UTILIZATION OF TEXTILE ETP AND TANNERY SLUDGE IN CEMENT MORTAR

DEPARTMENT OF CIVIL ENGINEERING

EAST WEST UNIVERSITY

UTILIZATION OF TEXTILE ETP AND TANNERY SLUDGE IN CEMENT MORTAR

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DECLARATION

It is hereby declared that this thesis work has been performed by the authors under the supervision of Dr. Md. Naimul Haque, Associate Professor, Department of Civil Engineering. EWU. Neither this thesis work nor any part of it has been submitted elsewhere for the award of any degree or diploma (except for publication).

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List of Abbreviations

ASTM	American Society for Testing and Materials
ASR	Alkali-Silica Reaction
AAS	Atomic Absorption Spectrophotometer
BDS	Bangladesh Standard
BTMA	Bangladesh Textile Mills Association
BTMA	Bangladesh Textile Mill Association
CETP	Common Effluent Treatment Plant
ETP	Effluent Treatment Plant
TETPS	Textile Effluent Treatment Plant Sludge
GDP	Gross Domestic Product
LL	Liquid Limit
MSW	Municipal Solid Waste
PI	Plasticity Index
PL	Plastic Limit
RMG	Ready-Made Garments
TCLP	Toxicity Characteristics Leaching Procedure
TS	Tannery Sludge
UNIDO	United Nations Industrial Development Organizations
WDNC	Water Demand for Normal Consistency
WTO	World Trade Organization
WG	Waste Glass
XRF	X-ray fluorescence

XRD	X-Ray Diffraction
3R	Reduce, Reuse and Recycle
TCLP	Toxicity Characteristics Leaching Procedure

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Abstract

The textile ETP and tannery sludge are waste products that are generated after the treatment of wastewater from ETP and CETP. The textile ETP and tannery sludge have the potential to become a serious environmental burden for Bangladesh in the future because of their high rate of generation, with very limited safe disposal options. On the other hand, day by day the demand and price of cement are increasing. The main purpose of this study is to evaluate the technical feasibility of utilizing textile ETP and tannery sludge in cement mortar both as separate and mixed-mode. An attempt was taken to replace 5%, 10%, 15%, 20% cement by textile ETP and tannery both as a separate and mixed-mode in cement mortar by weight. To evaluate the characteristics of the textile ETP and tannery sludge the pH, moisture content, organic matter content, chemical composition (XRF), TCLP (Heavy Metal) tests are studied. The normal consistency, initial and final setting time, compressive, tensile strength, specific gravity, water absorption of cement mortar by partial replacement of textile ETP and tannery sludge both as separate and mixed-mode are studied to evaluate the properties of cement mortar. Considering the results of this study, it can be said that the textile ETP and tannery both as separate and mixed-mode can be a replacement of cement up to 10% in cement mortar and can be used for the purposes of S-type mortar and the textile ETP sludge as separate and the mixed-mode of textile ETP and tannery sludge can be a replacement of cement up to 20% and can be used for the purposes of N-type mortar.

Chapter 1
Introduction

1.1 Background

Cement mortar is a hardening material used to bind building blocks such as stones, bricks, and concrete masonry units together. cement mortar is developed by mixing cement, sand, and water. It was invented in the middle of the 19th century. Cement mortar is used because of quick setting and hardening time which saves time to construct a structure. Mainly sand and binding materials are responsible for the strength and durability of the mortar. cement mortars are also used for plastering on the exposed surface of masonry. Cement Mortar is one of the largest using materials in the construction industry of Bangladesh. The consumption rate of cement mortar in Bangladesh is rapidly increasing and predicted will be sustained. As the cost of construction materials especially cement is gradually increasing day by day, therefore, a cheaper solution for cement mortar is required.

The Textile and clothing industry has a large contribution to Bangladesh's economy. Because of this industry Bangladesh's economy growing rapidly. In 2002 Bangladesh's total commodities exports, 77% was exported by textile clothing and ready-made garments (RMG) (World Trade Organization, 2008). The textile industry is using 1500 billion m^3 groundwater every year in Bangladesh (Guha, et al., 2015). As a result, the textile industry of Bangladesh has been discharging 2 million m^3 effluents per day and this effluent has been treating in an Effluent Treatment Plant (ETP). Every year this industry's Effluent Treatment Plant (ETP) is generating 2.81 million metric tons of sludge in Bangladesh from this sector (Workshop, 2011).

Same as textile the leather industry also produced a huge amount of waste water and solid waste. which is known as tannery waste (Hashem et al., 2015). Normally after per ton of hides /skins proceed around 100-150 kg of sludge is created (UNIDO, 1998). The government of Bangladesh has made a large Common Effluent Treatment Plant (CETP), to treat the wastewater generated from this industry which is situated in BSCIC Tannery Industrial Estate, Hemayetpur. According to (Aalamgir, et al.,2017) BSCIC Tannery Industrial Estate’s CETP has been generating 20,000 m^3 of tannery effluent and 232 tons of solid waste per day.

This sludge generation rate is very high from both industries. Several options are available to manage those sludges. In Bangladesh, landfill is the only option to manage those sludges. According to (Morshed & Guha, 2014) both of the sludges can be used with cement for concrete block making, can be used for preparing brick, can be incinerated to produce electricity, can be used for sanitary landfilling, can be used for biogas generation, and can also be used for composting (Hammadi, et al., 2007). In previous, some researchers are successfully utilized the municipal solid waste, grass waste, textile dyeing industry waste in concrete block, brick, ceramics in a particular mixing proportion.

A possible long-term solution for the textile ETP and tannery sludges appears to be recycling the sludges and using them for beneficial purposes. In this study, the textile ETP and tannery sludges are utilized in cement mortar both as a separate and mixed mode. By utilizing those sludges in cement mortar will reduce the construction cost and solve the disposal problem of the large volume of sludges.

1.2 Environmental and Social Effect

The textile ETP and tannery sludge disposal are becoming difficult day by day in Bangladesh. Nowadays landfill is the only option to dispose of those sludges. Due to the utilization of the textile ETP and tannery sludge in cement mortar, some of the difficulties of sludge disposal will be reduced. The textile and tannery industry will get an alternative way of disposal of those sludges. Because of this study, this sludge can be sold as a product and the construction industry will be interested to buy these sludges. Also, can be causes generation of employment.

1.3 Objectives with Specific Aims of The Thesis

The major goal of this study is to assess the feasibility of using textile ETP and tannery sludge as partial replacement of cement in the cement mortar. The specific objectives of the study were:

I. To assess the quality of textile ETP and tannery sludge from environmental pollution point of view i.e. the presence of harmful chemicals and heavy metals.

II. To prepare cement mortar by partial replacement of cement by textile ETP and tannery sludge both as separate and mixed-mode.

III. To evaluate the properties of cement mortar and determine an optimum cement-: fine aggregate: -sludge mix proportion without compromising the quality of cement mortar.

1.4 Outline of Methodology/ Experimental Design

Raw materials (textile ETP and tannery sludge) were collected from Integrated Textile Resources Ltd. (Network Group) and BSCIC Tannery Industrial Estate.

After collecting the raw materials both of the samples were oven-dried for 24 hours at 105°C. after oven-dried the samples, the basic physicochemical characteristics, including moisture content, pH, and the organic matter content was analyzed. The chemical composition was also analyzed for a dried mixed mode of textile ETP and tannery sludge. For chemical composition XRF test was conducted. The heavy metal content for a dried mixed mode of textile ETP and tannery sludge was analyzed, AAS (Shimadzu AA 6800) standard followed to determine heavy metal content. Soil sample collected from East-West University's engineering material laboratory and river sand was used and cement sample was collected from a local cement supplying shop. Portland composite cement (type II) was used to make cement mortar. A total 108 of cement mortar cube and briquet was made at East-West University's engineering material laboratory. The sludge-sand-cement mixture in varying proportions (0%,5%,10%,15%, and 20%) used to made the cement mortar cube and briquet. Cement mortar cubes and briquets has been kept for 3,7, and 28 days of curing. After curing all cement mortar cubes and briquets then the samples went through a number of tests including specific gravity, water absorption, compressive strength and tensile strength analyzed to determine a suitable condition for producing perfect quality cement mortar.

1.5 Organization of the Thesis

This study shows the probability of textile ETP and tannery sludge to be used in cement mortar. Chapter 2 shows a previous study on sludge stabilization through construction materials. Chapter

3 shows the detailed methodology that was held in this study. Chapter 4 is the results that we obtained in this study. Chapter 5 deals with the conclusion where overall findings, and recommendation for future work have been discussed. At last, Appendix A contains the chemical composition test report by the Department of Glass and Ceramic Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh. Appendix B and C contains the organic matter content and TCLP (Heavy Metal Determination) test report by BRT, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.

Table 1.1: Scheduling of Thesis Work

2021	February	March	April	May	June	July	August	September	October	November	December	January (2022)
Topic Selection												
Chapter 1 (Introduction)												
Chapter 2 (Literature Review)												
Chapter 3 (Methodology)												
Sample Collection												
Experimental Tests and Data collection												
Chapter 4 (Result and Discussion)												
Chapter 5 (Conclusion and Recommendation)												
Chapter 6 (Cost Estimation)												
Final Submission												

Chapter 2

Literature Review

This chapter deals with the previous studies on textile ETP and tannery sludge in construction materials, some other waste materials which were utilized in construction materials, two or more waste material mixture, and their use in construction materials.

2.1 Previous Studies on Sludge Stabilization through construction materials

A. Textile Effluent Treatment Plant Sludge

In the past several researchers had tried to find the reuse of textile sludge as a construction material. Most of the researchers had been tried to invent brick, cement paste, and cement mortar using textile sludge. In 2001 Ansari and Thakur used clay- sludge binder system. They had mixed up to 45% dry textile sludge to make brick. They had observed that the performance of the brick could be improved by flare-up the clay at 600° C temperature (Ansari et al., 2001). Arul et al. (2015) they had investigated that textile ETP sludge and they found that textile ETP sludge could be the replacement for cement. It was found that 15% of textile sludge can be replaced with cement, and the fine particles of textile ETP sludge have lower water absorption of concrete. They also found that the replacement of cement up to a certain percentage may reduce the emission of harmful gases in this way resulting in reduced emissions during the production of cement. They got good strength and durability test results from their sample. Balasubramanian et al. (2006) they had found that 20% textile ETP sludge can be replaced with cement to make cement concrete flooring tiles. According to BIS 1237-1980 concrete hollow blocks and solid blocks are used for non-load bearing units. Patel, Hema, and Suneel Pandey had used up to 70% of textile sludge to produce cement sludge blocks including pozzolanic cement using fly ash (Patel et al., 2012). The compressive strength results of those mixers suggested that those mixers could be used for various structural and non-structural members. Because of the cement and sludge binder system, it was confirmed the member or structure will remain stable for neglected leaching of heavy metals. Mariappan et al. (2018) they had found that textile ETP sludge can be used as a replacement for cement. It was found that up to 20% and 10% textile ETP sludge can be used as a replacement fine aggregate and cement. Goyal et al. (2019) had used 5% textile sludge as a replacement of cement without any damage in properties of cement mortar and paste. It was found there will be a decrease in compressive strength and split tensile strength of the cement mortar using 5% textile sludge. They had found there will be no major phase changes in cement hydration because of adding of textile sludge but if the amount of adding textile sludge is increased there might be a change in cement hydration.

Cheriaf et al. (2000) they had investigated and found that the water/binder ratio increases with the inclusion of textile ETP sludge. They had found 0.30, 0.38, 0.40 and 0.45 for 10%, 20%, 30%, and 40% textile ETP sludge replacement. They had also done the compressive strength test for 10% replacement they found that the compressive strength is increasing. After 28 days curing compressive strength test result was greater than after 7 days curing test result. For 20% and 30% replacement, it was also increased. But for 40% replacement, the result was not good. For 30% replacement after 28 days of curing, the sample gave the highest compressive strength around 30 MPa. After 90 days of curing, they had found that the compressive strength is increasing.

S. Jeevanandam et al. (2015) they had replaced textile ETP sludge with cement. They found that the consistency of the mortar was increased as the replacement of sludge was increasing. The initial and final setting time of the mortar was increasing as the replacement of sludge was increasing. They also found that the compressive strength results are reduced when the replacement of sludge percentage for cement was increased. They had found the pH of the curing water is increasing.

The electrical conductivity of the sample at 7- and 14-days curing did not show much variation. Based on the test results they had found that textile ETP sludge can be replaced with cement up to 20%.

B. Shathika Sulthana Begum et al. (2013) they used textile ETP sludge as a replacement for clayey soil to manufacturing bricks. They found that when the percentage of sludge concentration in bricks is increasing then the compressive strength is decreasing. For 15% sludge concentration in clay the brick met the standard compressive strength value for first-class brick. For 30% concentration, it met the second-class brick compressive strength requirement. For 15% and 30% concentration in clay both of them satisfy the norms of weight loss and bulk density properties of good quality bricks. they did not find any effect of efflorescence up to 15% concentration in clay.

Mohammad Sohrab Hossain et al. (2018) they had investigated the textile ETP sludge and it was found that textile sludge from ETP can be a replacement material for clay soil in the bricks manufacturing but which requires much less firing temperature compared to the conventional process and low temperature reduced the risk of producing NOXs and SOXs. It was also found textile sludge can be used up to 50%. At this percentage, they had got the BS of 1.5 MPa, IS of 6.41 kJ/m^2 and water uptake of 22.72% was satisfied as bricks manufacturing requirements. For 450°C burning a large number of voids are created in the body of the bricks and they got lesser density, BS, electrical resistivity, and greater IS, firing shrinkage, water absorption capacity from their sample. They had also found that the use of 50% gamma-irradiated textile sludge from ETP can be produce eco-bricks.

Jewaratnam et al. (2020) they had used up to 10% textile wastewater treatment plant sludge in clay brick and cement blocks and it was found that 10% at 1180°C have compressive strength above 48.5 N/mm2 that can be categorized as engineering brick class B. when the amount of sludge increases then the waster absorption increases but at fixed proportion, when the firing temperature increase, the water absorption is decreased. They replaced up to 10% sludge in cement mortar and the compressive strength was found 27.53 N/mm2 at 21 of curing day and water absorption was only 0.73% which is low so based on results it can be categorized as load-bearing class 3. In the end, it was found that up to 10% of sludge can be used in the production of clay bricks.

Jahagirdar et al. (2013) investigated the reuse of textile mill sludge in fired clay bricks. They used (5% to 35%) sludge in clay bricks and fired the brick at 600ºC to 800ºC for 8, 16 and 24 hours. They found that up to 15% addition of sludge the brick gives compressive strength above 3.5MPa and the water absorption ratio is also less than 20%. So, for clay brick manufacturing up to 15% textile mill sludge can be used.

B. Tannery Sludge

Barros et al. (1999), Stephan et al. (1999) they had investigated and found that when tannery sludge is added to cement, chromium oxide reacts with calcium ions and inhibits the formation of portlandite and C3S. In samples with TS, more severe ettringite peaks high levels of calcite are obtained. In addition, the adding of chromium in cement sample is very low. Montañés et al. (2014) they had found that when they mixed tannery sludge in cement the chromium did not exceed the maximum allowable limits specified in the relevant hygiene standards. Researchers Piasta et al. (2017) had found that tannery sludge included at 0.7% by weight of cement did not change the chemical of cement but lightly decreased its flexural and compressive strength after 28 days. They had investigated and found that approximately 60% of organic combustible substances, which might have caused the strength to decrease. Another researcher's Lakrafli et al. (2013) had found that dried waste can be used in cementitious materials to decrease the thermal conductivity of walls though the thermal conductivity starts increasing the waste is moistened. Malaiškienė, Jurgita, Olga Kizinievič, and Viktor Kizinievič had used tannery sludge (TS) in construction mortars (Malaiškienė et al., 2019). they replaced cement or natural aggregate-sand with 6% tannery sludge. It was found that porosity and water absorption of the mortar were decreased, they found up to 26% strength was increased and 4% density and ultrasonic pulse velocity was increased. They had tested the XRD analysis and found that all analyzed mortars included similar standard minerals—portlandite, quartz, ettringite, calcite, dolomite, and alite. They modified the specimens with TS that contained a higher amount of portlandite, C-S-H and a lower amount of ettringite, as well as a lower amount of non-hydrated cement minerals. SEM tests confirmed the XRD analysis results. They also found that the values of chromium extracting from cement mortars met the requirements for non-hazardous waste prescribed in 2003/33/EC and in the normative documents of other countries.

