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Optimum Utilization of Fly Ash for Stabilization of Sub-Grade Soil using Genetic Algorithm

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Abstract: Sub-grade soil stabilization is one of the primary and major processes in the construction of any highway. The aim of this research paper is to formulate a model based on Genetic Algorithm which can be used to predict variation in the values of CBR of the Sub-grade Soil with the addition of a specific percentage of Fly Ash. The input values for this study were those which directly affect the CBR values i.e., directly proportional to CBR. It includes Liquid Limit (LL), Plasticity Index (PI), Optimum Moisture Content (OMC) & Fraction of Fly Ash added (F.A in %).For analysis of stabilization of soil using fly ash, Evolver 5.7 an add-in software of excel is used. Properties used for analysis are Liquid Limit, Plastic Limit, Optimum Moisture Content and California Bearing Ratio. This model will help all types of agencies involved in road construction like NHAI, Infrastructure Developers and Construction Contracting Organizations to pre-determine the soil stabilization achieved due to fly ash for a particular type of sub-grade soil.

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Keywords: Optimization; genetic algorithm; fly ash; soil stabilization.

1. Introduction

Emerging trend of using waste material in soil stabilizing or soil strengthening is being operational all over the world in present days. The main reason behind this trend is the excessive production of waste like fly ash, plastics, rice husk ash which is not only hazards but also creating deposition problems. Using some of these waste materials in construction practice will reduce the problem in a great extent.

The history of stabilization of soil has a long background with hundreds of research results. Several research results with waste materials such as fly ash, plastics; rice husk ash has also been published with their benefits. Some of the recent relevant research work has briefly mentioned here, Alhassan (2008)[8] has shown the potential benefits of using RHA with the natural soil. It has been reported that both CBR as well as unconfined compression values has increased with the addition of RHA with natural soil. Also the OMC (Optimum Moisture Content) increase while MDD (Maximum Dry Density) has decreased due to RHA mixed with natural soil. Brooks (2009) [8] reported the soil stabilization with RHA and fly ash mixed with natural soil. In this study also showed improvement in CBR values and unconfined compression strength. The effect of marble dust with RHA in a mix with expansive soil has been studied by Sabat and Nanda (2011). It has been seen that with addition of RHA and marble dust with soil, the MDD deceases and OMC increases. Also the CBR and UCS values increase substantially due to adding these two with the natural soil. The study of Yulianto and Mochtar

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(2010) [15] shows the effectiveness of using rice husk ash (RHA) and lime as a pozzolanic material with natural soil. The results showed good improvement on its physical and engineering behaviour of the stabilized peat soil. The values of wet unit weight and specific gravity increase while the water content and void ratio decrease with the increase of curing period. The increment of curing period is also altered its engineering behaviour that is increasing the soil strength and reducing its compressibility.

In this study the objectives are; Evaluation of Compressive Strength (CBR) of Fly Ash Stabilized Sub-Grade Soil, to identify factors affecting Compressive Strength (CBR) of Stabilized Sub-Grade Soil containing Fly Ash and Sensitivity Analysis of Sub-Grade Soil CBR is using Genetic Algorithm.

Fly Ash is the residual remains after the combustion of coal which is made up of very fine particles of Silicon Dioxide (SiO_2) (Amorphous & Crystalline), Aluminium Oxide (Al_2O_3), Iron Oxide (Fe_2O_3) and Calcium Oxide (CaO). It has various applications in the field of Construction such as Concrete Production, in Cement Clinkers, Substitute Material in Brick Manufacturing, Mineral Filler in Bituminous Concrete, etc. One such application is Sub-grade Soil Stabilization for Road Construction.

Fly Ash Mix with Lime and/or Cement can be used for stabilizing of sub-grade soil having poor compressive strength for Road Construction. After it has been added the reactions that take place between fly ash, lime and water gives rise to cementitious products which bonds the soil particles together. Soils having high amounts of clay in their composition require a high lime/fly ash ratio to ensure an abundant supply of lime for the lime-fly ash reaction and for lime-clay stabilization.

