International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 5, ISSN No. 2455-2143, Pages 142-148
Published Online March – April 2016 in IJEAST (http://www.ijeast.com)

EFFECT OF CEMENT-FLY ASH ADDITIVE ON COMPACTION AND STRENGTH OF RESERVOIR DREDGED MATERIAL

Rachit Sharma,
UG Student
Ansal University Gurgaon,
Haryana, India

Abstract— **Tremendous quantities of reservoir deposited sediments are required to be dredged regularly to maintain the storage capacity of the reservoir. The reservoir dredged material (RDM) can be utilized as construction material after admixing with additives such as cement and fly ash thereby improving its strength characteristics. This research paper presents results of laboratory investigation carried out to study the compaction and unconfined compressive strength characteristics of different mix combinations of ordinary Portland cement, fly ash and reservoir dredged material (RDM). The results reveal that the unconfined compressive strength of the reservoir dredged material treated with cement and fly ash is significantly improved. The stress-strain curves reveal the brittle behavior of the composite material with increasing cement and fly ash contents resulting in brittle failure. The unconfined compressive strength for the optimum cement: fly ash: reservoir dredged material:: 5: 10: 85 composite is substantial to be used as construction material in road pavements and embankments.**

Keywords: **Reservoir Dredged Material, Compaction, Unconfined Compressive Strength.**

I. INTRODUCTION

The siltation of reservoirs of the dams constructed for hydropower projects is a major problem arising due to the soil erosion and construction activities in the river catchments. The deposits of silts and other material not only reduce the effective storage capacity of the reservoir but also create environmental and ecological problems. Sutlej is a major river originating from the Himalayas and flowing through northern Indian states to finally confluence with Arabian Sea. Bhakhra dam is a major gravity dam constructed across Sutlej in the fifties of the 20^{th} century thereby creating an eighty kilometre long reservoir known as Govindsagar. However, over the years, the effective water storage capacity of the reservoir has reduced greatly due to the deposition of silt and other materials brought by river Sutlej and its tributaries such as river Spiti. The silt deposits and other materials can be dredged and possibly used for various construction works which will not only solve the problem of reduction in reservoir capacity but will also avoid environmental degradation caused by the mining of construction material the natural streams. The demand for power-supply has necessitated the installation of thermal power stations using coal as fuel thereby producing huge quantities of fly ash as a by-product. The dumping of fly ash is degrading the agricultural land besides polluting the ground water and causing human health hazards. The super thermal power station at Ropar in the vicinity is producing large quantities of fly ash which if used effectively as construction material will solve the problems caused to the environment and the resulting health hazards.

Research has shown that fly ash can be effectively used to improve the material characteristics due to its pozollonic reaction and micro filler action. But this reaction is time-dependent and the strength characteristics of the composite material are improved after a longer curing period. To overcome this problem, small amount of cement can be used as binder which will accelerate the hardening reaction thereby fast development of strength in the composite material. The reservoir dredged material on its own possesses poor material characteristics and hence is inadequate as a construction material. However, fly ash can be mixed to modify its characteristics and cement can be added as a binder to impart sufficient strength so that it can be used as sub-grade material. The present experimental investigation is concentrated on the utilization of reservoir dredged material (RDM) in combination with fly ash and cement by studying its compaction and unconfined strength characteristics.