Juel et al. (2017) has used the tannery sludge in brick production. They mixed the sludge with clay with a different mixing ratio (10%, 20%, 30% and 40% by dry weight). They prepared the bricks within both laboratory-controlled and field conditions. They found compressive strength ranged from 10.98 MPa to 29.61 MPa and water absorption ranged from 7.2% to 20.9%, the results have met the criteria for bricks as a construction material as per Bangladesh Standards and ASTM. Volumetric shrinkage, weight loss and efflorescence test results of the bricks were satisfied.

Tania Basegio et al. (2002) investigated and found, 10% of tannery sludge can be used safely in clay brick production. Basically, they investigated to characterize a clay product with the addition of tannery sludge as a raw material. Their previous results of the environmental compatibility of the process showed that there were emissions of Sulphur compounds, as well as zinc and chloride compounds.

Md. Ariful Islam Juel et al. (2017) investigated and found, when the percentage of tannery sludge replacement is increased then the water absorption increased and the compressive strength decreased but TS-amended bricks have been generally found to meet both BDS and ASTM requirements for bricks to be used in construction. Replacement of 10% tannery sludge by weight is suitable for clay brick production without diminishing its engineering properties. They found that reduced shrinkage, weight, and bulk density as well as the absence of efflorescence of TS-amended bricks can make the use of these more appealing. They also found that TCLP tests showed that an increase in firing temperature caused further immobilization of heavy metals such as chromium. In the end, they have found that 10% of tannery sludge can be a perfect be replacement in the production of clay brick.

C. Other Sludge or Waste Materials

Tangtermsirikul et al. (2004) according to their research incineration of municipal solid waste (MSW), and calcium carbide waste (CCW) as a method for reducing the volume of the waste is currently receiving widespread attention. The Volume reduction of MSW by either method ranges from 60% to 75%. MSW generates two general types of ash: fly ash and bottom ash. If MSW ash and CCW have potential use in concrete, it will not only be able to decrease the consumption of cement raw materials but also be able to solve disposal problems of the MSW Ash and CCw together. The CCW can be replaced with cement. The setting time of paste was delayed importantly. Compressive strength of mortars replaced with CCW was also greatly reduced compared with the control mortar, compared with a mortar without CCW in place of the mortar. It was found that it is possible to use CCW to make cement, but the construction time of the paste is delayed significantly, and the construction strength is greatly reduced. They investigated and found that when compared to the control cement, all MSWI and CCW cement tested show somewhat different characteristics in terms of setting qualities. The compressive strength of mortars made using CCW cement was similar to that of mortars made with control cement. However, when the ash percentage in the raw meal was raised, the compressive strength of mortars made with MSWI cement was lower than that of control cement mortars. MSWI and CCW cement expanded less than the control cement in a sodium sulfate solution. MSWI cement have the least amount of expansion.

Mohammed S. Nasr et al. (2019) they investigated that black tea waste ash can be used in cement mortar. black tea waste ash can be replaced with cement. Using black tea waste ash as a cement replacement reduces the flow rate of the cement mortar. The black tea waste ash can improve the compressive strength of the hardened mortar. The best improvement is given by replacing the cement with 7.5% black tea waste ash, about 10% higher than conventional mortar. When they replaced black tea waste ash in a range of 5%-10% with cement the flexure strength of mortar affected negatively. They found that substituting the cement with 2.5% black tea waste ash can increase the flexure strength by about 2%.

Nurhayat Degirmenci et al. (2011) according to their investigation recently, many studies have been focused on the uses of waste glasses as partial replacement of natural aggregates in concrete. The use of waste glasses as concrete aggregates did not have a valuable effect on the workability and strength but decreased the slump, air content, and fresh weight of concrete. A major concern for using waste glass in concrete is the alkali-silica reaction (ASR) which can be very detrimental to the stability of concrete. The combined usage of waste glass with industrial by-products can be a more suitable alternative to using it alone in mortar. Considering all of the glass types used in this study generally, there is an increasing trend of expansion by increasing the amount of waste glass used in the mixture. The rate of compressive strength depends upon the level of waste glass replacement and curing age. They got that the compressive strength increased with curing age. They found that with an increase in the waste glass content the compressive strength of the mortars decreased. The smooth and plane surface of the large waste glass particles could significantly weaken the bond between the cement paste and the waste glass particles. The white waste glass containing mortar exhibited generally high compressive strength at all ages. The colour of the waste glass has a small effect on the compressive strength which could be ignored. It was found that up to 30% WG replacement of sand the WG containing mortars can achieve improved or equivalent strength performance compared to mortars made with 100%LS. At 10% replacement WG aggregates, the flexural strength values of the mortars were close to the 100% LS mortar. The reduction in flexural strength of samples is generally higher than the reduction in compressive strength of the same samples that were tested at similar ages. The reuse of waste glass in construction can also reduce the demand for the sources of primary raw materials. In the end, they found that the utilization of waste glass offers important benefits both environmentally and economically.

Magdalena Dobiszewska et al. (2017) according to their study concrete thereby cement production consumes much energy and large amounts of natural resources. Every ton of cement production releases nearly one ton of carbon dioxide which is detrimental to the environment Basalt powder is a waste that emerged from the preparation of aggregate used in asphalt mixture production which is used as a fine aggregate replacement. It has a beneficial effect on some properties of mortar and concrete. Their study was conducted on cement pastes and mortars made without and with basalt powder used as partial replacement of cement. In this study chemical composition is typical for basalt rock, silica and alumina oxide dominate which is in about 51%, calcium and iron oxide. Scanning electron microscopy and XRD diffractogram are done for knowing the roughness and shape of basalt powder particles. XRD spectrum indicates that in mineralogical composition, the plagioclase, pyroxene and amphibole dominate the replacement of cement by basalt powder does not affect the normal consistency of binder cement paste. They found that the initial and final setting times were generally prolonged for cement pastes with the addition of basalt powder with some exceptions. They also found that cement replaced by basalt powder positively affected the mechanical properties of cement mortars. Flexural and compressive strength at 2 and 28 days of curing time. After adding up to 8% of basalt powder leads to an increase of both, flexural and compressive strength. It was found when basalt powder content leads increase then the shrinkage of mortar is increases. Until 14 days the shrinkage of mortars with the addition of basalt powder was lower than the shrinkage of control mortar. As curing time increased from 14 days to 90 days, the results changed inversely. After 90 days of curing, it was found that the shrinkage of mortars with basalt was found higher than that of control mortar. Greater shrinkage can be caused by to increase in the water-cement ratio of mortar with basalt powder content. So, it can be said that the incorporation of waste basalt powder into cement mortar as a partial substitution of cement is environmentally friendly and economically feasible.

Xianwei Ma et al. (2013) they investigated and used ground waste concrete powder on cement properties. It was found that when the amount of the ground waste concrete powder was more than 30%, but it had almost no effect on setting time, ground waste concrete powder reduced water demand for normal consistency (WDNC) of cement paste. They found that when the amount of the ground waste concrete powder is less than 20% then the downward trend of the strength was not very clear. More than 20% ground waste concrete powder, however, evidently reduces the strength. They found that the compressive strength of concrete with 20% ground waste concrete powder and recycled aggregate reaches 23.6 MPa at 28 days.

Chapter 3

Methodology

This chapter mainly described the full working procedure which was followed in this study. The methodology for collation of samples (sand, textile ETP and tannery sludge, and cement) analytical procedures to determine characteristics of sludge, sludge-cement-sand mix, preparation of cement mortar cube and briquet, and tests for cement mortar using sludge-cement-sand mixtures and chemical composition and TCLP for the sludge (mixed mode of textile ETP and tannery sludge) are discussed in a sequential manner.

3.1 Collection of Sludge Samples

Textile ETP sludge (TETPS) was collected from an effluent treatment plant of Integrated Textile Resources Ltd. (Network Group). Integrated Textile Resources Ltd. (Network Group) is a famous textile printing factory in Bangladesh. The wastewater generating from the factory is treated in a bio-chemical effluent treatment plant (ETP) and 1000 m^3 wastewater can be treated in the effluent treatment plant. After treatment raw sludge was stored into the dump zone of the effluent treatment plant. The sludge sample was collected from the dump zone shown in Figure 3.1 and 3.2 then carried using polythene bags.

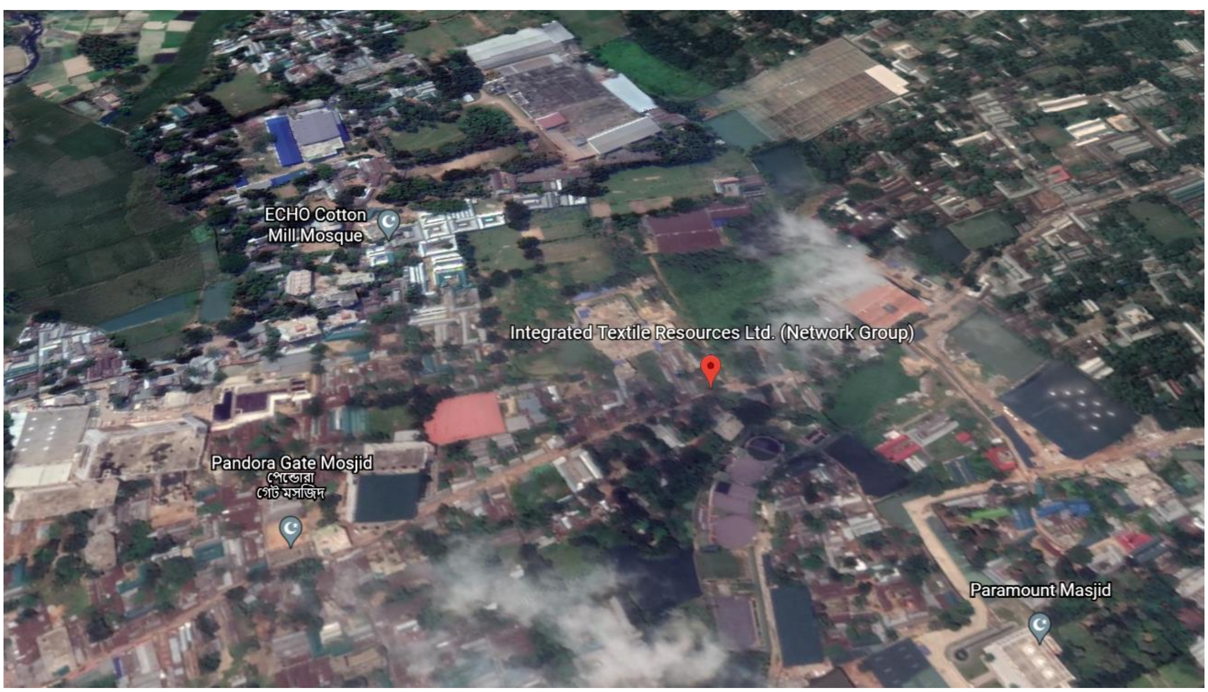

Figure 3.1: Location of Integrated Textile Resources Ltd. (Network Group) (From Google Earth)

Figure 3.2: Damp Zones of Textile effluent treatment plant sludge (TETPS)

Tannery Sludge sample was collected from a Common Effluent Treatment Plant (CETP) of BSCIC Tannery Industrial Estate. BSCIC Tannery Industrial Estate is a large treatment plant that treats the solid waste and wastewater generated from tannery processing. A huge quantity of waste and wastewater is treated in Common Effluent Treatment Plant (CETP) and after treatment, the sludge is dumped into the dump zone. The sludge sample was collected from the dump zone shown in Figure 3.3 and 3.4 then carried using polythene bags.

Figure 3.3: Location of BSCIC Tannery Industrial Estate (From Google Earth)

Figure 3.4: Damp Zones of Tannery Common Effluent Treatment Plant Sludge (CETPS)

3.2 Collection of Cement and Sand Samples

Portland composite cement (PCC) (Type II) was used and it was collected from a local store. The river sand was used and it was collected from East West University's engineering material laboratory.

3.3 Sample Preparation

Around 10 kg of textile ETP sludge and tannery sludge was taken into a tray and put into the oven at 105° C for 24 hours. After 24-hour heat, the color of textile ETP sludge remained the same but the color of tannery sludge has changed it became dark color to ash color. The textile ETP sludge and tannery sludge became dry and hard after the heat so the textile ETP sludge and tannery sludge were hammered and turned into powder form.

Figure 3.5: Tannery Sludge Before Oven Dry Condition

Figure 3.6: Tannery Sludge After Oven Dry Condition

Figure 3.7: Textile Effluent Treatment Plant Sludge Before Dry Condition

Figure 3.8: Textile Effluent Treatment Plant Sludge After Dry Condition

Figure 3.9: Sludge was Hammered and turned into Power Form

3.3.1 Alternative Way of Sample preparation

If the oven is not available then the sun can be an option to prepare the sample. 250 gm of each sample (textile ETP and tannery sludge) was taken. The textile ETP sludge and tannery sludge sample were kept in the sun for 4 hours every day, after 4 days of sun-dried both of the samples dry weight and moisture content was determined. After sun-dried the samples has showed the same color which they showed after oven dry. The temperature was normal 27°-29°C.

3.4 Characteristics of Textile ETP and Tannery Sludge

The whole flow chart of this study has been submitted in Figure 3.15. The analytical method adopted in this study of samples has been shown in Table 3.1. Physical characteristics like moisture content, presence of organic matter content has tested.

3.4.1 Moisture Content

The moisture content of the sludge (textile ETP, tannery sludge both as separate and mixed mode) sample was determined using the wet technique. ASTM D 2216 – Standard was followed to determine the moisture content of the sludge (textile ETP, tannery sludge both as separate and mixed mode) samples. 2.5 grams of both sand and the sludge (textile ETP, tannery sludge both as separate and mixed mode) sample was taken respectively at ambient temperature. After that, the sample was dried in an oven at 105°C for roughly 24 hours. Then the sample was placed in a desiccator until the samples cooled after dried in the oven. Then the sample weight (W_d) was taken again in gram. Equation (3.1) used to calculate all sample moisture content. The same procedure was followed to determine moisture content for all sludge (textile ETP, tannery sludge both as separate and mixed mode) samples.

$$\text{Moisture Content, } \% = \frac{2.5 - W_d}{2.5} \times 100\% \qquad (3.1)$$

Here,

W_d = dry weight of the Sample.

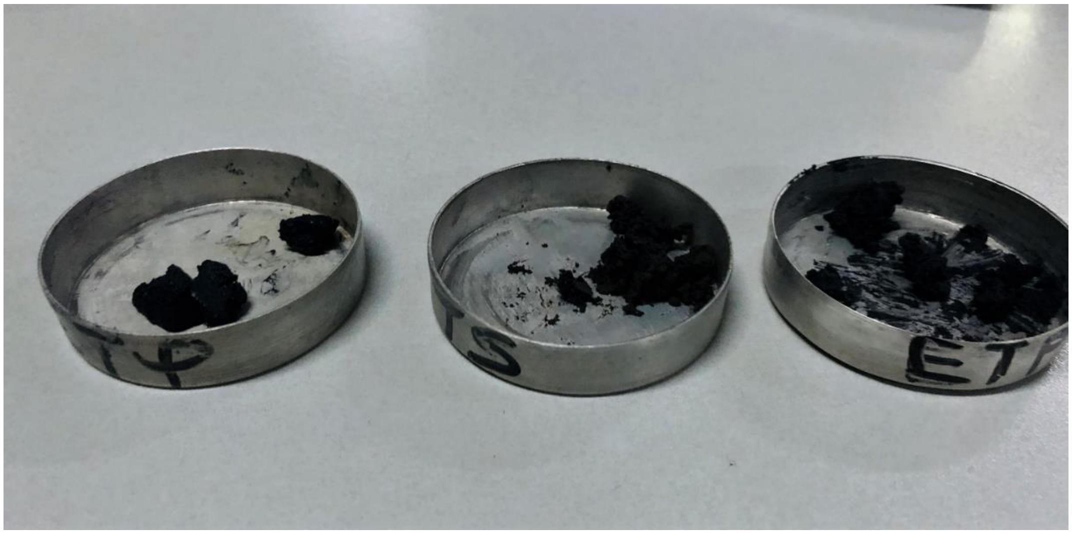

Figure 3.10: Moisture Content Measurement of Textile ETP, Tannery Sludge and Mixture of Textile ETP, Tannery Sludge

3.4.2 pH

The pH of the sludge (textile ETP, tannery sludge both as separate and mixed mode) sample was analyzed with the electrometric method. A pH meter was used to determine the pH of the sample (textile ETP, tannery sludge both as separate and mixed mode). Around 25-gm sample (textile ETP, tannery sludge both as separate and mixed mode) was taken in a 100 ml beaker and filled the beaker with 75 ml distilled water. The beaker was placed in a magnetic stirrer, inserted the Teflon coated stirring bar, and stirred well. Then the electrode was placed in the beaker containing the sample (textile ETP, tannery sludge both as separate and mixed mode), and checked the reading in the pH meter. The same procedure followed for all samples.