Pavement engineers have long recognized long term benefits of increasing the strength and durability of pavement subgrade soil by mixing in a cementitious binder during reconstruction or new construction. Millions of dollars can be saved by soil subgrade stabilization in comparison to cutting out and replacing the unstable subgrade soil. When included in pavement design, stabilizing the subgrade can result in reducing the thickness of other pavement layers.

Finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. In comparison, maximization means trying to attain the highest or maximum result or outcome without regard to cost or expense. Putting together a portfolio in such a way that return is maximized for a given risk level, or risk is minimized for a given expected return level. An optimization tool that allows us to generate an entire tradeoff curve in a single iteration will be more useful to the decision-making process that generates just a single point at a time [3].

Many human inventions were inspired by nature. Artificial neural networks are one example. Another example is Genetic Algorithms (GA). Genetic Algorithms search by simulating evolution. It starts from an initial set of solutions or hypotheses, then generating successive generations of solutions. This particular branch of Artificial Intelligence was inspired by the way living things evolved into more successful organisms in nature. Thus Identifying different factors that affect the strength of soil by the addition of fly ash in different proportion of sand and then inserting the data into Evolver will result into prediction of soil strength is the present scope of the study.

2. Literature Review

Subgrade soils are an essential component of pavement structures, and inadequate subgrade performance is the cause of many premature pavement failures. Clay subgrades in particular may provide inadequate support, particularly when saturated. Soils with significant plasticity may also shrink and swell substantially with changes in moisture conditions. These changes in volume can cause the pavement to shift or heave with changes in moisture content, and may cause a reduction in the density and strength of the subgrade, accelerating pavement deterioration. There is a substantial history of use of soil stabilisation admixtures to improve poor subgrade soil performance by controlling volume change and increasing strength. Lime and cement have been used successfully for many decades, and more recently Class C fly ash has been used as an economical alternative to improve subgrade performance.

The benefits of Class C fly ash may be divided into three categories (adapted from Ferguson, 1993)[12]:
(a) Drying agent. Fly ash hydrates when exposed to water. As a water consumer, it can be used as a drying agent for wet soils when acceleration of the drying process is desired.

(b) Control of volume change. Fly ash reduces shrink/swell behaviour because it does not experience significant volume change itself, so its addition acts to dilute the effects of the swelling clays that are present. It also contains some lime, which acts through ion exchange to reduce the clay particles' affinity for water (Ferguson and Levorson, 1999)[12].
(c) Increase strength. Fly ash acts as a weak cementing agent that increases the strength of the treated soil. Much of this strength gain occurs very quickly; however, for some soil–ash combinations there may be additional strength gains over time owing to pozzolanic reactions as with lime. The immediate strength gain is of particular value because it results in a subgrade that serves as a superior working platform for asphalt paving and compaction equipment.
The permanence of these improvements is uncertain. McCallister and Petry (1991)[12] showed in laboratory testing that stabilisation with an inadequate amount of lime could yield improvements in soil behaviour that were non-permanent. Laboratory research by Parsons and Milburn (2003a) showed some evidence that the plasticity of fly ash stabilised soils can also revert to native levels with leaching. However, Ferguson and Zey (1992)[12] found that fly ash stabilised soils performed well in the field after a period of two years.