Some of the applications of reservoir dredged material in combination with fly ash and dredged cement have been studied by a number of researchers. Shao et al[1] showed that both the mixes of dredged material with 6% cement and 9% cement are appropriate to use as a sub-base material in road construction. From the economical point of view, 6% cement is a better amount for the solidification of dredged sediments. Silitonga et al[2] showed that a mixture of fly ash, lime and cement has the most potential as an alternative for the stabilization of dredged sediments on the basis of unconfined compressive strength characteristics. Dubois et al[3] showed the potential of using dredged marine sediments in road construction enhancing its characteristics by using binders (cement and/or lime). The mechanical characteristics of the mixes are compatible with their use as a base course material. Zentar et al[4] showed that the dredged sediments along with traditional granular materials and hydraulic binders can be used as the road material. Petavy et al[5]showed that storm-water sediments can be treated and reused as road embankments and as a capping layer. Jauberthie et al[6]showed that deposited fine estuarine silt behind the tidal barrage can be possibly used as a sub-base for lightly trafficked local roads after stabilization with various mixtures of quicklime, Portland cement and a mixture of both to achieve the required geotechnical characteristics. The results showed an increment in the unconfined compressive strength and the California bearing ratio with both lime and cement treatments. Grubb et al[7] presented the results of stabilization of dredged material (DM) using different combinations of lime, high alkali, cement kiln dust and slag cements, and fly ash. These blends may be used in large-scale fill construction as it is sustainable, cost-effective and is not harmful to human health and the environment. Tribout et al[8]showed that the use of treated sediments with materials treated using hydraulic binders enhance the tensile strength. Further, the results suggest that the use of treated sediments as road materials is not detrimental and brings mechanical benefits also. Wang et al[9] showed that cement/lime-based solidification is an environmentally favorable solution for the management of dredged marine sediments, instead of traditional solutions such as immersion. The test results show the use of solidified dredged sediments as a material in road construction to be beneficial. It has been seen that cement is superior to lime in terms of strength improvement but adding 6% cement is an economical and reasonable method to stabilize fine sediments. Miraoui et al[10]presented the experimental methodology to develop a formulation of road material made from dredged sediment treated with steel slag, a co-product of the steel industry. Zentar et al[11]showed the effectiveness of using siliceous–aluminous fly ash and cement in solidifying Dunkirk marine sediments by conducting laboratory tests to evaluate the compatibility of solidified material as roadbed materials. Azhar et al. [12] showed that the water-binder ratio gives high impact on the increment of the dredged marine soil strength. As the water-binder ratio decrease, the dredged marine soils (DMS) strength will increase.

The utilization of fly ash in soil stabilization has been studied by many researchers such as Mitchell and Katti[13], Cokca[14], Consoli et al[15], Senol et al[16], Kumar & Sharma[17], Bhuvaneshwari[18], Edil et al[19], Chauhan et al[20], Rao and Subbarao[21], Tastan et al[22] and Muntohar[23] highlighting the advantageous use of fly ash in improving the properties of soil. The main objectives of this work are to: (1) investigate the compaction characteristics of the blended materials, (2) determine the unconfined compressive strength of the composite material at different curing periods and (3) establish the applicability of solidified dredged material as construction material.

II. EXPERIMENTAL PROGRAM

2.1. Materials

The reservoir dredged material (RDM) used in the study was collected from Govindsagar reservoir of Bhakhra dam on Sutlej river in Bilaspur (HP). The dredged material mainly consists of deposited fine sand and silt and was collected as representative sample from the sides of the reservoir. Fly ash was obtained as the residue after electronic precipitation of the burnt gases in Ropar thermal power plant. The cement used in the study was ordinary Portland cement (OPC) available in market supplied from nearby cement plant.

2.2. Methods

The materials were tested in the laboratory in accordance with the relevant ASTM standards. The specific gravity tests were performed in accordance with ASTM D854-10[24]. The standard proctor compaction tests were performed in accordance with ASTM D698-07e1 [25]. The size of compaction mould used was 101 mm diameter and 125 mm height. The reservoir dredged material was oven-dried for 24 hours in thermostatically controlled oven then passed through 4.75 mm sieve and mixed with water to perform standard Proctor tests for obtaining the optimum moisture content (OMC) and the maximum dry density (MDD). This process was repeated for cement and fly ash and compaction tests were conducted as earlier. Further, the compaction tests were performed on cement: fly ash: reservoir dredged material :: 4: 8: 88, 5: 10: 85 and 6: 12: 82 to determine the optimum dry density (OMC) and maximum dry density (MDD) of the mixes. Initially, predetermined quantities of cement, fly ash and RDM were mixed in a dry state and subsequently mixed with water thoroughly and then compacted as earlier. After obtaining the maximum dry density and optimum moisture content of these combinations, further testing was adopted to determine the strength characteristics. Unconfined compressive strength

