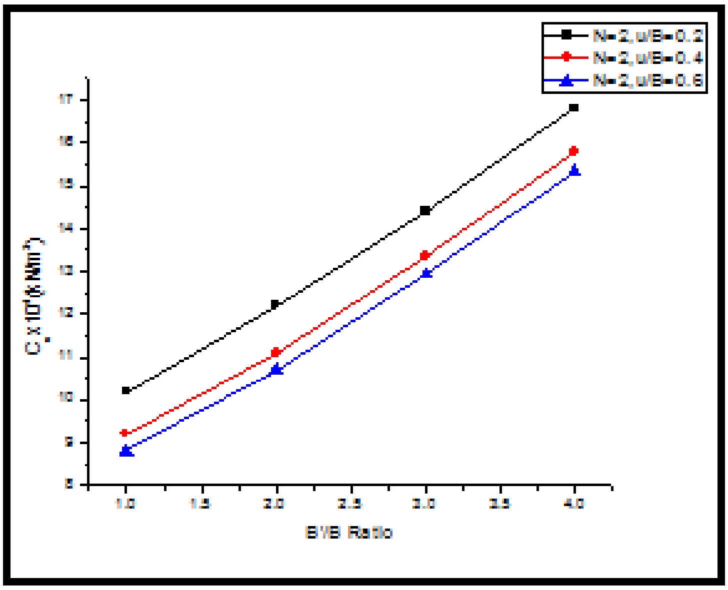

Figure 11: Width of geogrid (B'/B) vs. Cu for N=2 and different top layer spacing of geogrid.

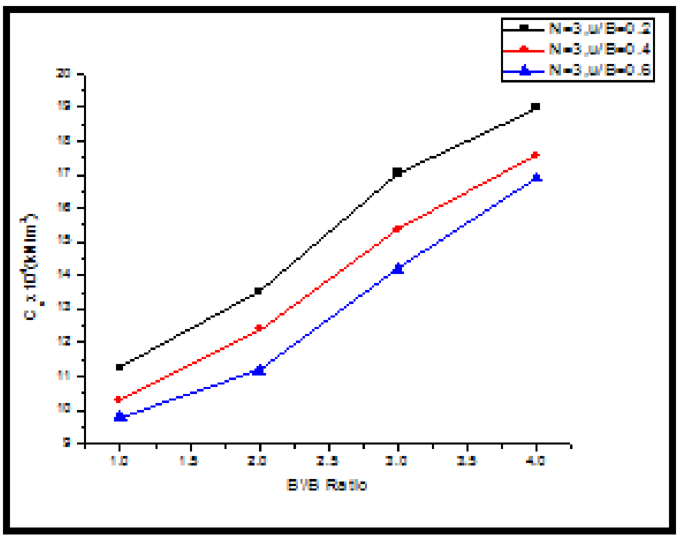

Figure 10: Width of geogrid (B'/B) vs. Cu for N=1 and different top layer spacing of geogrid

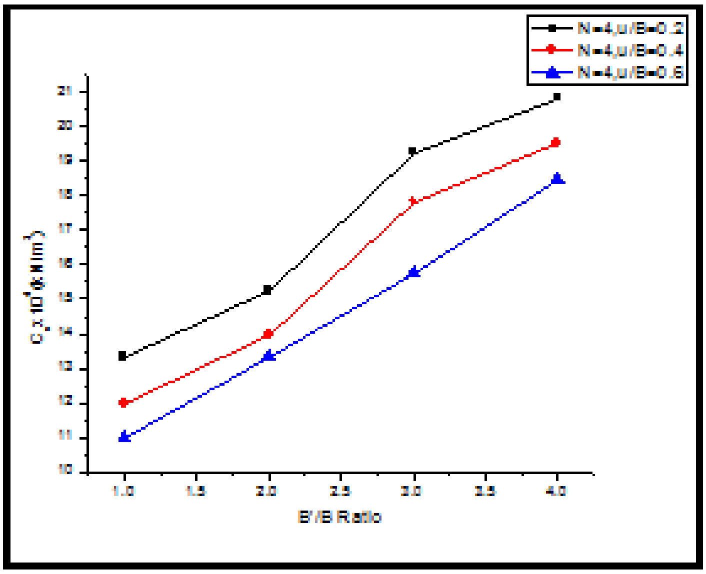

Figure 13: Width of geogrid (B'/B) vs. Cu for N=4 and different top layer spacing of geogrid.