2.1 Various Methods of Soil Stabilisation

Some of the conventional methods of soil stabilisation can be Mechanical, Cement, Lime, Bituminous, Thermal & Electrical, Mechanical Stabilization is the simplest method of soil stabilisation. The process involves improving the subgrades of low bearing capacity by changing its gradation. Two or more types of natural soils are mixed to obtain a composite material which is superior to any of its components. Cement Stabilization can be done by mixing pulverised soil & Portland cement with water after which compacting the mix gives a strong material. A well graded soil requires about 5% cement, whereas poorly graded; uniform sand may require about 9% cement. Non-plastic silts require about 10% cement, whereas plastic clays may need about 13% cement. Lime Stabilization involves addition of lime to the soil for stabilisation of the soil. It is mostly useful for clayey soils. When lime reacts with soil, there is exchange of cations in the absorbed water layer & a decrease in plasticity of the soil occurs. The amount of lime required for stabilisation varies between 2 to 10% of the soil. Bituminous Stabilisation is generally done with asphalt as binder. As asphalts are normally too viscous to be used directly, these are used as cut-back with some solvent, such as gasoline. These are also used as emulsions, but in this form they may require a longer drying period. The amount of bitumen required generally varies between 4 to 7% by weight. Actual amount is determined by trial & error, Arora (2008) [8]. Thermal Stabilisation is done either from extreme heating to extreme cooling of the soil. Electrical Stabilisation of clayey soils is done by a process known as electro-osmosis. As Direct Current is passed through a clayey soil, pore water migrates to the negative electrode i.e., cathode. This is an expensive method & is mainly used for drainage of cohesive soils which also improves the properties of the soil.

New method of soil stabilisation by adding different chloride compounds which included NaCl, $MgCl_2$& $CaCl_2$. Various amounts of these salts (2%, 4%, and 8%) were added to the soil which gave positive effects on the compaction characteristics, consistency limits and compressive strength of the soil. The increase in the percentage of each of the chloride compounds increased the maximum dry density & decreased the optimum moisture content. The liquid limit, plastic limit and plasticity index decreased with the increase in the salt content of the soil, Abood et al. (2007)[1].The unconfined compressive strength also increased as the salt content increased.

An innovative method of soil stabilisation for expansive soils using rice husk ash (RHA) and fly ash, which are waste materials, is formulated. Stress strain behaviour of unconfined compressive strength showed that failure stress and strains increased by 106% and 50% respectively when the fly ash content was increased from 0 to 25%. When the RHA content was increased from 0 to 12%, Unconfined Compressive Stress increased by 97% while CBR improved by 47%. A fly ash content of 15% is optimum for blending into RHA for forming a swell reduction layer, Brooks (2009)[4].

There is use of Cement Kiln Dust (CKD) for the purpose of soil stabilisation. Because of the free lime content and ability to enhance the effectiveness of other stabilizers like fly ash, CKD can be used extensively as a binder in soil stabilized base and sub base pavement applications. The use of CKD in stabilization of clays has been shown to improve the unconfined compressive strength and reduce the plasticity index using dust with low LOI. The laboratory and field test data shows that CKD was more effective than quicklime for stabilizing soil. Additional laboratory tests show that the influence of CKD & lime on the plasticity index of soils was similar and that both additives imparted some resistance to freeze-thaw and wet-dry cycles. In addition, the tests show that the LOI content was an important factor in the effectiveness of the CKD. Adaska&Taubert (2008)[2]. High LOI implies a higher percentage of bound water within its chemical structure and less CaO available to react. So a conclusion can be made that treatment with CKD can be cost effective & that it requires less construction time than treatment with quicklime.

2.2 Fly Ash for improving soil properties

Physical & chemical properties of soil due to fly-ash amendment vary according to the original properties of soil and fly ash but certain generalization could be made in most cases has been reviewed. Some of the general changes in properties of soil can be observed from the properties such as Soil Texture, Bulk Density, Water Holding Capacity and Soil pH. Application of high rates of fly-ash can change the surface texture of soils, usually by increasing the silt content. Fly-ash addition at 70t/ha has been reported to alter the texture of sandy & clayey soil to loamy. Addition of fly-ash at 200t/acre improved the physical and chemical properties of soil and shifted the textural class of the refuge from sandy loam to silt loam. The particle size range of fly-ash is similar to silt & changes the bulk density of soil. Application of fly-ash at 0%, 5%, 10% and 15% by weight in clay soil significantly reduced the bulk density and improved the soil structure, which in turn improves porosity, workability, root penetration and moisture-retention capacity of the soil. Fly-ash application to sandy soil could permanently alter soil texture, increase micro-porosity and improve the water-holding capacity as it is mainly comprised of silt-sized particles. Fly-ash generally decreased the bulk density of soils leading to improved soil porosity, workability & enhanced water-retention capacity, Basu et al. (2009)[3]. A gradual increase in fly-ash concentration in the normal field soil (0, 10, 20 up to 100% v/v) was reported to increase the porosity, water-holding capacity, conductivity and cation exchange capacity. Depending on the source, fly-ash can be acidic or alkaline, which could be useful to buffer the soil pH. The hydroxide and carbonate salts give fly-ash one of its principal beneficial chemical characteristics, the ability to neutralize acidity in soils.