International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 5, ISSN No. 2455-2143, Pages 142-148
Published Online March – April 2016 in IJEAST (http://www.ijeast.com)

tests were performed in laboratory in accordance with ASTM D2166-13[26]. The sizes of samples were of 38 mm diameter and 76 mm height. The specimens were pushed out from the mould directly after completion of the compaction at OMC and MDD and were stored in the curing chamber until testing after 1 day and 7 days. The physical properties of reservoir dredged material (RDM) and fly ash are given in table 1. The specific gravity of the dredged material is somewhat less than that of soil and its maximum dry density is much lower. The particle size distribution of reservoir dredged material tested as per ASTM D6913-04[27] and is shown in figure 1. The coefficient of uniformity C_u of reservoir dredged material is 5.01 and the coefficient of curvature C_c is 1.24 which indicates that it poorly graded fine silty sand.

Table-1. Physical properties of reservoir dredged material (RDM) and fly ash.

Property	Reservoir dredged material	Fly ash
Specific gravity	**2.59**	**1.97**
Maximum dry density (MDD), g/cm^3	**1.47**	**1.16**
Optimum moisture content (OMC), %	**21.1**	**31.8**

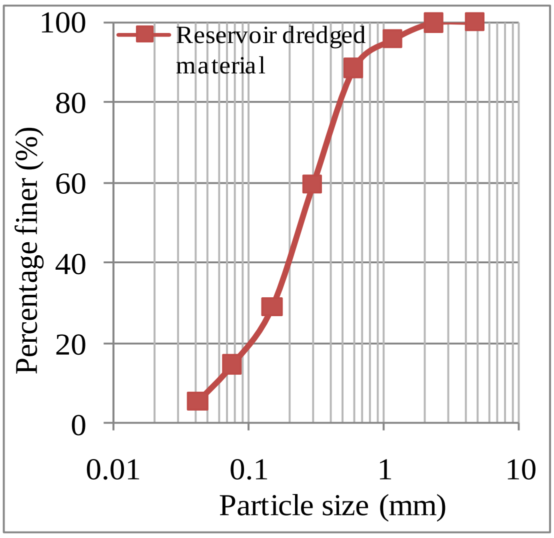

Fig. 1. Particle size distribution of reservoir dredged material (RDM)

The chemical composition of fly ash tested as per ASTM D5239-2004[28] is given in Table 2 and the fly ash of class F possessing low lime (CaO) content.

Table-2. Chemical composition of fly ash

Chemical Composition	Proportion (%)
Silica (SiO_2)	**55.69**
Alumina (Al_2O_3)	**26.33**
Calcium oxide (CaO)	**3.43**
Iron oxide (Fe_2O_3)	**6.90**
Potassium Oxide (K_2O)	**0.98**
Sulphur (as SO_3)	**0.45**
Magnesium Oxide (MgO)	**0.62**
Loss on ignition	**5.60**

The particle size distribution of fly ash tested as per ASTM D6913-04[27] is given in figure 2. The fly ash consists of uniformly graded, spherical particles with high specific surface area and hence the density is less.

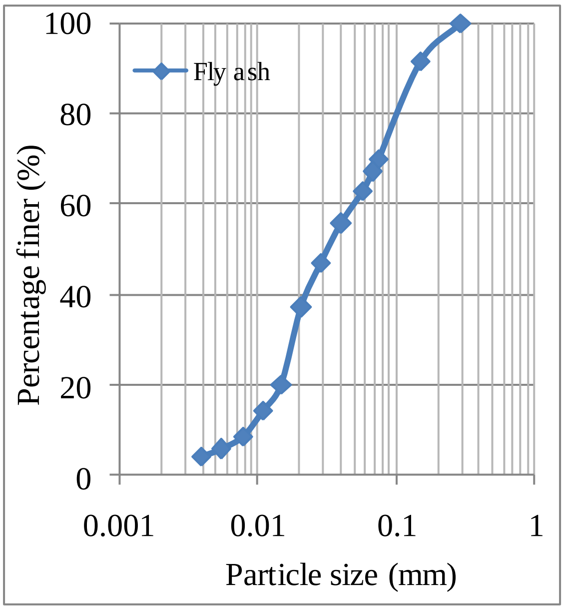

Fig. 2. Particle size distribution of fly ash

The physical characteristics of cement such as specific gravity, standard consistency, initial and final setting times and compressive strength are given in table 3.