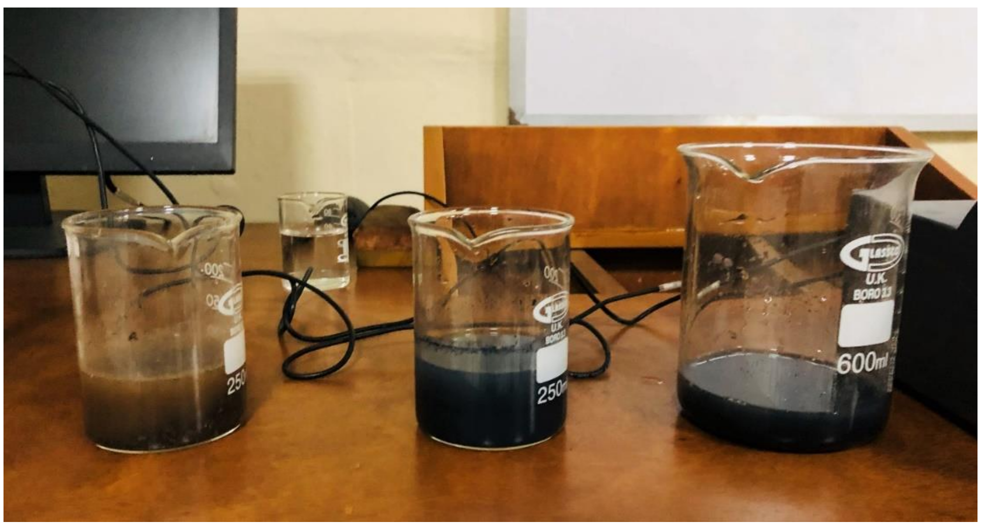

Figure 3.11: Sludge Samples Prepared for pH Measurement

Figure 3.12: Tannery Sludge pH Measurement

Figure 3.13: Textile Effluent Treatment Plant Sludge pH Measurement

Figure 3.14: Mixture of Tannery and Textile Effluent Treatment Plant Sludge pH Measurement

3.4.3 Organic Matter Content

The textile ETP and tannery sludge were mixed. The textile ETP and tannery sludge are mixed at 50%. The Bureau of Research Testing and Consultation (BRTC), Bangladesh University of Engineering and Technology (BUET), Dhaka is helped to determine the organic matter content for the prepared sludge samples. The prepared sample is tested at the Bureau of Research Testing and

Consultation (BRTC), Bangladesh University of Engineering and Technology (BUET), Dhaka, and dry combustion method is used and the result was collected.

3.4.4 Chemical Composition:

X-Ray Fluorescence (XRF-1800, Shimadzu) was used to determine the chemical composition of the mixed-mode of the textile ETP, tannery sludge. Department of Glass and Ceramic Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh helped to perform the chemical composition of the mixed-mode of the textile ETP, tannery sludge.

Table 3.1: Analytical Methods for Characterization of Sludge and Cement Mortar

For Dry Textile Effluent Treatment Plant Sludge and Tannery Sludge	
pH	BS 1377 (1990): Part 3
Moisture content	ASTM D 2216
Organic Matter Content	Dry Combustion Method
Chemical Composition	X-Ray Fluorescence (XRF)
TCLP (Heavy Metal)	EPA -1311
For Sludge-Cement Mortar Properties	
Normal Consistency	ASTM C187
Initial and Final Setting Time	ASTM C191
Compressive Strength	ASTM C109
Tensile Strength	ASTM C307 - 03
Specific Gravity	ASTM D854-00
Water Absorption	ASTM C 642-2013

3.4.5 TCLP of Sludge Sample (Heavy Metal Determination)

The textile ETP and tannery sludge were mixed. The textile ETP and tannery sludge are mixed at 50%. The Bureau of Research Testing and Consultation (BRTC), Bangladesh University of Engineering and Technology (BUET), Dhaka is helped to perform the TCLP of sludge sample (Heavy Metal Determination) for the prepared sludge samples. The prepared sample is tested at the Bureau of Research Testing and Consultation (BRTC), Bangladesh University of Engineering and Technology (BUET), Dhaka, and EPA -1311 is used and the result was collected.

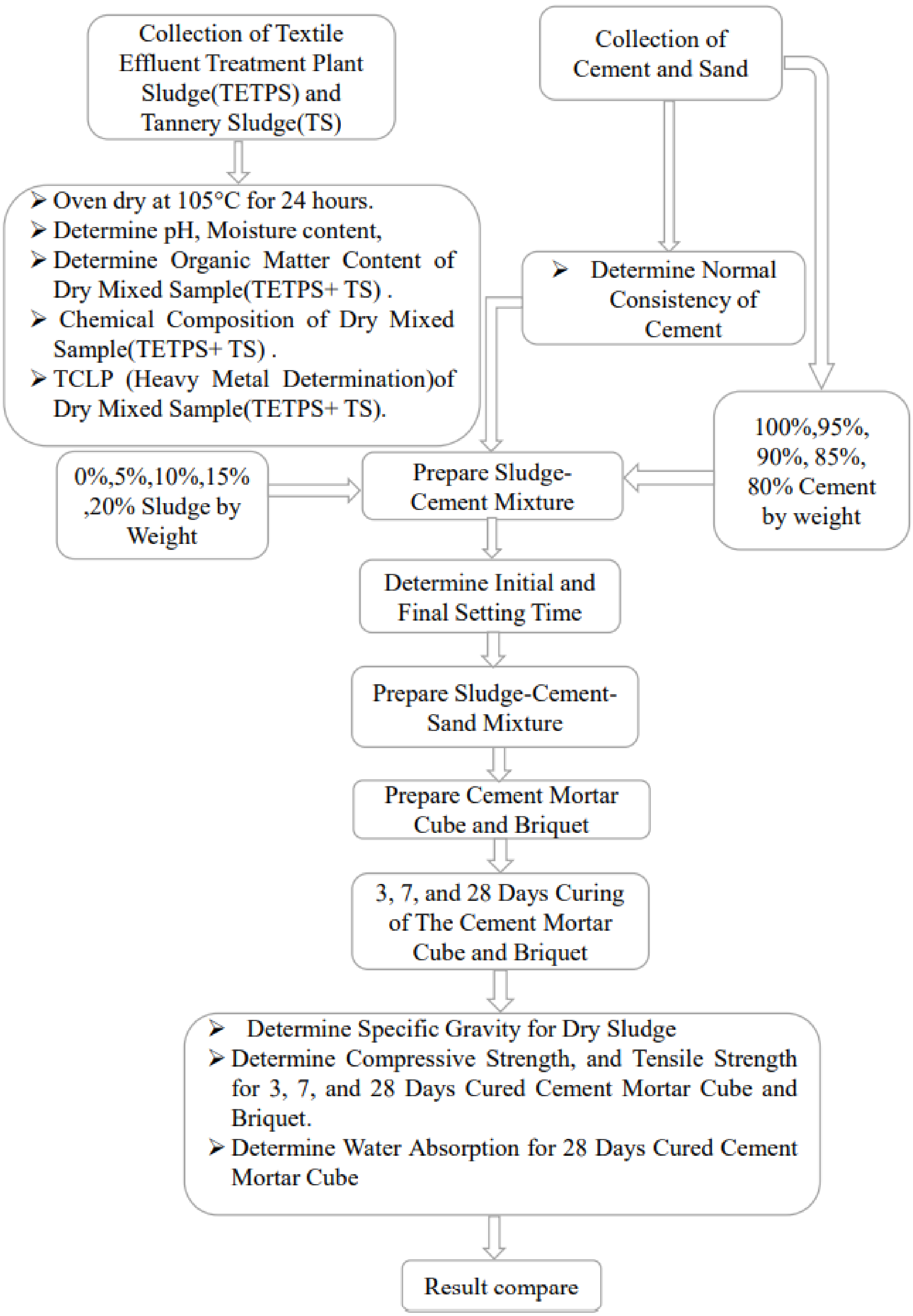

Figure 3.15: Flow Chart of The Total Process

3.5 Preparation of Cement Mortar

The sludge, cement, and sand mixture were divided into 3 categories' then in each category the sludge, cement, and sand samples were mixed in fore mixing ratios (0%, 5%, 10%, 15%, 20%, replacement by weight) of sludge-cement-sand mixtures. A set of sludge-incorporated cement mortar cubes prepared in East-West university's engineering material laboratory as per normal procedure (Figure 3.16). A 2 in × 2 in × 2 in (length= 2 in, width=2 in, height=2 in) mold was used to prepare cement mortar cube for compressive strength testing, and briquet gang mold used to prepare cement mortar briquet for the tensile strength testing. Cement and sand ratio 1:2.75 was used and waster and cement ratio were used 0.485. Around 72 cement mortar cube and 36 briquet samples of sludge-cement-sand mixture in varying proportion (0%, 5%, 10%, 15%, 20%, replacement by weight) was prepared. The samples divided into 3 categories. In first category textile ETP sludge used in cement mortar cube and briquet. In second category tannery sludge used in cement mortar cube and briquet. In third category both textile effluent treatment plant sludge and tannery sludge used in cement mortar cube and briquet. Portland composite cement (type II) used to prepare the cement mortar. Then all samples cured for 3 days, 7 days, and 28 days.

After the cement mortar cube and briquet manufactured in the engineering material laboratory, they subjected to the different test to determine the engineering properties.

Figure 3.16: Cement Mortar Cube and Briquet was Prepared

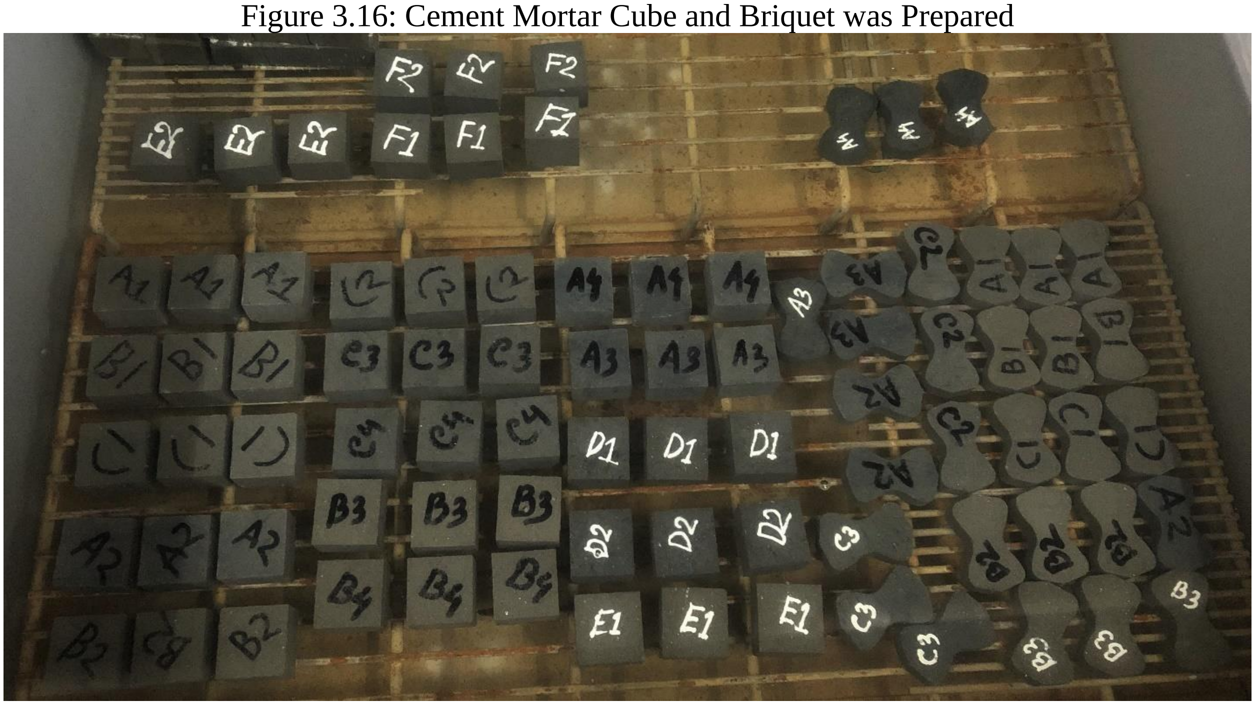

Figure 3.17: Cement Mortar Cube and Briquet Samples Was kept for 3 days, 7 days, and 28 days of Curing

Table 3.2: Composition of Cement Mortar

Sample	Sludge Used	0% Replacement by Weight	5% Replacement by Weight	10% Replacement by Weight	15% Replacement by Weight	20% Replacement by Weight
Category 1	Textile Effluent Treatment Plant Sludge (TETPS)	0% (Sludge)+100% (cement +Sand) = 100% (A0)	5% (Sludge)+95% (cement +Sand) = 100% (A1)	10% (Sludge)+90% (cement +Sand) = 100% (A2)	15% (Sludge)+85% (cement +Sand) = 100% (A3)	20% (Sludge)+80% (cement +Sand) = 100% (A4)
Category 2	Tannery Sludge (TS)	0% (Sludge)+100% (cement +Sand) = 100% (B0)	5% (Sludge)+95% (cement +Sand) = 100% (B1)	10% (Sludge)+90% (cement +Sand) = 100% (B2)	15% (Sludge)+85% (cement +Sand) = 100% (B3)	20% (Sludge)+80% (cement +Sand) = 100% (B4)

Category 3	Textile Effluent Treatment Plant Sludge (TETPS)+ Tannery Sludge (TS)	0% (Sludge)+100% (cement +Sand) = 100% (C0)	2.5% (TETPS)+2.5%(TS)+95 % (cement +Sand) = 100% (C1)	5% (TETPS)+5% (TS)+90% (cement +Sand) = 100% (C2)	7.5% (TETPS)+7.5% (TS)+ 85% (cement +Sand) = 100% (C3)	10% (TETPS)+10% (TS)+80% (cement +Sand) = 100% (C4)

3.6 Standard Test of Cement Mortar

Certain tests which indicate the quality of cement mortar conducted to check whether the cement mortar is suitable to be used as a construction material or not. Those tests include normal consistency, initial and final setting time, compressive strength, tensile Strength, water absorption, and specific gravity. All these test methods are described as follows.

3.6.1 Normal Consistency

For the normal consistency of cement, ASTM C187 was used. Vicat apparatus and plunger were used to determine the normal consistency of cement. First 300 gm sample was taken in a mixing plate and a trial water 27 % by weight of cement was taken. Then the water was mixed properly with cement and placed in the Vicat ring. After that, the Vicat ring was placed into the Vicat apparatus. The plunger was added to the apparatus. Then the plunger was set at a point where the plunger was touching the surface of the sample. After completing this thing, the plunger was released and recorded the penetration value. Whole procedure was repeated until the more than10mm penetration value was recorded and each time 2% extra water by weight was added. The amount of water required for 10mm penetration will be the normal consistency of cement.