2.3 Relevance of Genetic Algorithms

Non-convex optimization problems have been researched by a number of methods such as Artificial Neural Networks, Genetic Algorithms, Simulated annealing and Particle swarm methods [5, 9]. There are classical algorithm based approaches in structural optimization such as in the works of Hoppe and co-workers [3].Genetic algorithms (GAs) are modelling techniques based on biological behaviour. They rely on the speed of computers either to combine elements from two solutions (or parents) or to mutate a single solution to a complex problem to produce a third solution (or child) and evaluate it. If the third solution is "better" than one of the others, then it "survives" and the worst one "dies" – along the lines of the lines of "survival of the fittest" in Darwin's theory of evolution. The process continues through a number of iterations or "generations," with each solution contributing to the next generation in proportion to its "goodness." Random factors ensure that the solution space is adequately covered. Since genetic algorithms are generic and flexible and need little knowledge and information about the problem domain, Mawdesley et al. (2002) [6], they have found wide application in diverse areas.

Despite classical optimization techniques such as mathematical and heuristic approaches, genetic algorithms have become popular in dealing with "large combinatorial problems" e.g. constrained or unconstrained optimization, scheduling and sequencing, transportation, and many others. Genetic algorithms (GAs) are stochastic search techniques based upon the mechanism of natural selection and population genetics, Sriprasert and Dawood (2003)[7], A clear advantage of using GA over other methods is potential to locate global optimum or near global optimum solution without a necessity to search for all solution spaces. Moreover, the processing time only increased as the square of the project size and not exponentially.

Several studies have successfully applied GAs for optimization problems in construction scheduling, for instance, time-cost trade-off problem, resource allocation and levelling problem, and a combination of these two problems. However, none of these efforts has been able to solve and optimize the kind of multi-constraint scheduling problem. Therefore, to develop a practicable GA-based application that is particularly capable of optimizing such complex problem and to provide a background towards the formulation of the integrated problem, the problem is broken down into four main steps which include: (1) Setting the Chromosome Structure; (2) Deciding the Evaluation Criteria (Objective Function); (3) Generating an Initial Population; and (4) Generating Offspring Population (i.e., Solution) (Sriprasert and Dawood, 2003) [7].

There are studied 87 peer-reviewed prestigious journal articles published over the past 20 years from 1995 to 2010 focusing on areas influenced by genetic algorithm application. The findings indicate that mathematical programming for cost and schedule optimization (40.23%, 35 articles) is the most widely applied area, followed by construction method and process (27.59%, 24 articles), design and layout (21.84%, 19 articles), and management (10.34%, 9 articles), Kim (2010) [5]. A recent trend in solving the resource scheduling problems using GA is to develop an integrated meta-heuristic method by combining GA with other meta-heuristic method. An integrated GA approach has been successfully applied to many engineering optimization problems such as aerodynamic design, signal analysis, water resources planning and management, and others. So, the same approach can be used in the current research study to predict the sensitivity of the CBR values of soil samples containing different proportions of Fly Ash.