Table-3. Physical characteristics of ordinary Portland cement (OPC)

Property	Value
Specific gravity	**3.15**
Standard consistency (%)	**30.7**
Initial setting time (minutes)	**61**
Final setting time (minutes)	**595**
Compressive strength (N/mm^2) after 7 days	**35.5**

III. Results and Discussions

3.1. Compaction characteristics

Compaction is a process of increasing the compactness of mixture by removing the air void, addition of water which acts as lubricating agent and imparting compacting energy using rammer to achieve the maximum dry density. The water content-dry density curves of reservoir dredged material (RDM), fly ash and cement are shown in figure 3. The maximum dry density of reservoir dredged material is 1.47 g/cm^3 at optimum moisture content 21.1% which indicates the poor compaction characteristics of the material. The fly ash has a maximum dry density 1.16 g/cm^3 at optimum moisture content 31.8% indicating low compaction density and high OMC of the material.

The maximum dry density of ordinary Portland cement is 1.45 g/cm^3 at optimum moisture content 30.7%. The compaction characteristics of reservoir dredged material reveal that the material cannot be used as construction material since its density is low and it is cohesion less in nature. The characteristics of the material can be improved by adding fly ash and cement which provide binding action between its cohesion less particles.

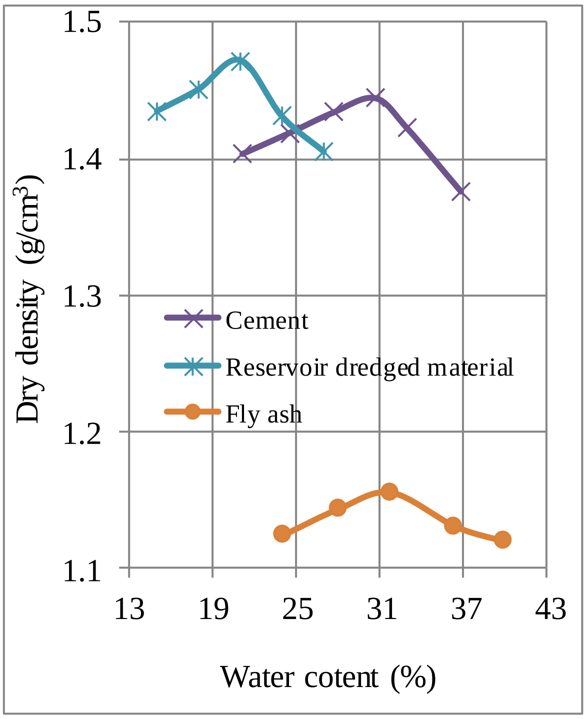

Fig. 3. Compaction characteristics of reservoir dredged material, fly ash and cement.

Based upon the literature data, marginal quantities of fly ash (8%, 10% and 12%) and cement (4%, 5% and 6%) were added to reservoir dredged material and compaction tests were performed on the composite material. The water content-dry density curves of the composites consisting of reservoir dredged material (RDM), fly ash and cement in the above proportions are shown in figure 4. The compaction characteristics of different material composites reveal that the maximum dry density is the highest for cement: fly ash: reservoir dredged material (RDM):: 5:10:85 combination compared with the other two composites.

The comparison of the values of OMC and MDD of individual materials and their composites is shown in table 4. The maximum dry density variation of the different composites is not much and the overall density of the reservoir dredged material composite decreases. This may be attributed to high specific surface area of fly ash particles and also to its less specific gravity compared to that of the reservoir dredged material which results in an increase in optimum moisture content and decrease in the maximum dry density. The increase in optimum moisture content is also due to hydration of cement since hydration process requires more water. Initial flocculation and agglomeration of the reservoir dredged material composite caused by cation exchange between cement and fly ash results in increase in volume and density decreases.