Figure 3.18: Normal Consistency Measurement of Cement

3.6.2 Initial and Final Setting Time

For initial and final setting time ASTM C191 standard was followed. The cement and sludge were mixed, a total of 300 gm of cement sample was taken. The cement was replaced by the sludge (textile ETP, tannery sludge both as separate and mixed mode) 0%, 5%, 10%, 15%, 20%, by weight of the taken cement sample and water was added 30% by weight, which was found by normal consistency measurement of cement and a cement paste was made. The textile ETP and tannery sludge was mixed combinedly and replaced the cement and the mixing system was followed in table 3.2's category 3. Then a conical ring was used for this experiment. Then the conical ring was placed on a nonabsorptive plate. After preparing the cement paste sample (sludge was mixed) the conical ring was filled with the cement paste. A Vicat apparatus was used to determine the initial and final setting time. We attached the 1-mm needle to the Vicat apparatus and bought it in contract with the surface of the test samples and quickly released and recorded the penetration value, shown in figure 3.19. The penetration was determined of the 1-mm needle at this time and in every 15-min until penetration of 25 mm or less was obtained the experiment was repeated. When the penetration of 25 mm or less was got, the time was recorded and that time was the initial setting time. Then the Vicat apparatus needle was replaced by an annular attachment and bought it in contract with the surface of the test samples and quickly released. The procedure was repeated in every 15 minutes until the needle makes an impression there on, while the attachment fails to do so. Then the time was recorded. The time period was elapsed between the time when water was added into the sample and the time at which the annular attachment fails to make an impression on sample is taken as final setting time. The room temperature was adjusted at 22° C to 23° C.

Figure 3.19: Initial and Final Setting Time Measurement of Cement Mixed with Sludge Samples by Weight

3.6.3 Compressive strength of Cement Mortar Cube

After preparing the cement mortar (textile ETP, tannery sludge both as separate and mixed mode) 2 inches of specimen mold used to prepare the cement mortar cube. ASTM C109 standard was followed during the experiment. The curing time of the cement mortar was 3, 7, and 28 days. The compressive strength of the cement mortar cube was determined at 3, 7, 14, and 28 days. First, the cement mortar cube placed into the testing machine then the load applied to the cement mortar cube at a constant rate of 200 to 400 lbs/s. The load is applied without interruption. the maximum load for cement mortar cube reached within 20 to 80 seconds. No adjustment was made in the controls of the testing machine while the cement mortar cube is yielding prior to failure. After failure the value of maximum load applied showed into the testing machine screen was recorded, shown in figure 3.20. The same procedure followed for the remaining cement mortar cube samples. The compressive strength determined using equation (3.10).

$$\text{Compressive Strength,} \quad C=\frac{W}{A} \tag{3.10}$$

Here,

C= compressive strength of cement mortar cube (2 in specimen) ($\frac{lb}{in^2}$)

W= Maximum load or Crushing Load (lb)

A= Specimen Area (in^2)

Figure 3.20: Compressive Strength of Cement Mortar Cube

3.6.4 Tensile Strength of Cement Mortar Briquet

Textile ETP and tannery sludge was used in cement mortar, cement mortar divided into 3 categories based on the use of waste in cement mortar. After preparing the cement mortar briquet maker mold was used to prepare the cement mortar briquet. Around 30 cement mortar briquets samples was made. Then the cement mortar briquet has been kept for 3-, 7-, and 28-days curing. The temperature was adjusted at 23-25°C during the whole procedure. After 3 days of curing the load (P) was applied using the briquette testing machine. No adjustment was made in the controls of the briquette testing machine while the cement mortar briquette was yielding prior to failure. After the failure of the cement mortar briquette, recorded the maximum load (P) which was applied in cement mortar briquette. After 7, 14, and 28 days of curing the same procedure followed for all samples of cement mortar briquette. ASTM C307-03 standard was followed to determine the tensile strength of cement mortar briquet. The equation (3.11) was used to determine the tensile strength of cement mortar briquet.

$$\text{Tensile Strength,} \quad S=\frac{P}{b\times d} \tag{3.11}$$

Here,

S= Tensile strength of cement mortar briquet, psi (MPa)

P = Maximum load or failure load on cement mortar briquet, lbs (N)

b = Width at the waist of the cement mortar briquette tested, in. (mm)

d = Depth of cement mortar briquette tested, in. (mm).

Figure 3.21: Tensile Strength of Cement Mortar Briquet

3.6.5 Specific Gravity

To determine the specific gravity sludge (textile ETP, tannery sludge both as separate and mixed mode) samples ASTM D854-00 standard was used. First 250 gm of textile ETP sludge was taken. A balance was used, first the weight of the empty pycnometer (W1) was recorded shown in figure 3.22. Then the 250 gm of textile ETP sludge was inserted into the pycnometer and the weight of the pycnometer + sample (W2) was recorded. Then water was filled into the empty pycnometer and the weight of pycnometer + water (W4) was recorded. After that, 250 gm of textile ETP sludge was inserted into the pycnometer and distilled water is added to fill about three-fourth of the pycnometer and trapped air was removed then the weight of pycnometer + textile ETP sludge + water (W3) was recorded. Equation 3.12 was to determine to calculate the specific gravity. For tanner sludge and a mixture of textile ETP sludge and tannery sludge same procedure was followed.

Specific Gravity, $\frac{(W2-W1)}{(w4-w1)-(W3-w2)}$ (3.12)

W1=Weight of the empty pycnometer

W2= Weight of pycnometer + sample

W3= Weight of pycnometer + Sample + water

W4= weight of pycnometer + water

Figure 3.22: Specific Gravity Determination of Sludge Samples

3.6.6 Water Absorption

Water absorption test of the samples (textile ETP, tannery sludge both as separate and mixed mode) was carried out according to ASTM C 642-2013 standard method. Water absorption was occurred on a 2×2×2 in (50.8 × 50.8 × 50.8 mm) specimens cement mortar cube. After preparing the cement mortar samples (textile ETP, tannery sludge both as separate and mixed mode) and then the cement mortar cube has been kept for 28 days curing. After 28 days of curing the samples (textile ETP, tannery sludge both as separate and mixed mode) was oven-dried for 24 hours at a temperature of 105° C. Then the oven-dried samples (textile ETP, tannery sludge both as separate and mixed mode) cooled at room temperature for 1.5 hours and then the oven-dry weight (W_D) was recorded. Then the oven-dried samples (textile ETP, tannery sludge both as separate and mixed mode) immediately immersed in water for the duration of 96 hours. After that the samples (textile ETP, tannery sludge both as separate and mixed mode) were taken out from water and remaining water was wiped with a soft cloth. Then the saturated sample weight (W_S) was recorded. Equation 3.15 was used to determine the water absorption.

$$\text{Water Absorption, \%} = \frac{(W_S - W_D)}{W_D} \times 100\% \qquad (3.15)$$

Here,

W_D= Dry weight of the f oven-dry sample (textile ETP sludge, tannery sludge mixed with cement and sand) in air, (gm).

W_S= Weight of the saturated surface-dry sample after 96 hours immersion in water (textile ETP sludge, tannery sludge mixed cement and with sand) in air, (gm).

Figure 3.23: Oven Dried Cement Mortar Cubes for Water Absorption Measurement

Figure 3.24: Water Absorption Measurement of Cement Mortar 3, 7, 28 days cured Cube

Chapter 4

Result and Discussion

In this chapter, the result collected from this study will be discussed. This chapter mainly represents the laboratory experiments to determine the characteristics of textile ETP and tannery sludge, engineering properties of cement mortar (textile ETP, tannery sludge both as separate and mixed mode used in cement mortar).

4.1 Characteristics of Textile ETP and Tannery Sludge

4.1.1 Alternative Way of Sample preparation

The sun-dried sample of textile ETP and tannery sludge weight is decreased and the dry weight of the textile ETP sludge is 198.2 gm and the tannery sludge is 226.2 gm. The amount of moisture of the sun-dried textile ETP sludge sample is 21% and tannery sludge is 10%. This test was conducted during the winter season so the moisture content is low. According to (Climate & Weather Averages in Dhaka, Bangladesh, 2021) the average temperature of Dhaka city range between 32° to 34° in the summer months (March - June). According to (Climate of the World, 2021) Bangladesh's maximum range is between 30° to 40° C in the summer months (March - June). So, if this sludge is sun-dried in the summer months (March - June) then the dry weight of the samples will be decreased and moisture content will be increased. For sun-dried sample preparation textile ETP and tannery sludge sample should be kept for at least four hours and seven days, then the samples will become moisture less.

4.1.2 Moisture Content

The moisture content of raw textile ETP and tannery sludge is shown in table 4.1. The moisture content of raw textile ETP and tannery sludge was found at 59% and 67%. When the textile ETP and tannery sludge were mixed then the moisture content was found 64%, the moisture content is increased because the moisture content of textile ETP and tannery sludge is not uniform everywhere. The selected portion of textile ETP and tannery sludge gave this result.

Table 4.1: Moisture Content of Raw Textile ETP and Tannery Sludge

Sludge Samples	Moisture Content (%)
Textile ETP Sludge	59%
Tannery Sludge	67%
Textile ETP + Tannery Sludge (Mixed mode)	64%

4.1.3 pH

After oven dry the raw textile effluent treatment plant sludge and tannery sludge at 105° C for 24 hours then the pH was determined and is shown in table 4.2. The dry textile ETP sludge pH was found 6.07 and the temperature was 27.7° C. According to Geography, QMUL if pH was measured less than 7 is considered acidic, pH greater than 7 is considered as basic, and pH closer to 7 is considered as neutral. So, the dry textile ETP sludge is classified as acidic. The dry tannery sludge pH was found 8.10 and the temperature was 28° C. So, the dry tannery sludge is classified as basic. When the dry textile effluent treatment plant sludge and tannery sludge were mixed then the pH was found 6.98 and the temperature was 27.1° C. so, the mixed mode of dry textile ETP and tannery sludge is classified as neutral.

Table 4.2: pH of Dry Textile ETP and Tannery Sludge

Sludge Sample	**pH**	**Temperature**
Textile ETP Sludge	6.07	27.7° C
Tannery Sludge	8.10	28° C
Textile ETP + Tannery Sludge (Mixed mode)	6.98	27.1° C

4.1.4 Organic Matter Content

The organic matter content of mixed mode of textile ETP and tannery sludge is found 53.76 using dry combustion method which is shown in table 4.3.

Table 4.3: Organic Content of a Mixture of Textile ETP and Tannery Sludge

Sludge Sample	**Organic Content (%)**
Textile ETP + Tannery Sludge (Mixed mode)	53.76

4.1.5 Chemical Composition

The chemical composition of mixed-mode of textile ETP and tannery sludge is determined using X-Ray Fluorescence (XRF-1800, Shimadzu) in Glass and Ceramic Engineering department, BUET. The chemical composition results are found as percentage of major oxides shown in table 4.4. The expected concentration for Portland Composite Cement (PCC) According to (Md. Alhaz Uddin, et al., 2013) is also shown in table 4.4. The mixed-mode of textile ETP and tannery sludge consists of similar chemical components which were found by (Md. Alhaz Uddin, et al., 2013) in the Portland composite cement (PCC) but in different quantities. So, the textile ETP and tannery sludge both as separate and mixed mode can be a partial replacement of cement in cement mortar.

Table 4.4: Chemical Composition of a Mixture of Textile ETP and Tannery Sludge

Analyte	**Sludge Sample Result (%)**	**Expected concentration for Portland Composite Cement (PCC) According to** (Md. Alhaz Uddin, et al., 2013)
CaO	33.0355	64.82
SiO_2	13.6849	20.60
Cr_2O_3	10.7118	-
Al_2O_3	10.2913	4.74
TiO_2	8.4906	-
MgO	7.0763	1.84
SO_3	5.8915	2.4
Fe_2O_3	4.7440	3.28
Na_2O	2.1392	0.21
P_2O_5	1.4806	-
Cl	0.9586	-
ZnO	0.7905	-
K_2O	0.5052	0.38
ZrO_2	0.1189	-
SrO	0.0811	-
LOI	-	1.73

4.1.6 TCLP of Sludge sample (Heavy Metal Determination)

Toxicity Characteristics Leaching Procedure (TCLP) test results of the mixed-mode of textile ETP and tannery sludge are shown in table 4.5. The concentration of all the metal leaching is lower than the USEPA guideline values which means this sample (mixed-mode of textile ETP and tannery sludge) will not pollute the surface and ground water. This sludge (mixed-mode of textile ETP and tannery sludge) sample is not hazardous. From the above TCLP test results, it can be concluded that textile ETP and tannery sludge both as separate and mixed-mode can be incorporated in cement mortar and end of the life cycle of this cement mortar it will not cause any environmental hazard.

Table 4.5: Heavy Metals of a Mixture of Textile ETP and Tannery Sludge

	Heavy Metal Concentration (mg/L)							
	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Sludge Sample	0	0	0.726	0	0	3.86	0.039	2.33
USEPA Guideline Values	5	1	5	-	0.2	-	5	150

4.2 Characteristics of Cement Mortar

After preparing the cement mortar samples and after completing the 3, 7, and 28 days of curing, some tests are done on the cement mortar samples to determine the properties of cement mortar. Those tests include normal consistency, initial and final setting time, compressive strength, tensile strength, specific gravity, water absorption. In this section, the result of those tests is discussed.

4.2.1 Normal Consistency

Normal consistency is determined for the raw cement samples. The test is started from the addition of 27% assumed water by weight and ended at 31% water addition, which showed in table 4.3. For 31% assumed water addition by weight 19mm penetration is found. According to ASTM C187 for 10mm penetration the normal range of values is between 22 to 30 percent by weight of dry cement. 30% water addition by weight is found for 10mm penetration. Which followed the standard range so, this result is used 30% water addition by weight for the next initial and final setting of the cement test.

Table 4.6: Normal Consistency of Cement

Normal Consistency (%)	**Penetration (mm)**
27	3
29	5
31	19

4.2.2 Initial and Final Setting Time

The initial and final setting time for cement replaced by 0%, 5%, 10%, 15%, 20% sludge is shown in table 4.4, 4.5, and 4.6. According to BDS EN 197-1:2003, the minimum initial setting time for Portland composite cement have to be 60 minutes and for the final setting time, it is not specified. In this case, cement replaced by 15% and 20% tannery sludge samples' initial setting time is less than 60 minutes. Except for these two samples (cement replaced by 15% and 20% tannery sludge), all samples' initial setting time is higher than 60 minutes. Cement replaced by 15% and 20% tannery sludge samples final setting time is found very early. For the initial and final setting time of cement replaced by 15% and 20% tannery sludge samples, this thing happened because tannery sludge is absorbed the added water of the samples so that cement replaced by 15% and 20% tannery sludge samples initial and final setting time is very early. For 15%, and 20% cement replaced by tannery sludge the initial and final setting time is determined again, for this time the water percentage is increased by 2%. 32% water is used but for 15 % cement replaced by tannery sludge no severe change was observed and for 20 % cement replaced by tannery sludge almost the same result was found which is shown in table 4.8. For all of the samples, it is observed that the initial and final setting time is decreased when the sludge inclusion in cement mortar increased, which is shown in Figures 4.1 and 4.2. Figure 4.3 and 4.4 showed that the reduction of initial and final setting time for inclusion of sludge (textile ETP, tannery sludge both as separate and mixed mode). For 5% and 10% inclusion of textile sludge, the initial setting time has increased 23% and 17 % more than normal initial setting time of cement without sludge inclusion. The final setting time is increased around 7% when 5% of textile sludge is added into cement. Except for 5% and 10% inclusion of textile sludge based on figures 4.3 and 4.4, it can be said that the initial and final setting time is reduced when the sludge inclusion is increased.