3. Case Study

The case study considered for taking soil sample was a project of the National Highways Authority of India involving the four Laning of the National Highway (NH-59) between Ahmedabad &Godhra connecting chainage 4.200 to 122.420 km (total = 118.2 km). The total cost of the project is Rs. 1008.5 crores with a total duration of 36 months starting from 27 Dec. 2010 to 24 June 2013.Fly Ash has been used here at various stretches along the highway. The source of fly ash was the nearest thermal power station to the project which is 90 km away at Vanakbori and was obtained free of cost. The type of fly ash used was Class-C which was non-plastic and negligibly cohesive. The Density of the fly ash obtained was 2.17 gm/cc with a maximum dry density (MDD) of 1.25 gm/cc and optimum moisture content (OMC) of 27-35%.

3.1 Data Analysis

The effect of addition of Fly Ash in different proportions to the Soil Sample can be observed from the properties like Liquid Limit, Plastic Limit, Optimum Moisture Content and California Bearing Ratio. Putting the data generated from experiments with respect to these properties in Evolver 5.7 will give us the predicted values of CBR for various proportions of Fly Ash added to the Soil Sample.

Evolver 5.7 is a true add-in to Microsoft Excel, integrating completely with your spreadsheet. Define your models, adjust your settings, run optimizations, monitor progress, and generates reports – while never leaving Excel. Streamlined dialog boxes mean fewer open windows to navigate. Evolver is available by itself or as part of the DecisionTools Suite, Palisade's complete risk and decision analysis toolkit. It is available for a free trial version of 15days which was been used as a part of this research study.

Standard optimization programs such as Excel's Solver are good at finding the best "local" solution, or combination of values to maximize or minimize the outcome of a straightforward spreadsheet model given certain constraints. They find a solution which seems to be producing favourable results and continue to work on that basis, without trying new solutions. This is known as "hill climbing." However, these programs are not set up to handle more complicated, nonlinear problems where the best local solution may not be the best absolute answer. Evolver, using innovative "mutations" and combinations of solutions, or "organisms," is well-suited to finding the best overall answer by exploring the entire universe of possible answers.

During an optimization, Evolver generates a number of trial solutions and uses genetic algorithms, OptQuest, or linear programming to continually improve results of each trial. With genetic algorithms, each possible solution becomes an independent "organism" that can "breed" with other organisms. The spreadsheet model acts as an environment for the organisms, determining which are "fit" enough to survive based on their results, and occasionally trying "mutations," or completely new solutions. After optimization, Evolver can display the results of the original, best, and last solution on your entire model, updating it with each scenario in a single click. This makes it easy to decide the best course of action. You can also generate reports directly in Excel for an optimization summary, log of all simulations, and log of progress steps.

3.2 Data Input

The data in Table-1 will be incorporated into Evolver 5.7 for analysis.

Table 1: Data obtained from experiments conducted

Sr. No.	Fly Ash Added (%)	Liquid Limit (%)	Plasticity Index (%)	Optimum Moisture Content (%)	California Bearing Ratio (%)	Maximum Dry Density (gm/cc)
1	0	61.56	28.35	21.38	5.64	1.41
2	10	62.73	27.6	29.27	10.51	1.38
3	20	64.66	28.67	25.24	20.53	1.41
4	30	66.28	27.63	26.01	9.11	1.38
5	40	69.42	30.51	25.74	10.57	1.36

Evaluation Criteria (Objective Function)

The Objective Function for applying Genetic Algorithm in this research study will be formulated as follows:

Y is directly proportional to the variables X1, X2, X3 & X4. So, the equation created will be as given in"Eq.1"

$$Y = b0 + b1X1 + b2X2 + b3X3 + b4X4 \quad (1)$$

Where,

Y = California Bearing Ratio (%),
b0, b1, b2, b3, b4 = constants,
X1 = Fly Ash Fraction (%),
X2 = Value of Liquid Limit (%),
X3 = Value of Plasticity Index (%), &
X4 = Value of Optimum Moisture Content (%).

The values of above constants will be solved using the Multi-Linear Regression Analysis in the Data Analysis Toolpak a built-in Add-In for Microsoft Excel. So by inputting the values of California Bearing Ratio, Liquid Limit, Plasticity Index, Optimum Moisture Content and Fly Ash Fractions we can obtain the values for the constants. Following values of the constants will be generated as shown in Table 2 below.