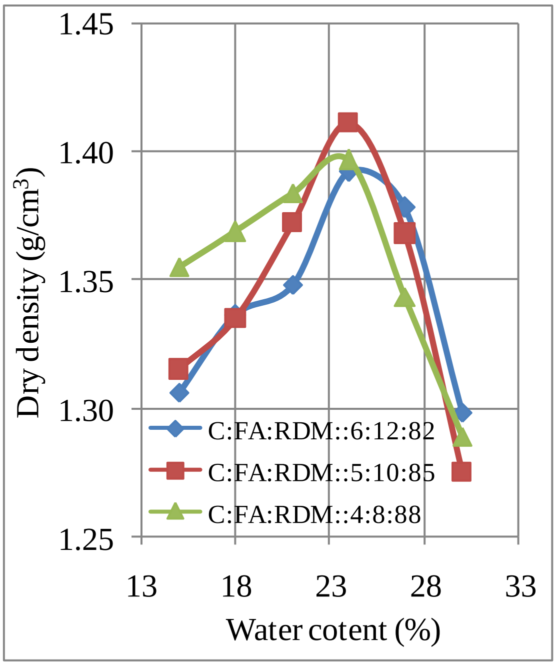

Fig. 4. Compaction characteristics of cement: fly ash: reservoir dredged material composite.

Table-4. Comparison of optimum moisture content and maximum dry density of materials and mixes

Materials	OMC (%)	MDD (g/cm^3)
Reservoir dredged material (RDM)	21.1	1.47
Cement	30.7	1.45
Fly ash	31.8	1.16
Cement: Fly ash: RDM::6:12:82	23.25	1.39
Cement: Fly ash: RDM::5:10:85	22.23	1.42
Cement: Fly ash: RDM::4:8:88	25.30	1.40

3.2. Unconfined compressive strength characteristics

Unconfined compressive strength (UCS) of composite material is one of the most important design parameters for the design of pavements and embankments. The variation of unconfined compressive strength of cement: fly ash: reservoir dredged material:: 4:8:88 with strain after curing periods of 1 day and 7 days is shown in figure 5. The unconfined compressive strength of the composite material is substantial (340 kPa) and increases to (508 kPa) with the curing period increasing from 1 day to 7 days. The post peak variation of UCS is also shown which reveals that the failure of the composite material is somewhat brittle with less post peak strain (increases from 1% to 1.5% after 1 day and 1.2% to 1.6% after 7 days), nearly half and one third of the pre-failure strain. This indicates that with the increase in curing period, the behavior of the composite material becomes more brittle.

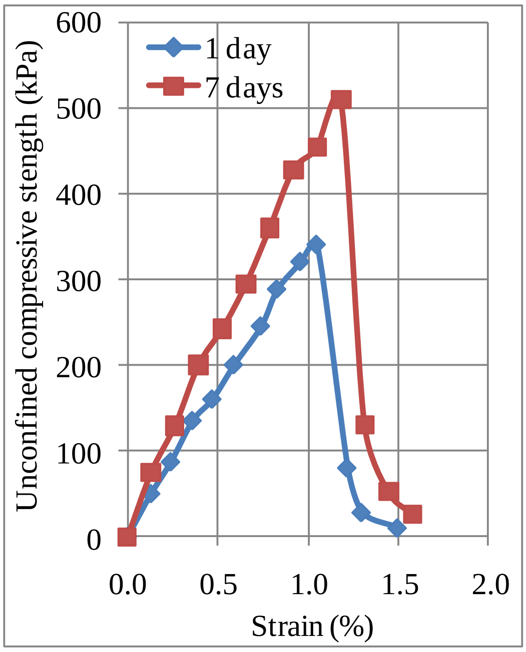

Fig. 5. Unconfined compressive strength of cement: fly ash: reservoir dredged material:: 4:8:88.