5. Conclusion

The ultimate bearing capacity of sand increased with using geogrid reinforcement. The settlement of footing was decreases with increases No of layer of Geogrids (N) and increases in width of geogrid (B'). Settlement of footing without geogrids decreased.

Modulus of sub grade reaction (K) increase with using geogrid reinforcement. Co-efficient of elastic uniform compression (Cu) increase with using geogrid reinforcement. Co-efficient of Elastic uniform compression (Cu) and other cyclic parameter (Cτ, Cϕ, Cψ) decreases with increasing top layer spacing (u/B) of geogrids layers and increases with increases width of geogrid (B'/B) and also depends on Number of layer of geogrids(N).

For design purposes, engineers need to balance between reducing spacing and increasing geogrid tensile modulus. The author believes that a value of h/B = 0.2 can be a reasonable value for use in the design of reinforced soil.

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Author Profile

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Self Curing Concrete with Light Weight Aggregate

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ABSTRACT

As water is becoming a scarce material day-by-day, there is an urgent need to do research work pertaining to saving of water in making concrete and in constructions. Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. However, good curing is not always practical in many cases. Curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance. Keeping importance to this, an attempt has been made to develop self curing concrete by using water-soluble Polyethylene Glycol as self-curing agent and light weight aggregate as Granite. The aim of this investigation is to study the strength and durability properties of concrete using water-soluble Polyethylene Glycol as self-curing agent. The function of self-curing agent is to reduce the water evaporation from concrete, and hence they increase the water retention capacity of concrete compared to the conventionally cured concrete. The use of self-curing admixtures is very important from the point of view that saving of water is a necessity everyday (each one cubic meter of concrete requires 3m3 of water in a construction, most of which is used for curing).In this study, compressive strength and split tensile strength of concrete containing self-curing agent is investigated and compared with those of conventionally cured concrete. It is found through this experimental study that concrete cast with Polyethylene Glycol as self-curing agent is stronger than that obtained by sprinkler curing as well as by immersion curing. In the present study, the affect of admixture (PEG 400) on compressive strength, split tensile strength and modulus of rupture by varying the percentage of PEG by weight of cement from 0% to 0.2% were studied for M20. It was found that PEG 400 could help in self curing by giving strength on par with conventional curing. It was also found that 0.1% of PEG 400 by weight of cement was optimum for M20 grade concretes for achieving maximum strength without compromising workability. Concrete derives its strength by the hydration of cement particles. Hydration isn't a momentary action but a long time process. Even if higher w/c ratio is used, water gets evaporated into the atmosphere leading to insufficient hydration especially in the top layer. Hence extra water needs to be added i.e., curing. Each 1m3 of concrete requires about 3m3 of water for construction most of which is for curing (conventional). If curing is neglected, the quality of concrete will experience a sort of irreparable loss. A self-curing concrete primarily comprising coarse aggregates, fine aggregates, cement, and mixing water, and further comprising a self-curing agent added during mixing, wherein the self-curing agent absorbs moisture from air and then releases it into the concrete, thereby achieving self-curing without external curing method after placing, wherein a specific amount of the self-curing agent is added to the concrete such that a 10% higher compressive strength than that of concrete without curing is achieved, wherein the added solid amount of the self-curing agent is about 0.1%- 0.2 wt. % of cement weight of the concrete, wherein the added self curing agent comprises polyvalent alcohol selected from the group consisting of xylitol, sorbitol, phytosterols and butylene glycol.

Keywords: Self Curing Concrete, Light Weight Aggregate

1. POTENTIAL MATERIALS

- Cement of 53 Grade
- Fine Aggregate
- Coarse Aggregate
- Waste Granite As Coarse Aggregate Replacement
- Peg 400

Polyethylene Glycol, Paraffin Wax, Acrylic acid are some of the commonly available hydrophilic materials in market.