Table 2: Values of Coefficients

	Coefficients	Standard Error	t Stat
Intercept	1332.29818	0	65535
X1	4.87656512	0	65535
X2	-28.043084	0	65535
X3	14.1435032	0	65535
X4	-0.0605342	0	65535

Therefore, the Objective Function is given in "Eq.2":

$$Y = 1332.298 + 4.877*X1 - 28.043*X2 + 14.144*X3 - 0.061*X4 \quad (2)$$

3.3 Functioning of Evolver 5.7

For Optimization Goal the Maximum option is selected & to define the same, the Cell has to be selected in the excel. The value for which the Model has to be optimized is selected as 21 rounded off from 20.53 which is the value for CBR from experiments.

Now to define Range for which the optimization has to be performed, Model Definition is opened & Add is clicked in the Adjustable Cell Ranges section of the excel sheet. In this manner all the five Cell Ranges are defined. Now next step is defining Constraints. For that Add in the Constraints section is clicked where the Constraint is described, Entry Style selected in Formula & the Objective Function is entered with required values as given in "Eq. 2".In the same fashion all the five constraints are entered.

To perform optimization first it is to be checked that all constraints are met with in the Constraint Solver. Steps followed to perform this check: Click Utilities from Evolver layout > Select Constraint Solver, if all constraints are met with, then Optimization is performed by clicking on Start in the Evolver excel layout. If not then Evolver starts performing optimization to solve the constraints first. Evolver excel performs optimization until all the constraints are met with. It can also be set to perform optimization for a specific time period or can also be stopped manually in the following window. Optimization was performed for a total of 410 trials/iterations in a time period of 8 seconds.

3.4 Comparison of Experimental & Predicted Values

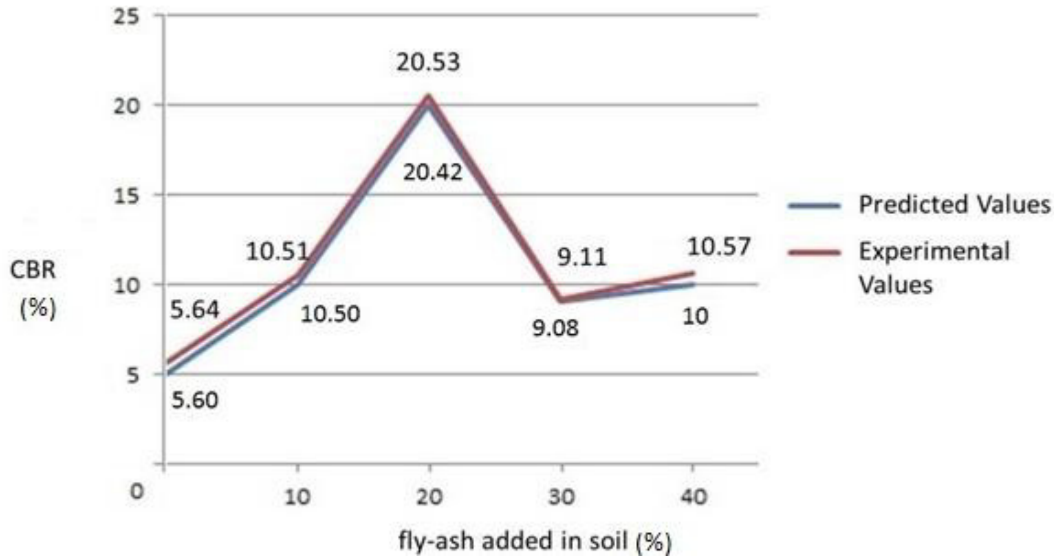

Fig. 1: Experimental vs. Predicted CBR values

The graph generated for Experimental & Predicted values of CBR almost are overlapping indicating the accuracy of the Evolver Model formulated in this research study as given in figure 1.