Table 4.7: Initial and Final Setting Time of Cement

Sludge Used (%)	Penetration Value (mm)	Cement Initial Setting Time (minute)	Cement Final Setting Time (minute)
0%	25	128	190

Table 4.8: Initial and Final Setting Time of Cement (Cement is replaced by Textile ETP Sludge)

Sludge Used (%)	Penetration Value (mm)	Textile ETP Initial Setting Time (minute)	Textile ETP Final Setting Time (minute)
5%	25	158	204
10%	25	150	190
15%	25	109	157
20%	25	81	130

Table 4.9: Initial and Final Setting Time of Cement (Cement is replaced by Tannery Sludge)

Sludge Used (%)	Penetration Value (mm)	Tannery Sludge Initial Setting Time (minute)	Tannery Sludge Final Setting Time (minute)
5%	25	91	117
10%	25	66	108
15%	25	25	70
20%	25	24	61

Table 4.10: Initial and Final Setting Time of Cement (Cement is replaced by Textile ETP+ Tannery Sludge)

Sludge Used (%)	Penetration Value (mm)	Textile ETP+ Tannery Sludge Initial Setting Time (minute)	Textile ETP+ Tannery Sludge Final Setting Time (minute)
5%	25	119	147
10%	25	92	121
15%	25	74	109
20%	25	73	99

Table 4.11: Initial and Final Setting Time of Cement (Cement is replaced by Tannery Sludge and 32% Water used)

Sludge Used (%)	Penetration Value (mm)	Tannery Sludge Initial Setting Time (minute)	Tannery Sludge Final Setting Time (minute)
15%	25	39	100
20%	25	22	73

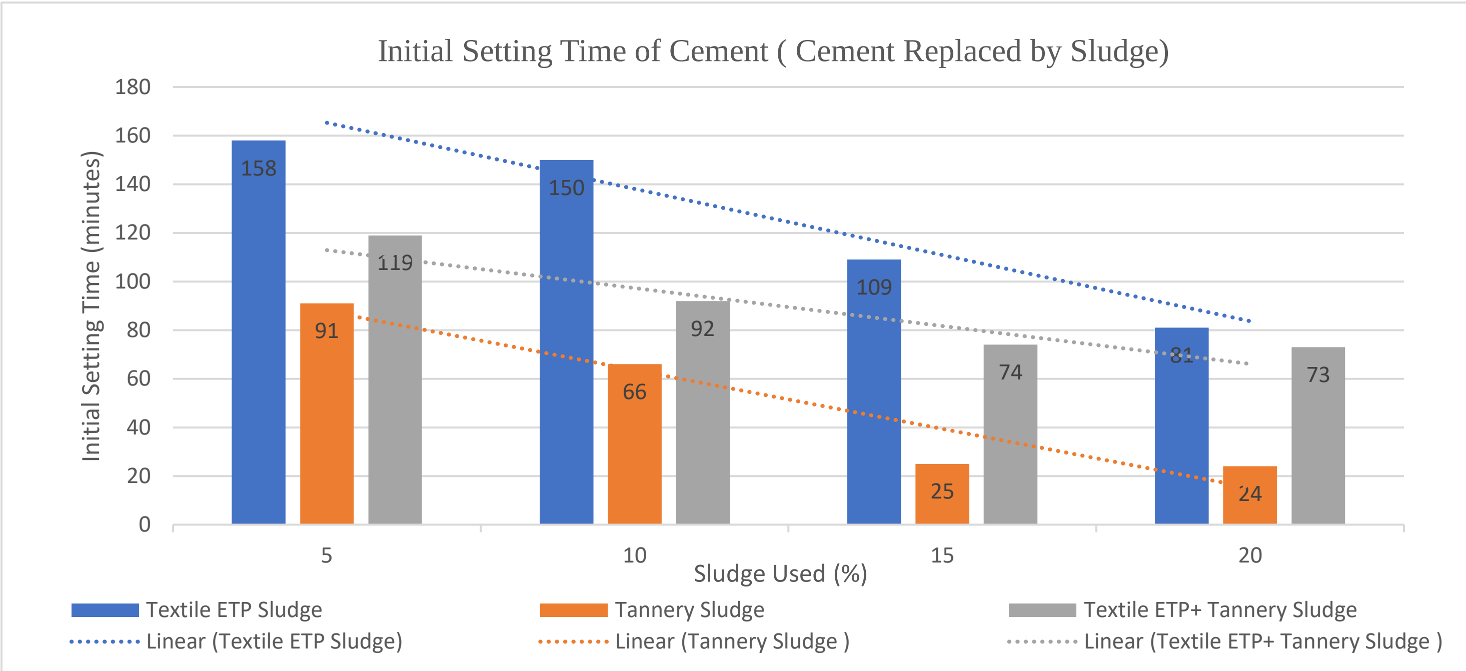

Figure 4.1: Initial Setting Time of Cement (Cement Replaced by Sludge)

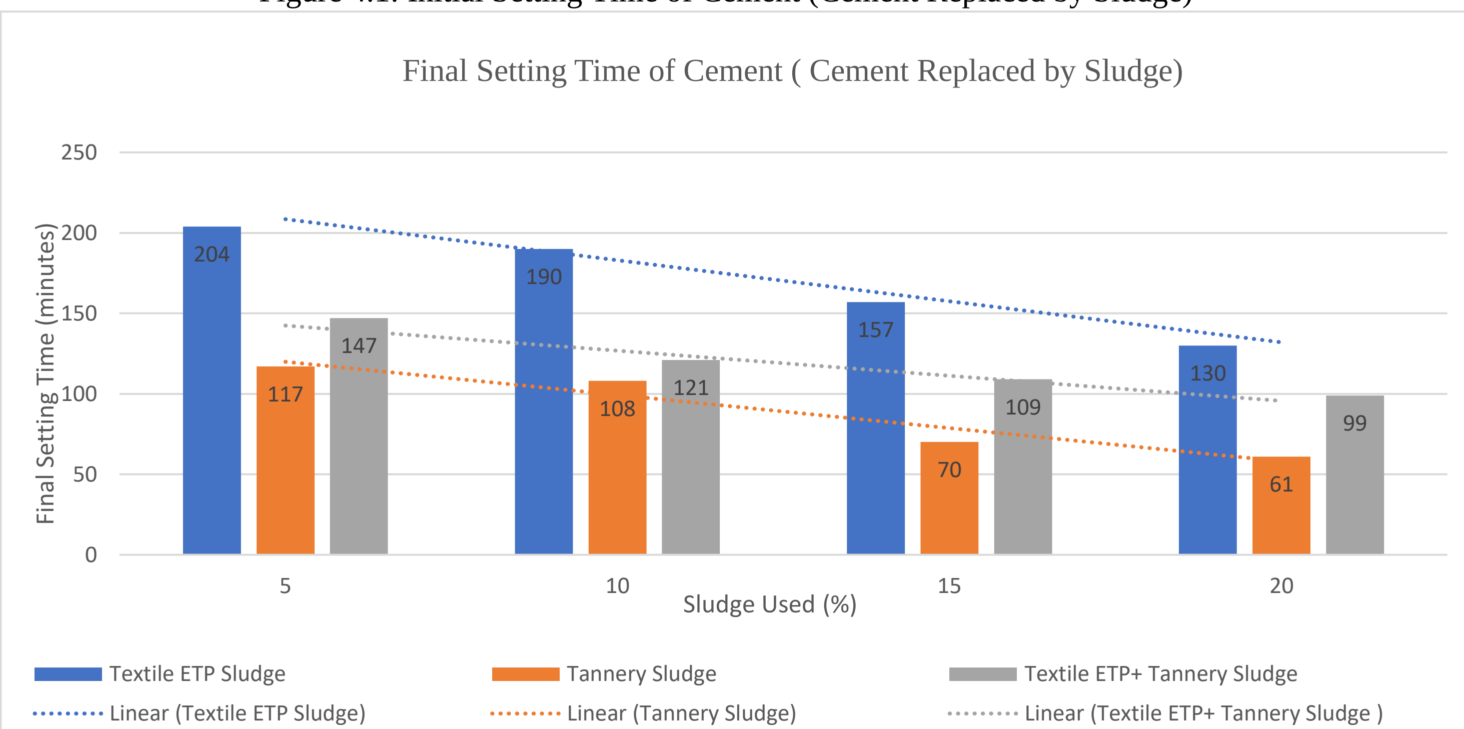

Figure 4.2: Final Setting Time of Cement (Cement Replaced by Sludge)

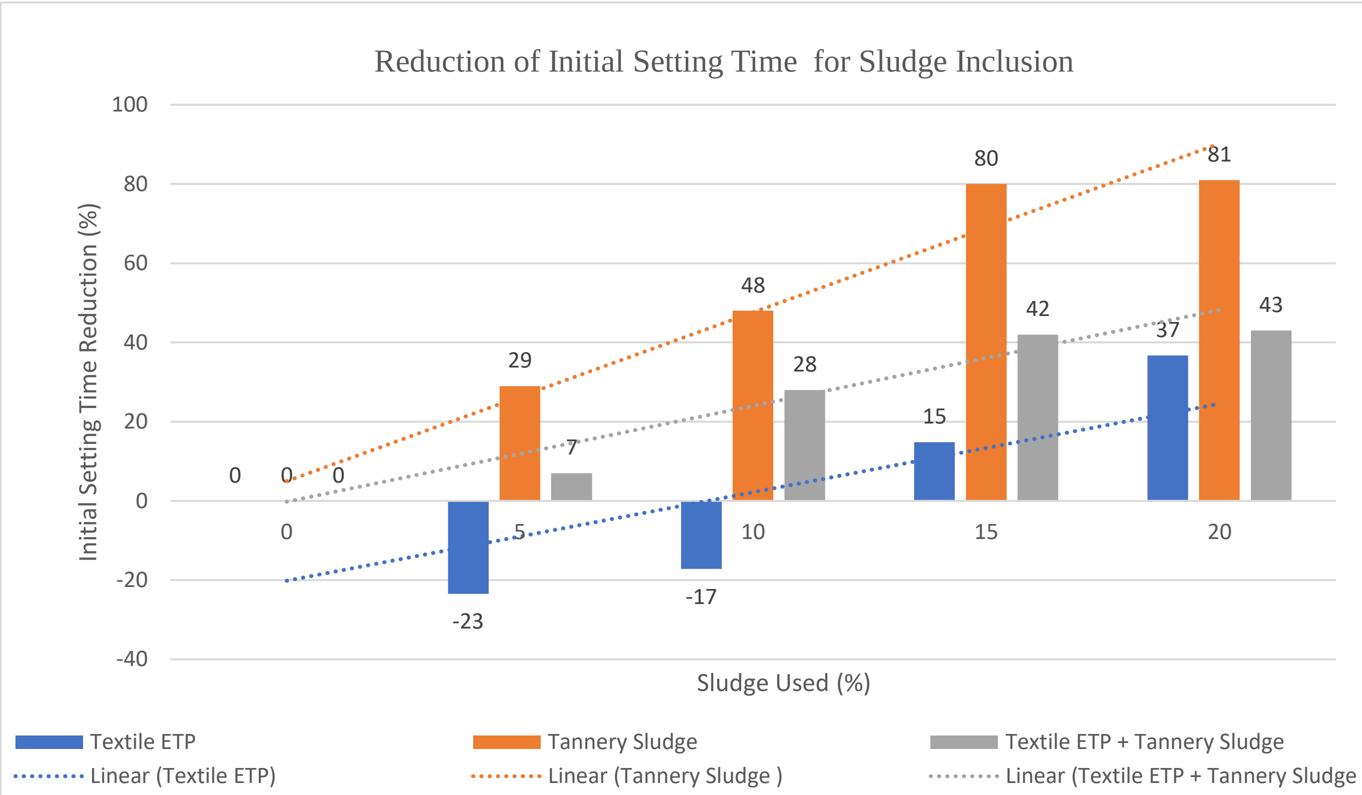

Figure 4.3: Reduction of Initial Setting Time for Sludge Inclusion

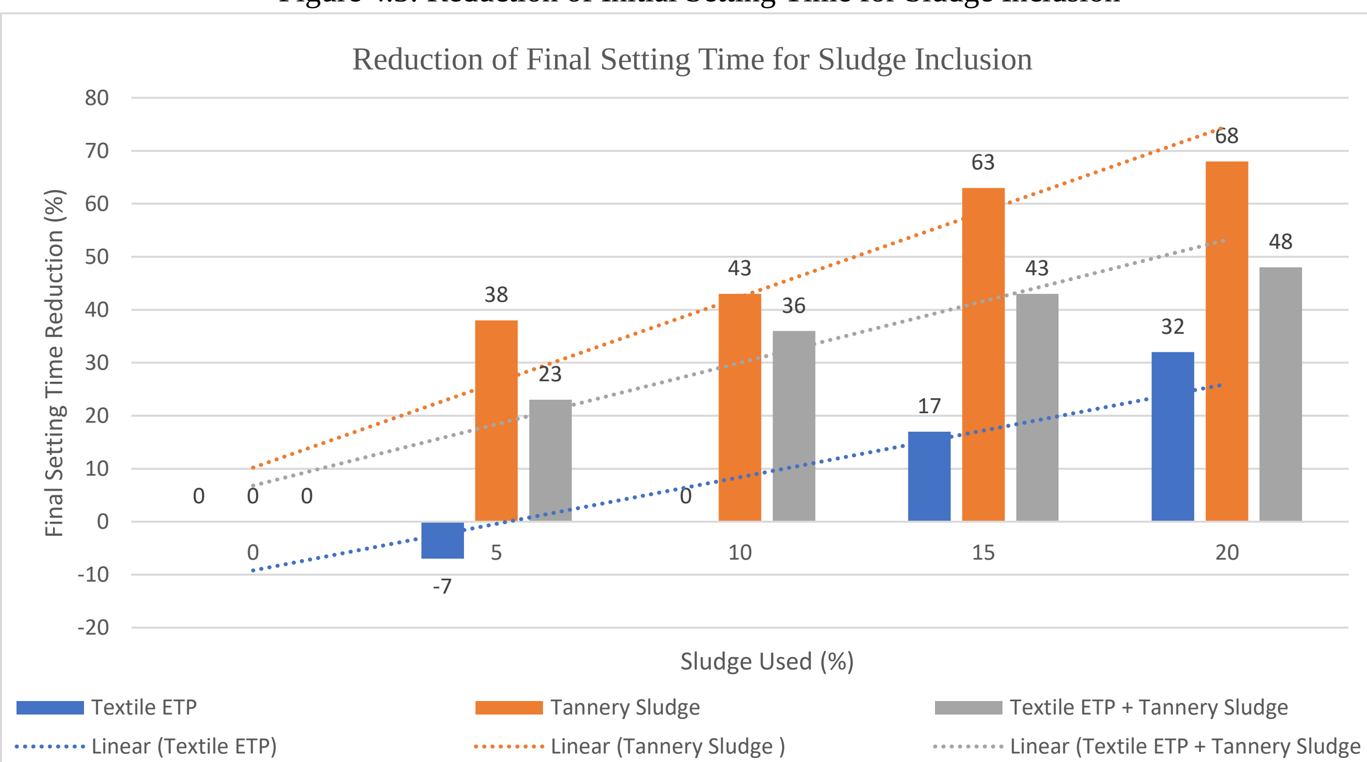

Figure 4.4: Reduction of Final Setting Time for Sludge Inclusion

4.2.3 Compressive Strength of Cement Mortar Cube

After 3, 7, 28 days of curing, the compressive strength of cement mortar for different percentages of sludge inclusion is shown in tables 4.9, 4.10, 4.11. After 28 days of curing and after analyzing the results at the B1 sample an error is found. B1 sample compressive strength is lower than B2 sample compressive strength but the B1 sample should have a higher compressive strength than B2. This happened because of some mixing issue. Both of the sludge (textile ETP and tannery sludge both as separate and mixed mode) required proper mixing with cement. During the sample preparation period of the B1 sample for 28 days of curing the tannery sludge is not mixed with cement properly. after 3 and 7 of curing of B1 and B2 samples and analyzing the B1 and B2 samples 3- and 7-days compressive strength results, those results are ok. So, this happened because of the sludge and cement mixing issue. According to ASTM C270-14a, the S-type mortar should have a minimum compressive strength of 1800 Psi at 28 days and the N-type mortar should have a minimum compressive strength of 750 Psi. 5% and 10% textile ETP and tannery sludge both as separate and mixed mode replacement of cement by weight samples have more than 1800 Psi compressive strength at 28 days. 15% and 20% textile ETP and tannery sludge both as separate and mixed mode replacement of cement by weight samples have more than 750 Psi compressive strength at 28 days. So, 5% and 10 % textile ETP and tannery sludge both as separate and mixed mode replacement of cement by weight can be used for the purposes of S-type mortar, and 15% and 20 % textile ETP and tannery sludge both as separate and mixed mode replacement of cement by weight can be used for the purposes of N-type mortar. Figures 4.5, 4.6, and 4.7 is shown that the compressive strength is decreased, when the textile ETP and tannery sludge both as separate and mixed mode inclusion is increased.