The variation of unconfined compressive strength of cement: fly ash: reservoir dredged material:: 5:10:85 with strain after 1 day and 7 days curing periods is shown in figure 6. The unconfined compressive strength of composite material is 440 kPa after 1 day which increases to 668 kPa after 7 days curing period. The unconfined compressive strength is higher than that for the previous composite mix and the increase in UCS with curing period is larger than that for the previous composite. Somewhat brittle failure of the composite is revealed with less post peak strain (increases from 1.4% to 1.8% after 1 day and 1.6% to 2.0% after 7 days curing period), nearly 1: 3.5 and 1: 4 of the pre-failure strain. The comparison of UCS-strain curves (figure 5 and figure 6) shows more brittle failure for the composite material containing higher cement and fly ash content.

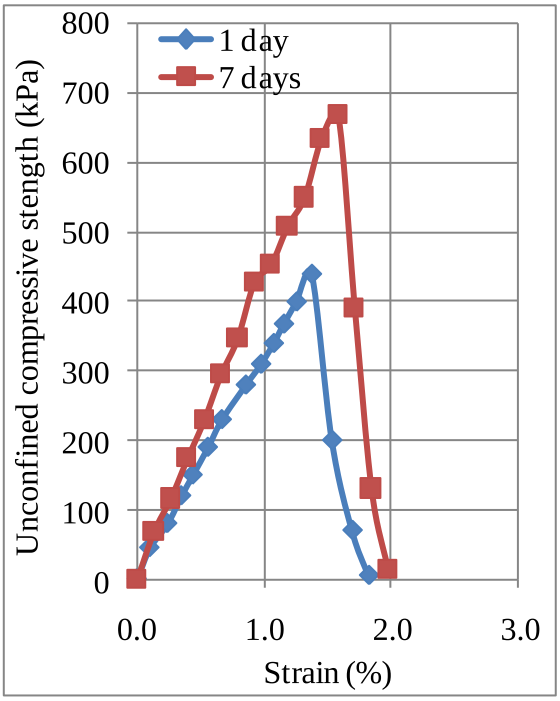

Fig. 6. Unconfined compressive strength of cement: fly ash: reservoir dredged material:: 5:10:85.

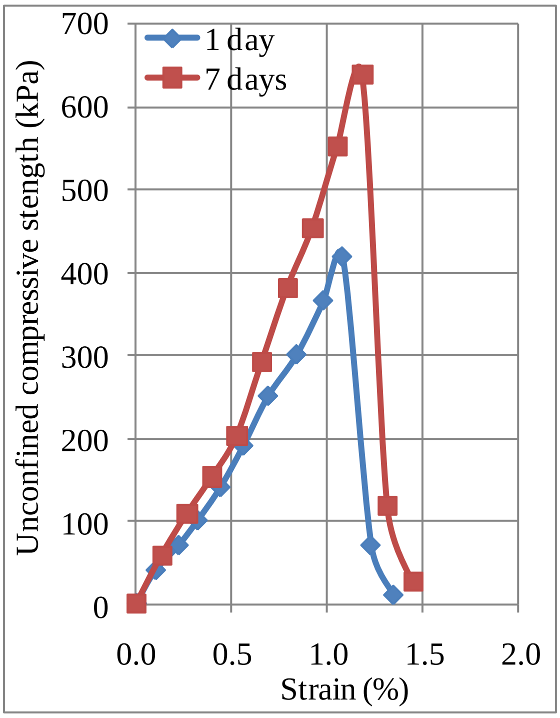

Fig. 7. Unconfined compressive strength of cement: fly ash: reservoir dredged material:: 6:12:82.

Figure 7 illustrates the variation of unconfined compressive strength for cement: fly ash: reservoir dredged material:: 6: 12: 82 with strain after curing period of 1 day and 7 days. The unconfined compressive strength of the composite material increases from 418 kPa after 1 day to 638 kPa after 7 days curing period, the increase in UCS being more compared with cement: fly ash: reservoir dredged material:: 4: 8: 88 composite but less compared to cement: fly ash: reservoir dredged material:: 5: 10: 85 composite. The post peak unconfined compressive strength-strain curves indicate more brittle failure of the composite material as the post peak strain is less (increases from 1.1% to 1.35% after 1 day and 1.2% to 1.45% after 7 days), nearly 1: 4.5 and 1:5 of the pre-failure strain. The behavior of the composite material becomes more brittle with further increase in the cement and fly ash contents as can be deduced from the comparison of unconfined compressive strength-strain curves for the three composites.