Table 3: Difference between Experimental & Predicted values of CBR

Sr. No.	Fly Ash (in %)	Predicted CBR (%)	Experimental CBR (%)	Difference	Accuracy (%)
1	0	5.60	5.64	0.04	99.29
2	10	10.50	10.51	0.01	99.90
3	20	20.42	20.53	0.11	99.46
4	30	9.08	9.11	0.03	99.67
5	40	10	10.57	0.57	94.60

The difference between the Experimental & Predicted values is very minimal. It can be summarized as shown in Table 3 above. Advantage of this model is to determine the effect of fly ash added to the sub-grade soil on the thickness of different layers of the pavement which is directly proportional to the CBR values.

4. Conclusions

The following conclusions can be drawn from this research study conducted on the addition of Fly Ash in Sub-grade Soil using Genetic Algorithm:

Class-C fly ash highly resembles to soil in its chemical composition as they have the same major elements (N, P, K, Ca, S, Al, Na & Fe) and Trace elements (Mn, Zn, Cu, B, As, Cd, Co, Cr, Hg, Mo, Ni, Pb& Se). It also is similar to soil in its physical composition (Gravel, Sand & Silt/Clay Content). So it can be used as an additive to soil in pre-determined fractions to improve the index properties of the soil.The values of almost all the index properties of the soil undulate on the addition of Fly Ash. This indicates that addition of Fly Ash in the smallest of fractions affects the soil greatly. Fly Ash in the proportion of 10%, 20%, 30% & 40% (w/w) was added to the sample of soil collected from the site near Godhra(Eastern

Gujarat) which was loamy in nature & experiments were conducted on these composite soil samples. The experimental values of all the index properties except for OMC attain maximum for an addition of 20% of Fly Ash. OMC attains its highest value of 29.27% for 10% of fly Ash added from 21.38%.MDD value remains the same at 1.41 gm/cc for 20% fly Ash added. Similarly for UCS it was 0.152 N/mm^2 from 0.148 N/mm^2 for an addition of 20% fly Ash. or CBR it was 20.53% from 5.64% for addition of 20% Fly Ash. Further for the range of 20-30%, the experimental values of all the index properties drop down rapidly along with the range of 30-40%, the experimental values of all the index properties almost stay stable & start to stagnate.
As a result it can be observed that soil containing 20% Fly ash gave the best results of Soil Stabilization as compared to other proportions. The Evolver model has the capability to integrate the consequence of every input constraint for any required output constraint concurrently. The Evolver Model created to apply Genetic Algorithm for predicting CBR values returned values with good amount of accuracy. This indicates the relevance & effectiveness of Genetic Algorithm Models for solving various kinds of research problems.

The current model is only limited to predicting the CBR values of the soil based on the experimental data of index properties of the soil which were OMC, LL & PI. This model will be helpful for all types of agencies involved in road construction like NHAI, Infrastructure Developers and Construction Contracting Organizations to pre-determine the soil stabilization achieved due to fly ash for a particular type of sub-grade soil.

Another advantage of this model will be that it can predict the amount of fly ash needed for a particular value of CBR by applying it in a reverse manner. From various experiments conducted by eminent researchers of this field it has been found that the maximum value of CBR attained by adding fly ash in different types of soils are in the range of 15-20%. So, from this model the fraction of fly ash to be added for different types of soil for maximum stabilization can be determined.

5. Recommendations

Number of recommendations is suggested for using this work to construction in practice as follows;

In addition to Fly Ash effect of other additives and admixtures on sub-grade soil can also be studied by applying a similar kind of Genetic Algorithm model. For the stabilisation of Sub-grade soil, other by-products such as Copper Slag, Silica Fume, Dolime etc. can also be applied.

The methodology adopted in this research study can also be extended to other layers & materials in Highway Construction.A similar Genetic Algorithm based model can be formulated & applied considering the chemical properties to predict the effects of fly ash on other index properties of the soil.

Other branches and tools of Artificial Intelligence such as Artificial Neural Networks can also be utilized to conduct a similar research study.