2. RESULTS

- Water retention for the concrete mixes incorporating self-curing agent is higher compared to conventional concrete mixes, as found by the weight loss with time.
- Self-curing concrete resulted in better hydration with time under drying condition compared to conventional concrete.
- Performance of the self-curing agent will be affected by the mix proportions mainly the cement content and the w/c ratio.
- Use of Polyvinyl alcohol (0.48% by the weight of cement) as self-curing agent Provides higher compressive, tensile as well as flexural strength than the Strengths of conventional mix.
- Increase in the Percentage of polyvinyl alcohol results in the reduction of weight loss.
- Durability of self-curing concrete to sulphate salts and chloride induced corrosion is needed to be evaluated.
- The result also showed that compressive, tensile and flexural strength of self-curing concrete is found to be higher than conventional concrete.
- The self-curing concrete is a self-consolidating concrete and a high performance concrete.

3. APPLICATIONS

- Water scarcity
- Labor cost is high
- Water contains high fluoride content
- Inaccessible structures in difficult terrains

4. SELF-CURING CONCRETE

4.1 Introduction

Most of the concrete that is produced and placed each year all over the world already does self-cure to some extent. Some of it is not intended to have anything done to its exterior surface, except perhaps surface finishing. Yet the concrete's ability to serve its intended purpose is not significantly reduced.

Curing is the maintaining of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties (of concrete) may develop. Curing is essential in the production of concrete that will have the desired properties. The strength and durability of concrete will be fully developed only if it is cured. No action to this end is required, however, when ambient conditions of moisture, humidity, and temperature are sufficiently favorable to curing. Otherwise, specified curing measures shall start as soon as required.

Most of the concrete in the world is placed in quantities that are of sufficient thickness such that most of the material will remain in satisfactory conditions of temperature and moisture during its early stages. Also, there are cases in which concrete has been greatly assisted in moving toward a self-curing status either inadvertently or deliberately through actions taken in the selection and use of materials.

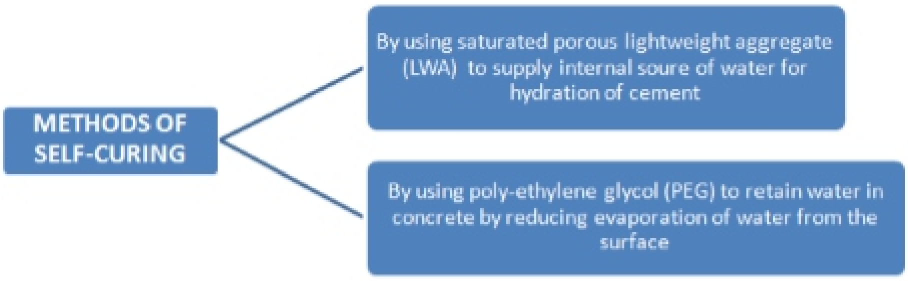
To achieve good cure, excessive evaporation of water from a freshly cast concrete surface should be prevented. Failure to do this will lead to the degree of cement hydration being lowered and the concrete developing unsatisfactory properties. Curing can be performed in a number of ways to ensure that an adequate amount of water is available for cement hydration to occur. However, it is not always possible to cure concrete without the need for applying external curing methods.

5. SELF CURING

The ACI-308 code states that "Internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water." "Internal curing" is often also referred as Self–curing. Self Curing Concrete can be achieved byadding self curing agents. The concept of self- curing agents is to reduce the water evaporation from concrete and hence increase the water retention capacity of the concrete. It was found that water soluble polymers can be used as self-curing agents in concrete. Curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance.

Currently, there are two major methods available for internal curing of concrete. The first method uses saturated porous lightweight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses poly-ethylene glycol (PEG) which reduces the evaporation of water from the surface of concrete and also helps in water retention.

Most paving mixtures contain adequate mixing water to hydrate the cement if the moisture is not allowed to evaporate. It should be possible to develop an oil, polymer, or other compound that would rise to the finished concrete surface and effectively seal the surface against evaporation.



6. METHODS OF INTERNAL CURING IN CONCRETE

Polyethylene Glycol

Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula H(OCH2CH2)nOH, where n is the average number of repeating oxyethylene groups typically from 4 to about 180. The abbreviation (PEG) is termed in combination with anumeric suffix which indicates the average molecular weights. One common feature of PEG appears to be the water-soluble nature. Polyethylene glycol is non- toxic, odorless, neutral, lubricating, non-volatile and non- irritating and is used in a variety of pharmaceuticals.