The curing period results in an increase in unconfined compressive strength because of the pozzolanic reaction of fly ash taking more time. The maximum increase in unconfined compressive strength occurs for cement: fly ash: reservoir dredged material:: 5:10:85 which has also higher maximum dry density and less optimum moisture content compared to those for the other composites. Cement causes instant reaction i.e. ion exchange reaction with soil molecules whereas fly ash results in pozzolanic reaction which is mainly dependent upon curing period.

3.3. Application as construction material

The unconfined compressive strength of the reservoir dredged material (RDM) can be significantly improved when admixed with cement and fly ash. Since the unconfined compressive strength for the optimum cement: fly ash: reservoir dredged material:: 5:10:85 composite is 668 kPa after 7 days curing period, it can be used as sub-grade material in the construction works of road pavements and embankments. Hence, the reservoir dredged material treated with 5% cement and 10% fly ash content can be adopted as the design mix in construction works.

IV. CONCLUSIONS

Based upon the laboratory testing of reservoir dredged material modified with cement and fly ash and its utilization as construction material, the following conclusions can be drawn:

1. The compaction characteristics of the reservoir dredged material (RDM) indicate its low maximum dry density at high optimum moisture content. When admixed with cement and fly ash, the maximum dry density is slightly reduced with small increase in optimum moisture content occurring due to the agglomeration and flocculation caused by the cation exchange reaction of cement and the pozzolanic action of fly ash resulting in volume increase.
2. The unconfined compressive strength of cement: fly ash: reservoir dredged material composite increases with curing period and higher value of UCS is achieved for cement: fly ash: reservoir dredged material:: 5:10:85 which can be considered as the optimum design composite mix.
3. The post-peak stress-strain curves reveal the brittle behavior of the composite material with increasing cement and fly ash contents resulting in more brittle type of failure.
4. The unconfined compressive strength for the optimum cement: fly ash: reservoir dredged material:: 5:10:85 composite is significant and it can be utilized as sub-grade material in the construction works of road pavements and embankments.

V. REFERENCES

[1] Y. F. Shao, X. N. Gong, E. K. Zheng, and Z. Y. Liu, “Experimental study on stabilization of dredged silts”, Trans. CSAE 23, pp. 191–194, 2007.

[2] E. Silitonga, D. Levacher and S. Mezazigh, “Effects of the use of fly ash as a binder on the mechanical

behaviour of treated dredged sediments", Environ Technol. 29, pp. 709–720, 2009.

[3] V. Dubois, N-E. Abriak, R. Zentar and G. Ballivy, "The use of marine sediments as a pavement base material", Waste Manage. 29, pp. 774–782, 2009.

[4] N. E. Zentar, V. D. Abriak, and M. Miraoui, "Beneficial use of dredged sediments in public works", Environ. Technol. 30; pp. 841–847, 2009.

[5] F. Petavy, V. Ruban, P. Conil, J. Y. Viau, and J. C. Auriol, "Two treatment methods for storm water sediments – pilot plant and land farming – and reuse of the treated sediments in civil engineering", Environ. Technol. 30, pp. 825–830, 2009.

[6] R. Jauberthie, F. Rendell, D. Rangeard and L. Molez, "Stabilization of estuarine silt with lime and/or cement", *Journal Applied Clay Science* 50; pp. 395-400, 2010.

[7] D. G. Grubb, M. Chrysochoou, C. J. Smith and N. E. Malasavage, "Stabilized dredged material I: parametric study", *Journal of Geotechnical and Geoenvironmental Engineering ASCE*, 2010.

[8] C. Tribout, B. Husson and A. Nzihou, "Use of treated dredged sediments as road base materials: environmental assessment", Waste Biomass Valor. 2: pp. 337–346, 2011.