Table 4.12: Compressive Strength After 3 days of Curing

	Sludge Used (%)	Code	Maximum Load (KN)	Compressive Strength (Psi)
Textile ETP Sludge	5	A1	15.83	889.68015
	10	A2	19.59	1101.00026
	15	A3	16.58	931.83177
	20	A4	12.03	676.11195
Tannery Sludge	5	B1	22.81	1281.97121
	10	B2	20.32	1142.02783
	15	B3	13.57	762.66327
	20	B4	13.03	732.31411
Textile ETP + Tannery Sludge	5	C1	21.29	1196.54393
	10	C2	20.52	1153.26827
	15	C3	9.46	531.67241
	20	C4	12.27	689.60047

Table 4.13: Compressive Strength After 7 days of Curing

	Sludge Used (%)	Code	Maximum Load (KN)	Compressive Strength (Psi)
Textile ETP Sludge	5	A1	25.35	1424.72468
	10	A2	20.06	1127.41527
	15	A3	17.29	971.73530
	20	A4	14.8	831.79193
Tannery Sludge	5	B1	28.31	1591.08307
	10	B2	22.91	1287.591421
	15	B3	14.7	826.1717108
	20	B4	13.81	776.1517909
Textile ETP + Tannery Sludge	5	C1	24.15	1357.28210
	10	C2	21.49	1207.78436
	15	C3	14.19	797.50861
	20	C4	13.18	740.74443

Table 4.14: Compressive Strength After 28 days of Curing

	Sludge Used (%)	**Code**	**Maximum Load (KN)**	**Compressive Strength (Psi)**
Textile ETP Sludge	5	A1	39.51	2220.547231
	10	A2	36.05	2026.087767
	15	A3	28.16	1582.652747
	20	A4	14.77	830.1058618
Tannery Sludge	5	B1	23.71	1332.55315
	10	B2	38.98	2190.76009
	15	B3	26.84	1508.46590
	20	B4	21.45	1205.53627
Textile ETP + Tannery Sludge	5	C1	34.21	1922.67580
	10	C2	34.83	1957.52114
	15	C3	26.66	1498.34951
	20	C4	19.49	1095.38004

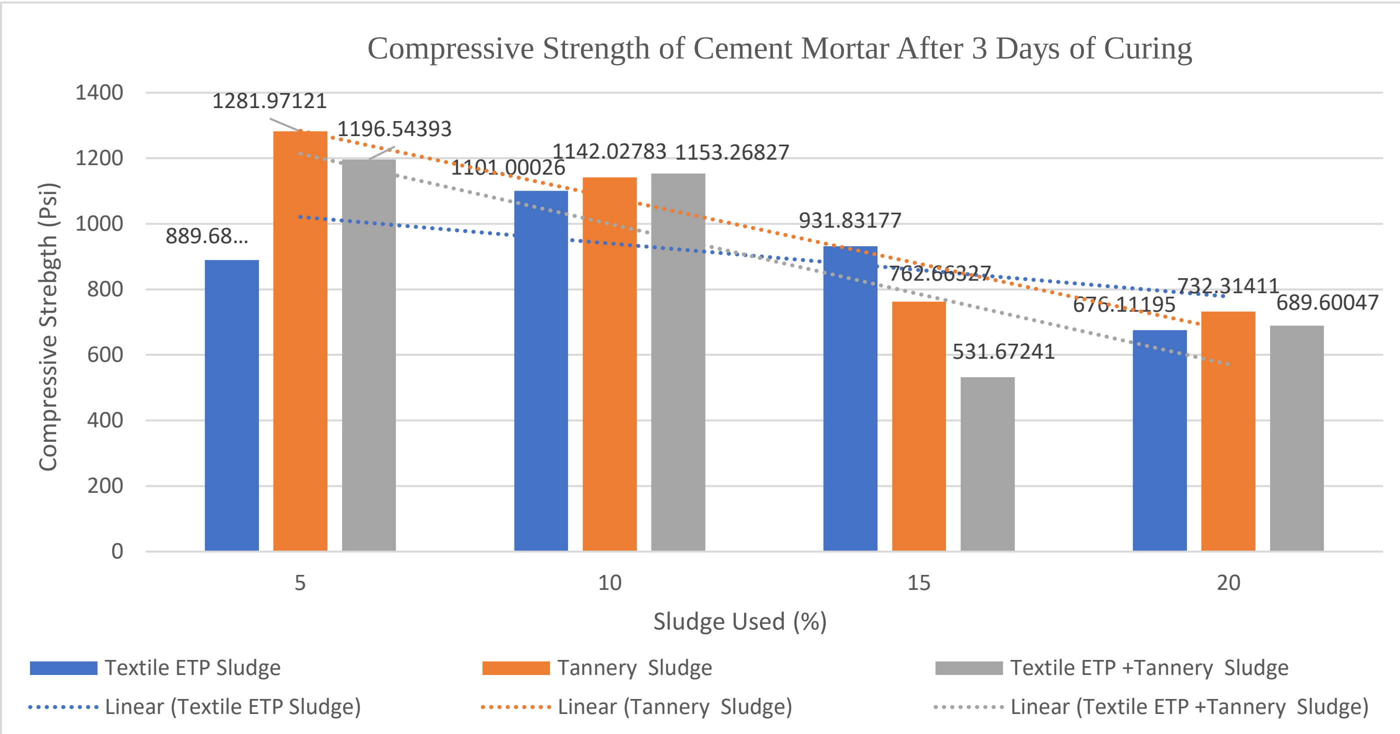

Figure 4.5: Compressive Strength of Cement Mortar After 3 Days of Curing

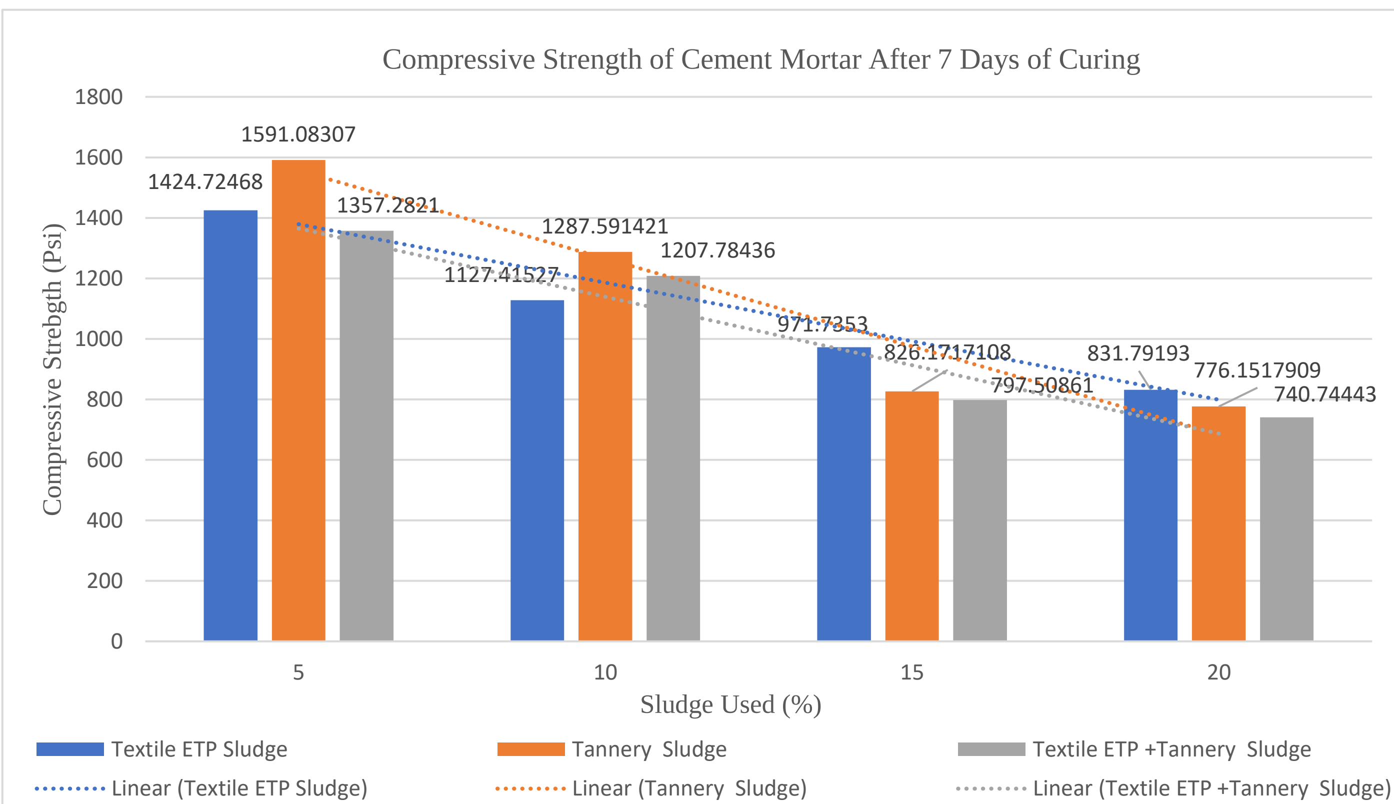

Figure 4.6: Compressive Strength of Cement Mortar After 7 Days of Curing

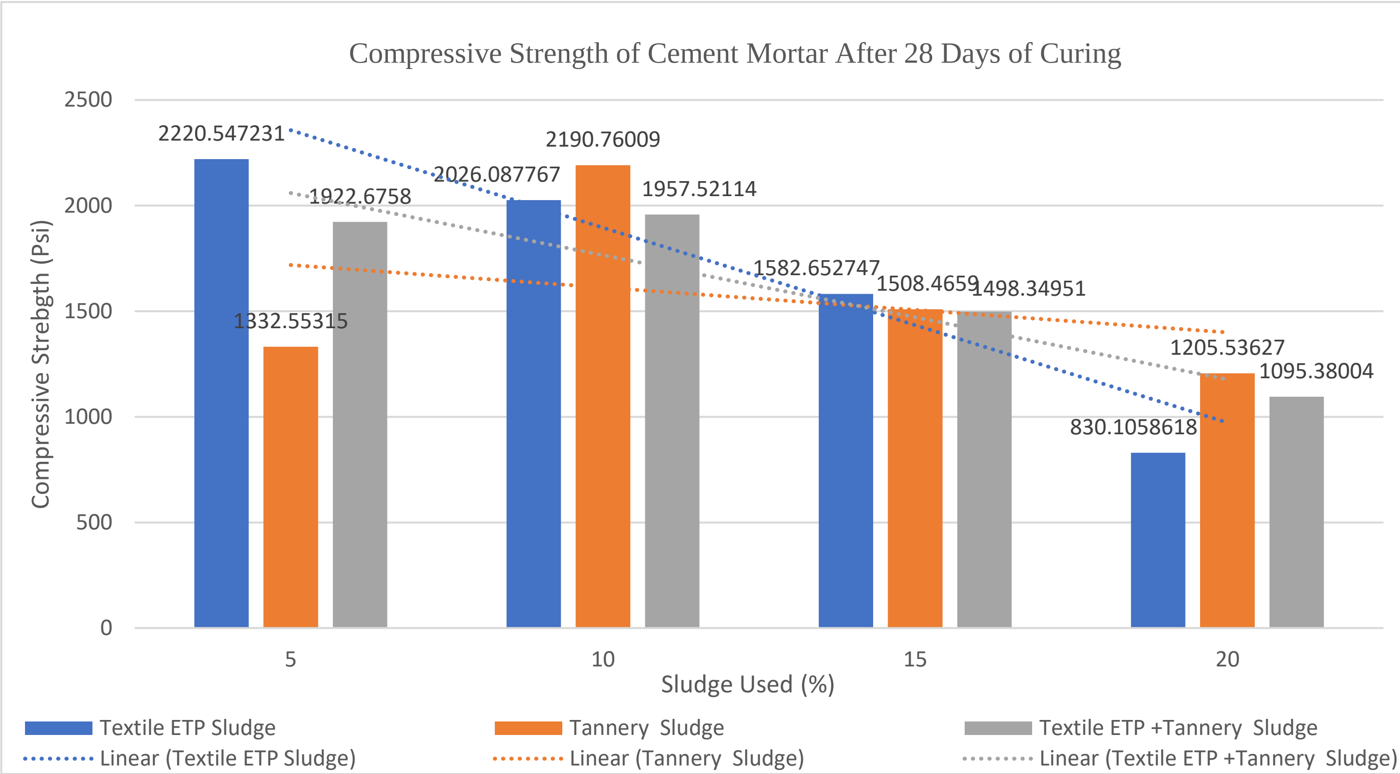

Figure 4.7: Compressive Strength of Cement Mortar After 28 Days of Curing

4.2.4 Tensile Strength of Cement Mortar Briquet

The tensile strength of the briquet samples (cement is replaced by textile ETP and tannery sludge both as separate and mixed mode) is shown in table 4.6, 4.7, 4.8, and figure 4.3, 4.4, and 4.5. Based on figures 4.3, 4.4, and 4.5 its clear that the tensile strength of cement mortar briquet is decreased when the inclusion of sludge (textile ETP and tannery sludge both as separate and mixed mode) is increased. some error result data are found in some samples and this occurred because of a mixing problem of sludge and cement. Textile ETP and tannery sludge required well mixing with cement. During the cement mortar preparation, textile ETP and tannery sludge were not well mixed with cement for that reason got some error result data. According to ASTM 307-03, chemical-resistant mortar during its service life is not, as usual, are not under tension, and tension test is not recommended for mortar so lower or higher tension will not produce any impact on mortar during service life.

Table 4.15: Tensile Strength After 3 days of Curing

	Sludge Used	Code	Maximum Load (N)	Tensile Strength (Psi)
Textile ETP Sludge	5	A1	1020	229.30554
	10	A2	1060	238.29791
	15	A3	550	123.64514
	20	A4	760	170.85511
Tannery Sludge	5	B1	1000	224.80935
	10	B2	750	168.60701
	15	B3	750	168.60701
	20	B4	600	134.88561
Textile ETP + Tannery Sludge	5	C1	800	179.84748
	10	C2	800	179.84748
	15	C3	960	215.81698
	20	C4	600	134.88561

Table 4.16: Tensile Strength After 7 days of Curing

	Sludge Used	Code	Maximum Load (N)	Tensile Strength (Psi)
Textile ETP Sludge	5	A1	1250	281.01169
	10	A2	1200	269.77122
	15	A3	950	213.56888
	20	A4	900	202.32841
Tannery Sludge	5	B1	1250	281.01169
	10	B2	870	195.58413
	15	B3	800	179.84748
	20	B4	700	157.36654
Textile ETP + Tannery Sludge	5	C1	1030	231.55363
	10	C2	1000	224.80935
	15	C3	1000	224.80935
	20	C4	800	179.84748

Table 4.17: Tensile Strength After 28 days of Curing

	Sludge Used	Code	Maximum Load (N)	Tensile Strength (Psi)
Textile ETP Sludge	5	A1	1300	292.25215
	10	A2	1550	348.45449
	15	A3	1200	269.77122
	20	A4	1300	292.25215
Tannery Sludge	5	B1	1320	296.74834
	10	B2	1300	292.25215
	15	B3	1200	269.77122
	20	B4	1300	292.25215
Textile ETP + Tannery Sludge	5	C1	1850	415.89730
	10	C2	1540	346.20640
	15	C3	1470	330.46974
	20	C4	1350	303.49262

