Chapter 6

Conclusions and Future Scope

6.1 Summary and Conclusions

The primary objective of this dissertation is to study and understand the effect of different factors on the mechanical properties of red mud. An attempt has also been made to incorporate an alternative approach based on design of experiment and results obtained from experimental design approach have been compared with conventional approach. Based on the results presented in various chapters, the major conclusions of the study can be summarized as follows:

(a) The unconfined compressive strength increases with the increase in lime content, dry density, curing time and molding moisture. The microstructural study proves the formation of a cementitious compound by pozzolanic reactions leading to an increase in the strength of the red mud with the addition of lime.

(b) A non-linear relationship is also observed between dependent (q_u) and independent (γ_d, L, w and t) variables for the range of studies.

(c) Water/lime ratio (w/L) and porosity and volumetric lime ratio (η/L_v) are introduced as fundamental design parameters to reach the strength of stabilized red mud.

(d) Cross-correlation analysis is also carried out to find the relative contribution of independent variables on the response (q_u). It shows that the parameters such as L, γ_d, t and w influence q_u directly whereas parameters like w/L, η/L_v influences indirectly. Further, it also infers that the parameter η/L_v contributes more than w/L on the response (q_u).

(e) Using conventional approach, different predictive equations linking various variables such as Water/lime ratio (w/L), porosity and volumetric lime ratio ($\eta/L_{v'}$), curing time (t) have also been suggested as a probable dosage methodology for the range of water content, lime content and dry density studied.

(f) The efficacy of all the predictive equations are checked using various statistical methods. The proposed predictive equations efficiently predict the unconfined compressive strength (q_u) of red mud-lime mix and it can be used as dosage method to control the compressive strength of stabilized red mud for the range of the present study.

(g) The multivariate study using conventional approach results in large number of experiments; and performing large number of experiments and recording data for multi variables is sometimes time consuming and expensive. Thus, experimental designed approach is being used as an alternative approach.

(h) The performance of predictive equations based on experimental design approach is in good agreement with conventional approach which confirms the

reliability of the proposed methods. It is recommended as an alternative approach and can be used with confidence. This helps in a reduction in the number of experiments and also results in the reduction of experimentation time and saving of the resources.

(i) Split tensile strength is also carried out to study the tensile behavior of the selected stabilized red mud specimen. Further, predictive equations are also proposed for the range of the studies and be used to evaluate the tensile properties of stabilized red mud. Additionally, relation between compressive and tensile strength is also proposed and reported between 0.11 and 0.16.

(j) Durability (wet-dry test) study is also undertaken to evaluate the endurance of the stabilized red mud mix. The results confirm that 3% of lime with all dry unit weights, doesn't guarantee the endurance of the mix and a minimum of 5% lime and dry unit weight of 15.5 kN/m^3 is the minimum requisite to satisfy the durability requirements of the mix.

(k) Response Surface Plots are also undertaken to study the variation of independent variables on response (weight loss). The results indicate that the loss of mass increases with the increase in wetting-drying cycles (N), $\frac{w}{L}$ and $\frac{\eta}{L_v}$ ratio and decreases with an increase in dry density (γ_d) and curing time (t). Whereas, no significant change appears in loss of mass due to change in molding moisture content (w). Additionally, a predictive equation, as ready reference, is also established to predict the loss of mass of the stabilized red mud.

(l) Optimization study indicates that some of the combinations of the mix satisfies the durability criteria and can be recommended for civil engineering applications. The results indicate that the stabilized mix meet the criteria as

sub-grade and sub-base materials for pavement layer materials and it can also be used as unfired bricks in low cost houses/shelters.

(m) The dataset obtained from conventional and experimental designed approaches is further used to check the performance of the artificial neural network. The results obtained from experimental designed ANN models are quite similar to those of conventional designed ANN models. Hence, the proposed ANN models may be an useful tool where the acquiring data set is expensive, time-consuming and tedious. It also confirms that large numbers of data sets are not always required for the successful execution of ANN; but ANN can also be successfully applied with less number of properly mapped datasets.

(n) Sensitivity analysis based on connection weight approach shows that porosity/volumetric lime ($\frac{\eta}{L_{v'}}$) has the maximum contribution over unconfined compressive strength followed by curing time (t) and moisture content (w).

(o) Based on the neural interpretation diagram, it is seen that the unconfined compressive strength of stabilized red mud increases with the increase in moisture content and curing time; whereas, it decreases with the increase in porosity/volumetric lime.

(p) A predictive equations based on the training dataset of experimental designed artificial neural network is also presented that can be used for the estimation of the unconfined compressive strength of stabilized red mud.

(q) The proposed predictive equations have also been demonstrated as reference for easy understanding application by the practicing engineers. It also demonstrates that the engineers have many options to achieve the target strength according to requirements, application areas, site conditions, equipment, materials and availability of manpower. Once the proportion of the mixture is

decided, it can be applied sequentially in the field. Finally, a flow chart showing details of construction schedule and quality control is also presented for easy application of the end product in the field.

6.2 Limitations and Scope for Future Work

Limitations

In the present study, i have made an attempt to study the different aspects of red mud for its resourceful utilization. It includes evaluation of the factors affecting the mechanical properties of the stabilized red mud, demonstration of predictive equations and development of construction and building materials for civil engineering applications. However, the present study is limited to laboratory test only and it will require detailed studies to validate these results with various model tests and field studies.Further, the proposed predictive equations work well within the range of the studies with which it has been developed, calibrated and validated. Extrapolation closely outside the range may either be a success or a failure like any other technique.

Future Scope

The scope of present study for future work is summarized as follows.

- Studies are also required to identify the use of other waste materials in conjunction with red mud and their long term performance in terms of strength, endurance and environmental assessment.