[9] D. Wang, N-E. Abriak, R. Zentar and W. Xu, "Solidification/stabilization of dredged marine sediments for road construction", Environ Technol. 33: pp. 95–101, 2012.

[10] M. Miraoui, R. Zentar and N-E. Abriak, "Road material basis in dredged sediment and basic oxygen furnace steel slag", Construction and Building Materials: 30; pp. 309–319, 2012.

[11] R. Zentar, D. Wang, N-E. Abriak, M. Benzerzour and W. Chen, "Utilization of siliceous–aluminous fly ash and cement for solidification of marine sediments". Constr Build Mater. 35: pp. 856–863, 2012.

[12] A. Azhar, C. M. Chan and A. T. AbdKarim, "Solidification potential of fine-grained dredged marine soils: water-binder ratio effects", Journal of Civil Engineering Research, 4(3A): 48-53, 2014.

[13] J. K. Mitchell and R. K. Katti, "Soil improvement: state of the art report", Proc. 10th International Conference on Soil Mechanics and foundation engineering; International Society of Soil Mechanics and Foundation Engineering, London, pp. 216-317, 1981.

[14] E. Cokca, "Uses of class C fly ash for the stabilization of an expansive soil", Journal of Geotechnical and Geoenvironmental Engineering, ASCE 127(7), pp. 568–573, 2001.

[15] N. C. Consoli, P. D. M. Prietto, J. A. H. Carraro and K. S. Heineck, "Behaviour of compacted soil-fly ash-carbide lime mixtures", Journal of Geotechnical and Geoenvironmental Engineering ASCE 127(9), pp. 574-584, 2001.

[16] A. Senol, M. S. Bin-Shafique, T. B. Edil and C. H. Benson "Use of class C fly ash for stabilization of soft sub-grade", Proc. Fifth International Congress on Advances in Civil Engineering, Istanbul Technical University, Turkey, 2002.

[17] B. R. P. Kumar and R. S. Sharma, "Effect of fly ash on engineering properties of expansive soils, Geotech Geoenviron Eng, ASCE 130 (7), 764–767, 2004.

[18] S. Bhuvaneshwari, R. G. Robinsonand S. R. Gandhi, "Stabilization of expansive soils using fly ash", Fly Ash India, Fly Ash Utilization Programme (FAUP), TIFAC, DST, New Delhi, 2005.

[19] B. Edil, H. A. Acosta, and C. H. Benson, "Stabilizing soft fine grained soils with fly ash", *Journal of Materials in Civil Engineering*, ASCE 18(2), pp. 283-294, 2006.

[20] M. S. Chauhan, S. Mittal, and B. Mohanty, "Performance evaluation of silty sand sub-grade reinforced with fly ash and fiber," Geotextiles and Geomembranes, Vol. 26, Issue 5, pp. 429-435, 2008.

[21] K. M. Rao and G. V. R. Subbarao, "Quantification of change in dry unit weight of mechanically stabilized expansive soils using fly ash", Geotide, pp. 338-343, 2009.

[22] E. O. Tastan, T. B. Edil, C. H. Benson and A. H. Aydilek "Stabilization of organic soil with fly ash", Journal of Geotechnical & Geoenvironmental Engineering ASCE 137(9), pp. 819-833, 2011.

[23] A. S. Muntohar, "Influence of plastic waste fibres on the strength of lime- fly ash stabilized clay", Civil Engineering Dimension, Vol. 11, No. 1, pp. 32- 40, 2012.

[24] ASTM D854-10, "Standard test methods for specific gravity of soil solids by water pycnometer," American Society for Testing of Materials, Pennsylvania, Pa, USA.

[25] ASTM D698-07e1, "Standard test methods for laboratory compaction characteristics of soil using standard effort," American Society for Testing of Materials, Pennsylvania, Pa, USA.

[26] ASTM D2166-13, "Standard test methods for unconfined compressive strength test for soils", American Society for Testing of Materials, Pennsylvania, PA, USA.

[27] ASTM D6913-04 "Standard test methods for particle size distribution (Gradation) of soils using sieve analysis", American Society for Testing of Materials, Pennsylvania, PA, USA.