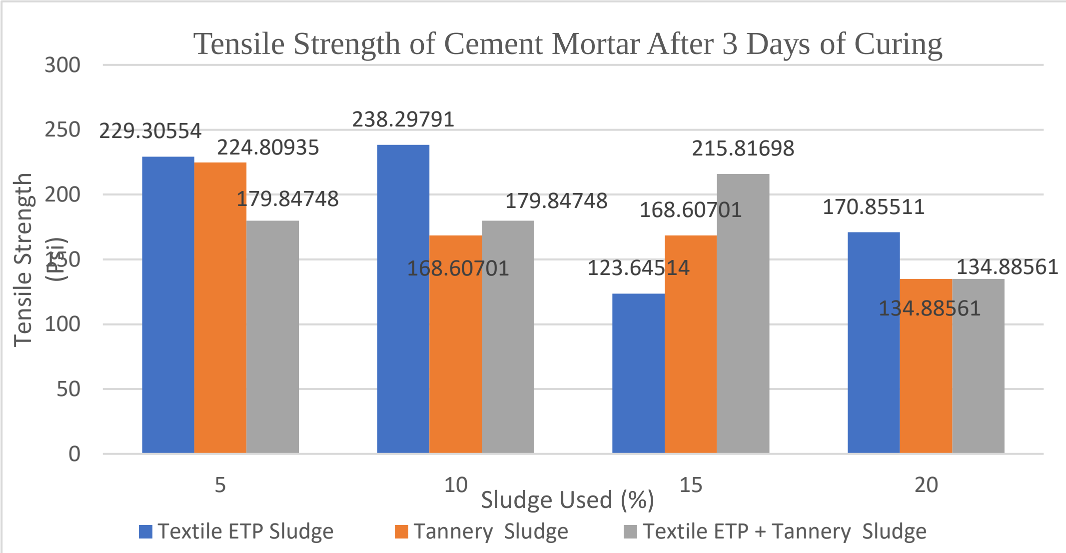

Figure 4.8: Tensile Strength After 3 days of Curing

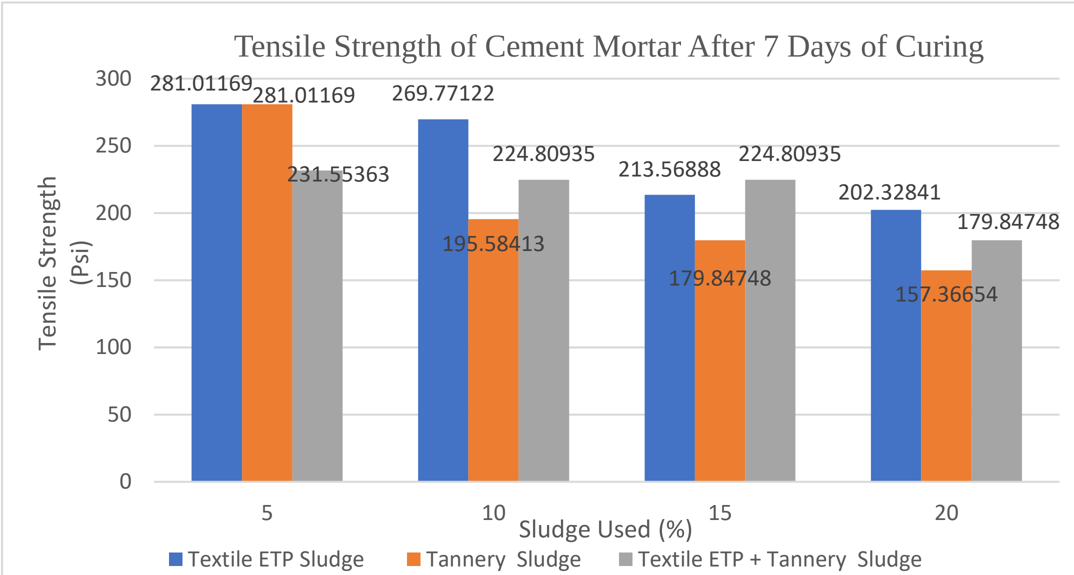

Figure 4.9: Tensile Strength After 7 days of Curing

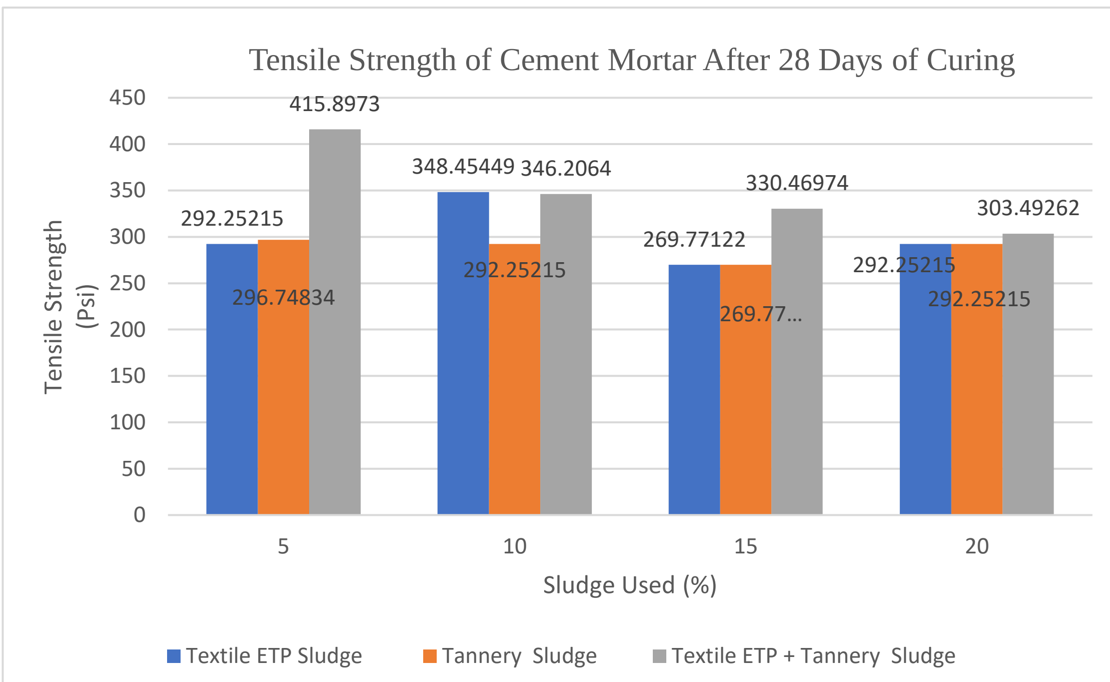

Figure 4.10: Tensile Strength After 28 days of Curing

4.2.5 Specific Gravity

The specific gravity of textile ETP and tannery sludge both as separate and mixed mode is found 1.11, 1.29, 1.2, shown in table 4.4. Textile ETP sludge specific gravity is less than tannery sludge, and the mixed mode of textile ETP and tannery sludge, which means if it is added in cement mortar it will reduce the resultant unit weight of the cement mortar. According to Shrikant, et al., 2013 sludge specific gravity were ranged from 1.2 to 2.32. tannery sludge, and the mixed mode of textile ETP and tannery sludge specific gravity are in the standard range. The specific gravity of textile ETP sludge is closer to the standard range so it will not cause any problem.

Table 4.18: Specific Gravity of Sludge Samples

Sludge Sample	**Specific Gravity**
Textile ETP Sludge	1.11
Tannery Sludge	1.29
Textile ETP Sludge + Tannery Sludge	1.2

4.2.6 Water Absorption

The water absorption results of cement mortar after 28 days of curing are shown in table 4.9. However, according to ASTM C55-17 specified that the normal and medium weight masonry units should have maximum water absorption of 8% and 11.3% respectively. As masonry is a rally of unit and mortars so the same limit can be considered for cement mortar. Therefore, it can be said that except for D2 all samples comply with the specifications. Figure 4.6 showed that the water absorption of cement mortar is decreasing when the sludge inclusion is increasing. An error is found in the D3 sample the water absorption result should have been more than D4. This happened because of some mixing problem in sludge and cement. These sludges required proper mixing with cement for an accurate result.

Table 4.19: Water Absorption After 28 days of Curing

Sludge Used	Code	Textile ETP Sludge Cube Weight of cube after 24-hour oven dry (W_d), (gm)	Textile ETP Sludge Cube weight after 96-hour immersion in water, (W_s) (gm)	water Absorption (%)
10	D2	210.20	237.40	12.94006
15	D3	235.80	250.40	6.19169
20	D4	217.60	234.20	7.62868
Sludge Used	Code	Tannery Sludge Cube Weight of cube after 24-hour oven dry (W_d), (gm)	Tannery Sludge Cube weight after 96-hour immersion in water, (W_s) (gm)	water Absorption (%)
10	E2	222.4	244.4	9.89209
15	E3	231.2	242	4.67128
20	E4	229.4	237.4	3.48736
Sludge Used	Code	Textile ETP + Tannery Sludge Cube Weight of cube after 24-hour oven dry (W_d), (gm)	Textile ETP + Tannery Sludge Cube weight after 96-hour immersion in water, (W_s) (gm)	water Absorption (%)
10	F2	221.2	244.8	10.66908
15	F3	231.4	241.6	4.40795
20	F4	227	236.4	4.14097

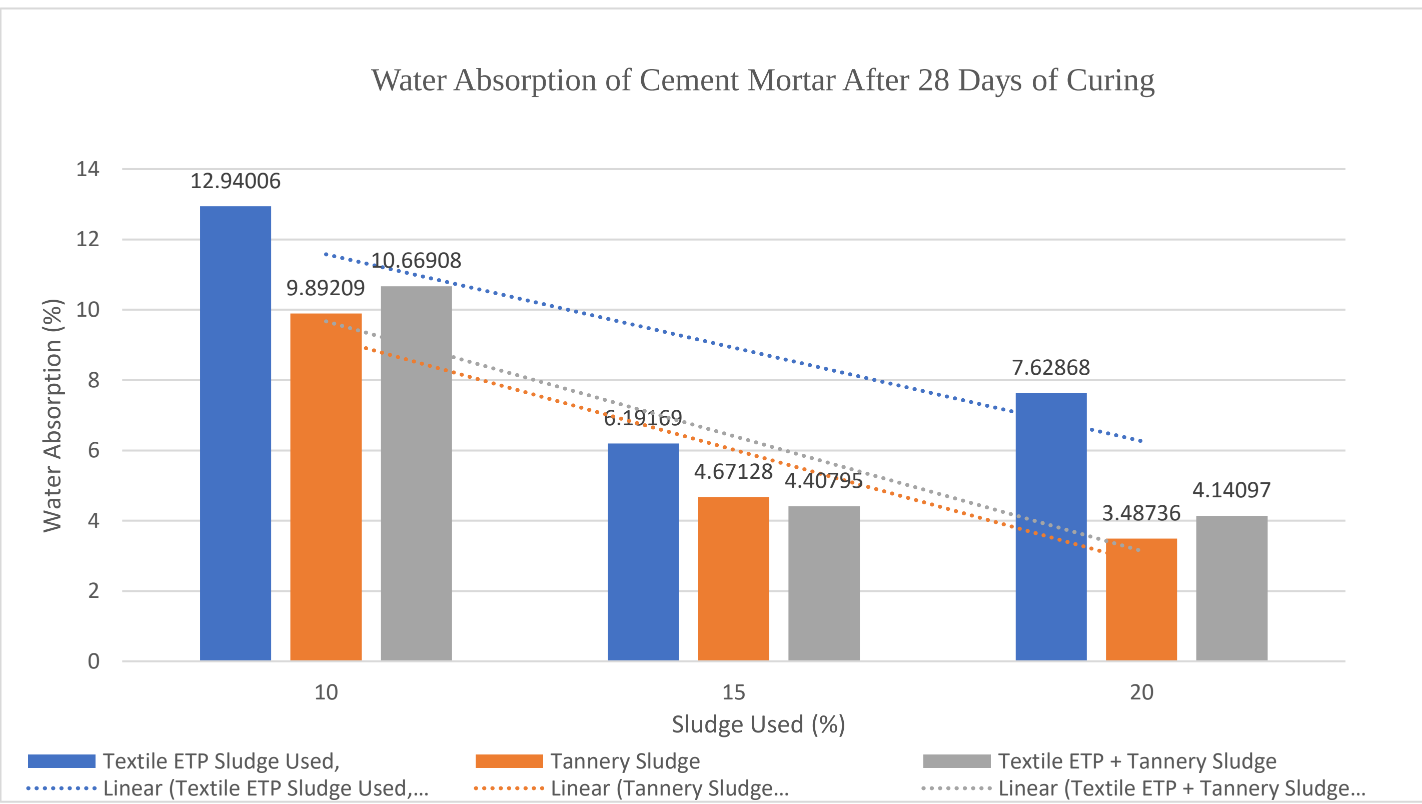

Figure 4.11: Water Absorption After 28 days of Curing

Chapter 5

Conclusion and Recommendation

5.1 Conclusion

In this study, the sludges generated from the effluent treatment plant (ETP) of the textile industry, and common effluent treatment (CETP) plant of the tannery and mixture of textile ETP and tannery sludge are utilized in cement mortar. These cement mortars have been investigated based on their physical and mechanical properties as well as on their environmental aspects. The cement mortars are prepared to incorporate 0%, 5%, 10%, 15%, 20% (by dry weight) of textile ETP, tannery sludge both as separate and mixed mode and the relevant engineering properties of the sludges incorporated cement mortar were assessed.

The major findings of this study are follows:

a. If an oven facility is not available then to remove the moisture from the textile ETP and tannery sludge need to dry in the sun at least for four hours and seven days. The moisture content of the textile ETP and tannery sludge is not uniform everywhere. Based on the pH value the dry textile ETP and tannery sludge are classified as acidic and basic separately and mixed-mode of textile ETP and tannery sludge is classified as neutral. The organic matter content of mixed-mode textile ETP and tannery sludge is 53.76. The mixed-mode of textile ETP and tannery sludge consists of similar chemical components present in the Portland composite cement (PCC) but in different quantities. The heavy metals like As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn concentration results of the sample (mixed-mode of textile ETP and tannery sludge) have complied with USEPA guideline values.

Based on the present investigation results it is evident that textile ETP and tannery sludge can be utilized safely in cement mortar for partial replacement of cement. Textile ETP and tannery sludge both as separate and mixed mode up to 10% replacement of cement fulfilled the compressive strength requirement at 28 days of S type mortar for masonry structure. Up to 20% of textile ETP and tannery sludge both as separate and mixed mode partial replacement of cement fulfilled the compressive strength requirement at 28 days of N-type mortar for masonry structure. It was found the compressive strength is decreased when the sludge inclusion increased. During the service life, cement mortar will not be under tension so low or high tensile strength of cement mortar will not cause any problem. The specific gravity of textile ETP and tannery both as separate and mixed mode complied the standard range of sludge specific gravity. All samples have followed the standard specification of water absorption except the D2 (Cement replaced by 10 % textile ETP sludge) sample. It will not cause any serious issues during the service life. In general, when the sludge inclusion increased the water absorption rate of cement mortar is decreased.

b. The initial setting time for all cement-sludge mix proportion of partial replacement of cement by textile ETP and tannery both as separate and mixed mode is found more than 60 minutes, except 15% and 20% partial replacement of cement by tannery sludge, and followed the standard specification of initial and final setting time of cement. It was found the initial and final setting time decreased when the sludge inclusion increased.

After analyzing the results, it can be said that textile ETP and tannery sludge is safe to use in cement mortar. The textile ETP and tannery sludge both as separate and mixed mode can be a replacement of cement up to 10% in cement mortar, and this mortar can be used in exterior, at or below-grade applications with normal to moderate loading conditions of masonry structures, the locations where the masonry is in contact with the ground such as paving or shallow retaining walls, and it can be also used in foundation walls, manholes, sewers, pavements, walks, and patios. The textile ETP sludge as separate and the mixed mode of textile ETP and tannery sludge can be a replacement of cement up to 20% in cement mortar, and this mortar can be used in above-grade masonry structures such as exterior load-bearing and non-load bearing walls, parapet walls, interior load-bearing walls, non-bearing partitions.

The textile ETP and tannery sludge both as separate use have to handle carefully otherwise it can be because of health and skin issues. 15% and 20 % partial replacement of cement by tannery sludge as separate cannot be used in cement mortar because of low initial setting time.

5.2 Recommendation for Future Work

a. Different researchers have shown that sewage sludge and textile dyeing industries sludge can be utilized in concrete, pavement blocks, ceramics, and brick. So, similar studies can be carried out for textile ETP, tannery sludge, and a mixture of textile ETP and tannery sludge.
b. Similar approach can be carried out using admixtures with cement-sludge mix.
c. Similar approach can be carried out using incinerated sludges (Textile ETP, tannery sludge both as separate and mixed mode) ash.