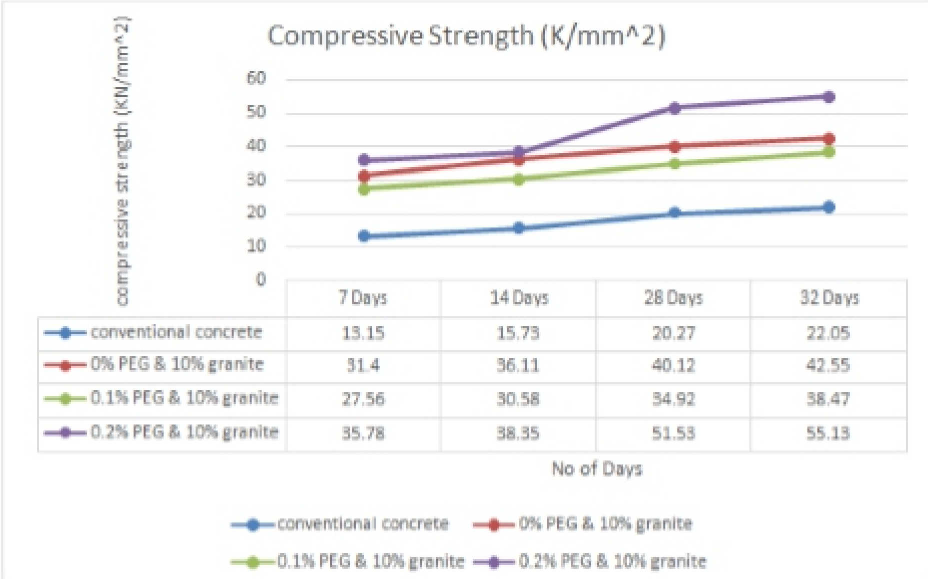
7. EXPERIMENT AND RESULT

Compressive Strength

Overall Result of Compressive Strength

Following table gives the overall results of compressive strength concrete produced with different percentages of PEG and replacement of CA. The variation of compressive

	Compressive strength	**Compressive strength**	**Compressive strength**	**Compressive strength**
Mix Designation	**7 DAYS (PC)**	**14 DAYS (PC)**	**28 DAYS (PC)**	**32 DAYS (PC)**
M20 **Conventional Concrete**	13.15	15.73	20.27	22.05
M20 **0% PEG & 10% Granit**	31.4	36.11	40.12	42.55
M20 **0.1% PEG & 10% Granite**	27.56	30.38	34.92	38.47
M20 **0.2% PEG & 10% Granit**	35.78	38.35	51.53	55.13