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REFERENCES:

- Journal Articles

[1] Abood, T. T., Kasa, A. B., and Chik, Z. B. 2007. Stabilisation of Silty Clay Soil using Chloride Compounds.Journal of Engineering Science and Technology, Vol. 2(1), pp. 102-110.

[2] Brooks, R. M. 2009. Soil Stabilization with Fly Ash and Rice Husk Ash.International Journal of Research and Reviews In Applied Sciences, Vol. 1(3), pp. 209-217.

[3] Hoppe, R. H. W. , Iliash, Y. ,Iyyunni, C.,Sweilam, N. H. 2006 , A posterior error estimates for adaptive finite element discritizations of boundary control problems ,Journal of Numerical Mathematics, vol. 14, no. 1, pp. 57-82.

[4] Mawdesley, M. J., Al-jibouri, S. H., and Yang, H., 2002. Genetic Algorithms for Construction Site Layout in Project Planning.Journal of Construction Engineering and Management, Vol. 128(5), pp. 418-426.

[5] Sabat, A. K., Nanda, R. P. (2011). Effect of marble dust on strength and durability of Rice husk ash stabilized expansive soil. International Journal of Civil and Structural Engineering, Volume 1, No 4, pp. – 939 – 948

- Book:

[5] Arora, K. R. 2008. Soil Mechanics and Foundation Engineering, Seventh Edition, Standard Publishers Distributors, Delhi, India.

- Symposium Proceedings:

[6] Adaska, W. S., and Taubert, D. H. 2008. "Beneficial Uses of Cement Kiln Dust." IEEE/PCA 50th Cement Industry Technical Conference, Miami, Florida, USA, May 19-22.
[7] Basu, M., Pande, M., Bhadoria, P. B. S., and Mahapatra, S. C. 2009. "Potential Fly-Ash Utilization in Agriculture: Global Review." Progress in Natural Science, Vol. 19(10), pp. 1173-1186.
[8] Biswas S,Biswass A,Dighade.,2012 "Utilization of Rice Husk with Lime in Subgrade Soil for a Rural Road" International Conference on Emerging Frontiers in Technology for Rural Area (EFITRA),Proceedings published in International Journal of Computer Applications® (IJCA)
[9] Ehert W.J,Cieniawski S.C,Ranjithan S.(1993),"Genetic-Algorithm-Based Design Of Groundwater Quality Monitoring System", Water Resource Centre (WRC) Research Report No.218
[10]Kim, J.-L. 2010. "Integrated Genetic Algorithm and Its Applications for Construction Resource Optimization." Proceedings of the 2010 Winter Simulation Conference - IEEE, Baltimore, Maryland, USA, December 5-8, pp. 3212-3219.
[11]Marler R.T., Arora J.S.2004 "Survey of multi-objective optimization methods for engineering" Struct Multidisc Optim 26, 365-395 Review Report
[12]Parsons R. L., Kneebone E., 2005."Field Performance of Flyash Stabilized Soil", Ground Improvement, Vol.9, No. 1, 33–38
[13]Roy, T. K. and Chattopadhyay, B.C. 2008. "A Study on the Effect of Cement on Alluvial Soil Strengthened With Pond and Rice Husk Ash for Construction of Road Subgrade" The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG), October, Goa, India
[14]Sriprasert, E. and Dawood, N. N., 2003. "Genetic Algorithms for Multi-Constraint Scheduling: An Application for the Construction Industry." Proceedings of the CIB W78 20th International Conference on Construction IT - Construction IT Bridging The Distance, Waiheke Island, New Zealand, April 23-25, pp. 341-353.
[15]Yulianto, F. E., Mochtar, N. E. (2010)."Mixing of rice husk ash (RHA) and lime for peat soil stabilization". Proceedings of the First Makassar International Conference on Civil Engineering, March 2010.

- Software

[14]Evolver 5.7 @ Palisade Corporation, makers of risk and decision analysis software, @Risk and the Decision Tools Suite.