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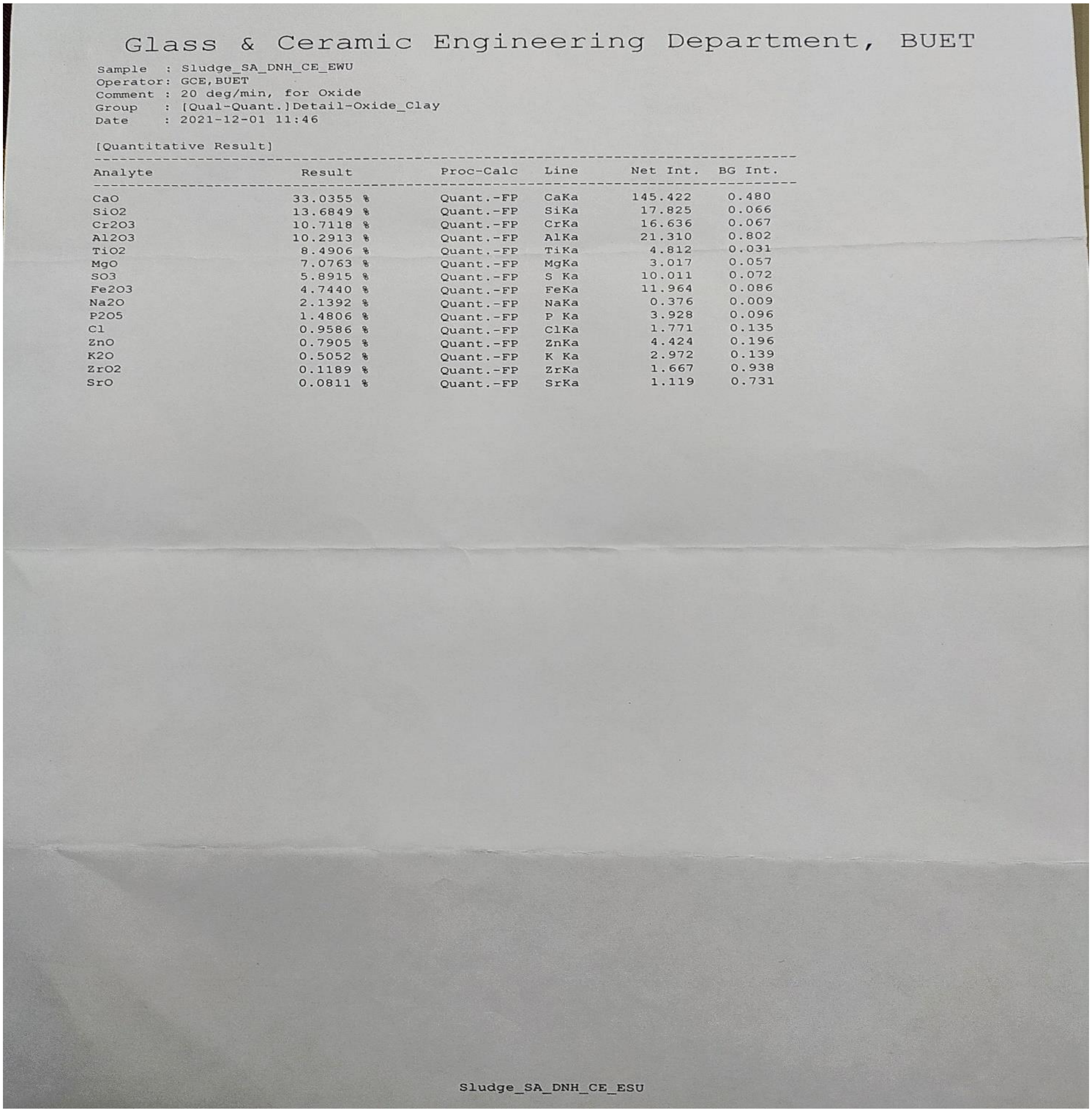
Appendix A

Appendix A contains the chemical composition test report by the Department of Glass and Ceramic Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.



Glass & Ceramic Engineering Department, BUET

Sample : Sludge_SA_DNH_CE_EWU
Operator: GCE,BUET
Comment : 20 deg/min, for Oxide
Group : [Qual-Quant.]Detail-Oxide_Clay
Date : 2021-12-01 11:46

[Quantitative Result]

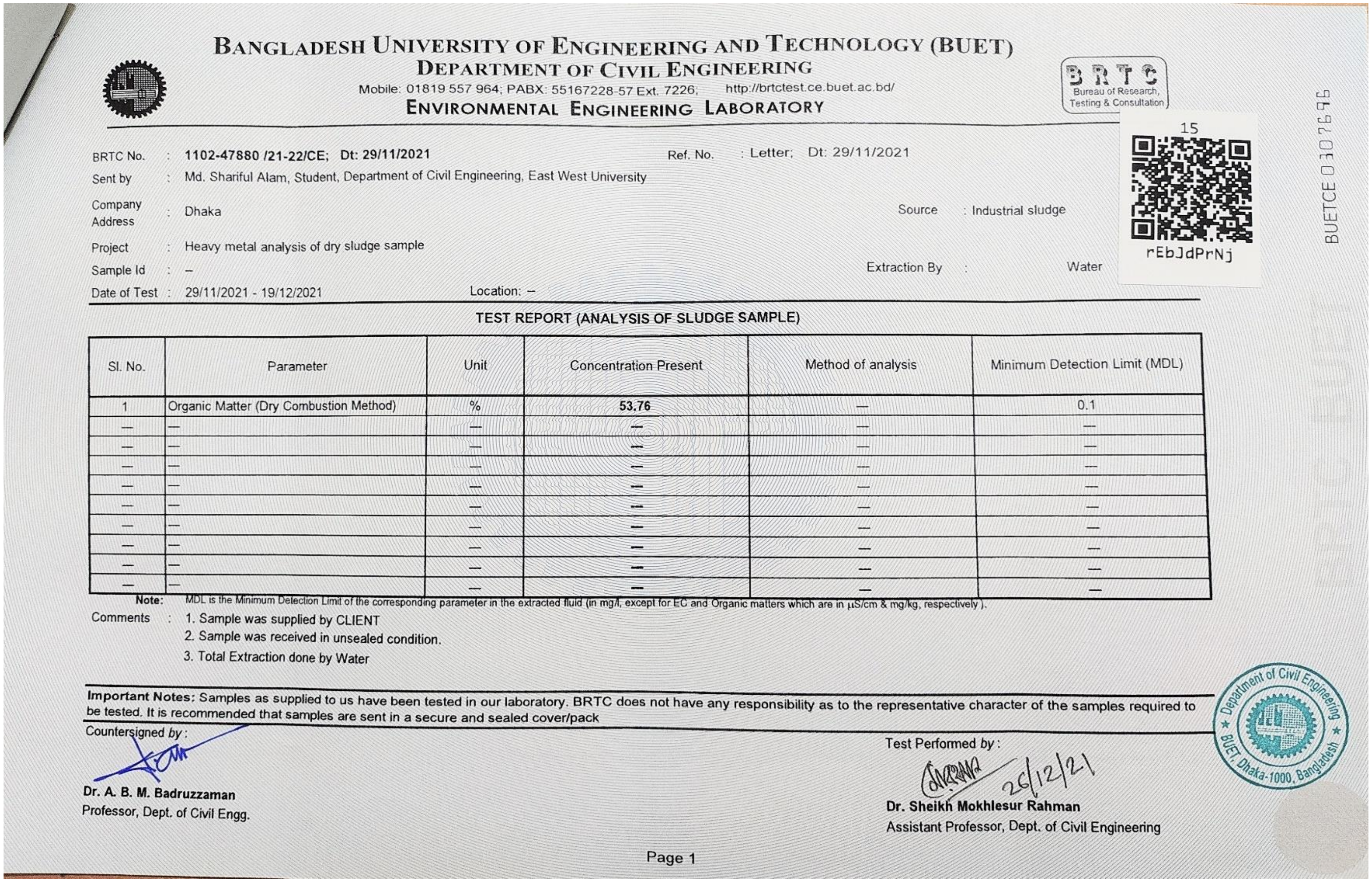
Analyte	Result	Proc-Calc	Line	Net Int.	BG Int.
CaO	33.0355 %	Quant.-FP	CaKa	145.422	0.480
SiO2	13.6849 %	Quant.-FP	SiKa	17.825	0.066
Cr2O3	10.7118 %	Quant.-FP	CrKa	16.636	0.067
Al2O3	10.2913 %	Quant.-FP	AlKa	21.310	0.802
TiO2	8.4906 %	Quant.-FP	TiKa	4.812	0.031
MgO	7.0763 %	Quant.-FP	MgKa	3.017	0.057
SO3	5.8915 %	Quant.-FP	S Ka	10.011	0.072
Fe2O3	4.7440 %	Quant.-FP	FeKa	11.964	0.086
Na2O	2.1392 %	Quant.-FP	NaKa	0.376	0.009
P2O5	1.4806 %	Quant.-FP	P Ka	3.928	0.096
Cl	0.9586 %	Quant.-FP	ClKa	1.771	0.135
ZnO	0.7905 %	Quant.-FP	ZnKa	4.424	0.196
K2O	0.5052 %	Quant.-FP	K Ka	2.972	0.139
ZrO2	0.1189 %	Quant.-FP	ZrKa	1.667	0.938
SrO	0.0811 %	Quant.-FP	SrKa	1.119	0.731

Sludge_SA_DNH_CE_ESU

Figure A-1: Report of Chemical Composition

Appendix B

Appendix B contains the organic matter content test report by BRT, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.



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ENVIRONMENTAL ENGINEERING LABORATORY

BRTC Bureau of Research, Testing & Consultation

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rEbJdPrNj

BUETCE 0107695

BRTC No. : 1102-47880 /21-22/CE; Dt: 29/11/2021 Ref. No. : Letter; Dt: 29/11/2021
Sent by : Md. Shariful Alam, Student, Department of Civil Engineering, East West University
Company Address : Dhaka Source : Industrial sludge
Project : Heavy metal analysis of dry sludge sample
Sample Id : –
Extraction By : Water
Date of Test : 29/11/2021 - 19/12/2021 Location: –

TEST REPORT (ANALYSIS OF SLUDGE SAMPLE)

Sl. No.	Parameter	Unit	Concentration Present	Method of analysis	Minimum Detection Limit (MDL)
1	Organic Matter (Dry Combustion Method)	%	**53.76**	—	0.1
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—

Note: MDL is the Minimum Detection Limit of the corresponding parameter in the extracted fluid (in mg/l, except for EC and Organic matters which are in µS/cm & mg/kg, respectively).

Comments : 1. Sample was supplied by CLIENT
2. Sample was received in unsealed condition.
3. Total Extraction done by Water

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/pack

Countersigned by :

Dr. A. B. M. Badruzzaman
Professor, Dept. of Civil Engg.

Test Performed by :
26/12/21
Dr. Sheikh Mokhlesur Rahman
Assistant Professor, Dept. of Civil Engineering

Department of Civil Engineering ★ BUET, Dhaka-1000, Bangladesh ★

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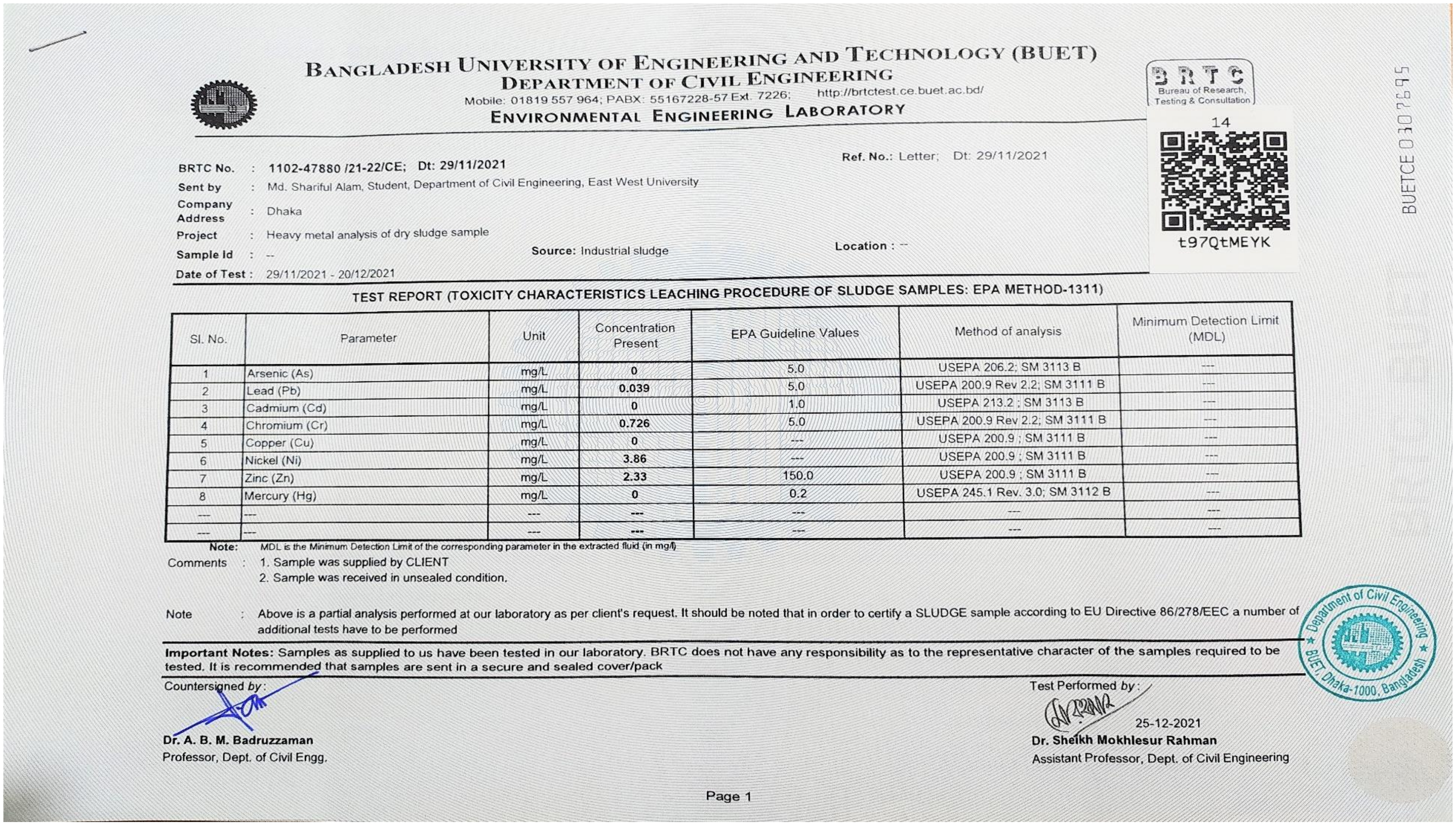
Figure B-1: Report of Organic Matter Content

Appendix C

Appendix C contains the TCLP (Heavy Metal Determination) test report by BRT, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.



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BUETCE 0307695

BRTC No. : 1102-47880 /21-22/CE; Dt: 29/11/2021 Ref. No.: Letter; Dt: 29/11/2021
Sent by : Md. Shariful Alam, Student, Department of Civil Engineering, East West University
Company Address : Dhaka
Project : Heavy metal analysis of dry sludge sample
Sample Id : -- Source: Industrial sludge Location : --
Date of Test : 29/11/2021 - 20/12/2021

TEST REPORT (TOXICITY CHARACTERISTICS LEACHING PROCEDURE OF SLUDGE SAMPLES: EPA METHOD-1311)

Sl. No.	Parameter	Unit	Concentration Present	EPA Guideline Values	Method of analysis	Minimum Detection Limit (MDL)
1	Arsenic (As)	mg/L	0	5.0	USEPA 206.2; SM 3113 B	---
2	Lead (Pb)	mg/L	0.039	5.0	USEPA 200.9 Rev 2.2; SM 3111 B	---
3	Cadmium (Cd)	mg/L	0	1.0	USEPA 213.2 ; SM 3113 B	---
4	Chromium (Cr)	mg/L	0.726	5.0	USEPA 200.9 Rev 2.2; SM 3111 B	---
5	Copper (Cu)	mg/L	0	---	USEPA 200.9 ; SM 3111 B	---
6	Nickel (Ni)	mg/L	3.86	---	USEPA 200.9 ; SM 3111 B	---
7	Zinc (Zn)	mg/L	2.33	150.0	USEPA 200.9 ; SM 3111 B	---
8	Mercury (Hg)	mg/L	0	0.2	USEPA 245.1 Rev. 3.0; SM 3112 B	---
---	---	---	---	---	---	---
---	---	---	---	---	---	---

Note: MDL is the Minimum Detection Limit of the corresponding parameter in the extracted fluid (in mg/l)

Comments : 1. Sample was supplied by CLIENT
2. Sample was received in unsealed condition.

Note : Above is a partial analysis performed at our laboratory as per client's request. It should be noted that in order to certify a SLUDGE sample according to EU Directive 86/278/EEC a number of additional tests have to be performed

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/pack

Countersigned by:
Dr. A. B. M. Badruzzaman
Professor, Dept. of Civil Engg.

Test Performed by:
25-12-2021
Dr. Sheikh Mokhlesur Rahman
Assistant Professor, Dept. of Civil Engineering

Department of Civil Engineering, BUET, Dhaka-1000, Bangladesh

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Figure C-1: Report of TCLP (Heavy Metal Determination)