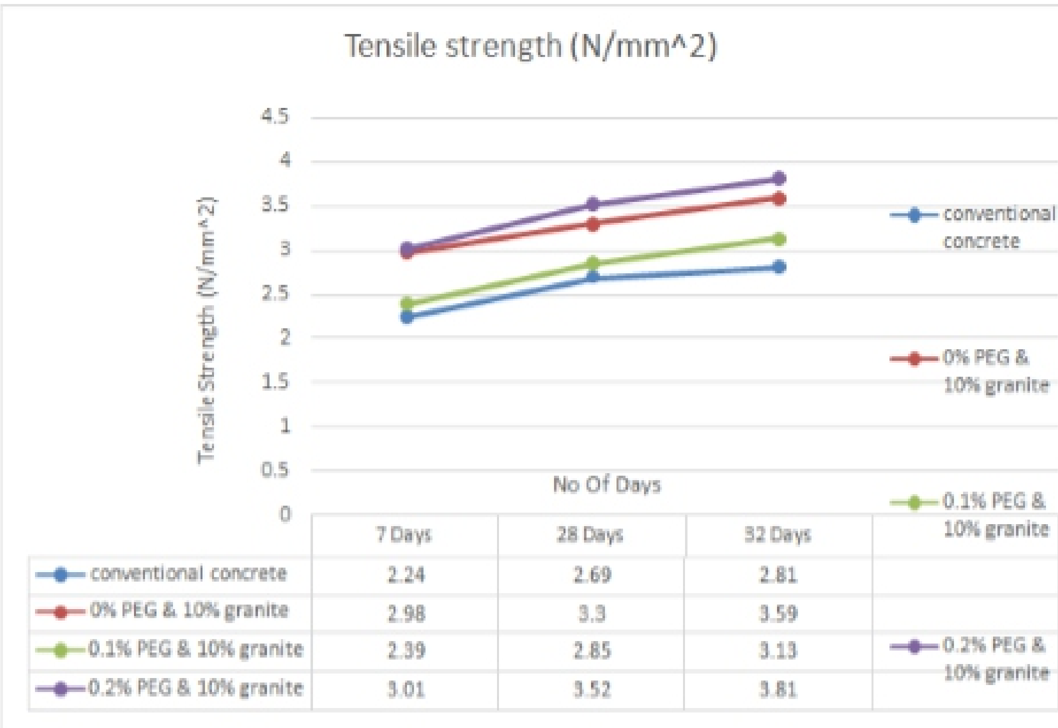


8. GRAPH REPRESENTATION OF COMPRESSIVE STRENGTH

Split Tensile Strength

Mix Designation	*Tensile Strength*	*Tensile Strength*	*Tensile Strength*
	7 DAYS (PC)	**28 DAYS (PC)**	**32 DAYS (PC)**
M20 Conventional Concrete	2.24	2.69	2.81
M20 0% PEG & 10% Granit	2.98	3.3	3.59
M20 0.1% PEG & 10% Granite	2.39	2.85	3.13
M20 0.2% PEG & 10% Granit	3.01	3.52	3.81

9. GRAPHICAL REPRESENTATION OF TENSILE STRENGTH



10. LITERATURE REVIEW

Wen-Chen Jau stated that "self-curing concrete is provided to absorb water from moisture from air to achieve better hydration of cement in concrete. It solves the problem when the degree of cement hydration is lowered due to no curing or improper curing by using a self-curing agent like poly-acrylic acid which has strong capability of absorbing moisture from the atmosphere and providing water required for curing concrete".

Tarun R. Naik in 2014 stated that Most of the concrete that is produced and placed each year all over the world already does self-cure to some extent. Some of it is not intended to have anything done to its exterior surface, except perhaps surface finishing. Yet the concrete's ability to serve its intended purpose is not significantly reduced.―Curing is the maintaining of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties (of concrete) may develop. Curing is essential in the production of concrete that will have the desired properties. The strength and durability of concrete will be fully developed only if it is cured. No action to this end is required, however, when ambient conditions of moisture, humidity, and temperature are sufficiently favorable to curing. Otherwise, specified curing measures shall start as soon as required. Most of the concrete in the world is placed in quantities that are of sufficient thickness such that most of the material will remain in satisfactory conditions of temperature and moisture during its early stages. Also, there are cases in which concrete has been greatly assisted in moving toward a self-curing status either inadvertently or deliberately through actions taken in the selection and use of materials. To achieve good cure, excessive evaporation of water from

a freshly cast concrete surface should be prevented. Failure to do this will lead to the degree of cement hydration being lowered and the concrete developing unsatisfactory properties. However, it is not always possible to cure concrete without the need for applying external curing methods. Most paving mixtures contain adequate mixing water to hydrate the cement if the moisture is not allowed to evaporate. It should be possible to develop oil, polymer, or other compound that would rise to the finished concrete surface and effectively seal the surface against evaporation new developments in curing of concrete are on the horizon as well. In the next century, mechanization of the placement, maintenance, and removal of curing mats and covers will advance as performance-based specifications quantify curing for acceptance and payment.

11. CONCLUSION

1. The optimum dosage of PEG4000 for maximum Compressive strength was found to be 0.1% for grades of concrete.
2. As percentage of PEG4000 increased slump increased for M20 grade of concrete.
3. Strength of self-curing concrete is better than with conventional concrete.
4. Self-curing concrete is the answer to many problems faced due to lack of proper curing.
5. Wrapped curing is less efficient than Membrane curing and Self-Curing it can be applied to simple as well as complex shapes.
6. It is concluded from above study that method of curing has considerable effect on the compressive strength of SCC.
7. Self-curing offers a compressive strength significantly greater than uncured or dry cured SCC.
8. The experimental study shows that the use of water soluble Polyethylene Glycols is possible as a self-curing agent.

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