USE OF STABILIZED TEXTILE ETP SLUDGE AS PARTIAL REPLACEMENT OF CEMENT

A Thesis submitted in partial-fulfillment of the requirements for the award of degree of

MASTER OF ENGINEERING

IN

STRUCTURAL ENGINEERING

Submitted by

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JULY, 2018

DECLARATION

I, Gaurav Jain hereby declare that the work presented in this thesis entitled, **"USE OF STABILIZED TEXTILE ETP SLUDGE AS PARTIAL REPLACEMENT OF CEMENT"**, in partial fulfillment of the requirement for the award of degree of **Master of Engineering** in **Structural engineering** submitted at Civil Engineering Department, Thapar Institute of Engineering & Technology (Deemed to be University), Patiala is an authentic record of my own work carried under the supervision of **Dr. Shweta Goyal, Associate Professor and Dr. Rafat Siddique, Senior Professor**, Department of Civil Engineering, Thapar Institute of Engineering & Technology (Deemed to be University), Patiala from January to July, 2018. The matter presented in this has not been submitted either in part or full to any other university or institute for the award of any other degree.

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CERTIFICATE

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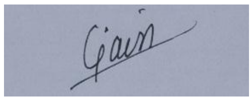

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ABSTRACT

Contaminated textile effluent treatment plant (ETP) sludge with heavy metals has become a major environment issue. One of the possible ways to using the sludge is in building materials. However, ETP sludge contains heavy metals, that affect mechanical properties of concrete when used. Some heavy metals that affect human health and is associated to have caused serious diseases which interrupts kidney, nervous system and blood vessels. In this study, appropriate treatment technology such as stabilization method are being used and to some extent, it is capable of controlling these metals. The object of the study is to stabilized sludge so as to control leaching of heavy metal.

One of the main objectives of this study is to evaluate utilizing stabilized effluent treatment plant sludge in cement mortars. For stabilization, Low-grade MgO is used in this study. Low-grade MgO is an economically feasible alternative in the stabilization of heavy metal from contaminated sludge.

The cement is replaced with 5%, 10% and 15% with or without stabilize textile ETP sludge. The compressive strength of mortar cube and sorptivity of a cylinder with the use of textile ETP as a partial replacement with cement is evaluated. The microstructure of the mortar mix was analyzed by Scanning electron microscopy (SEM). The leachability of heavy metals was analyzed by Inductively coupled plasma atomic emission spectroscopy (ICP-AES). At different percentage of stabilization of textile ETP sludge with LG-MgO, pH was measured by pH meter.

It was observed that with an increase in the percentage of replacement of cement with textile ETP sludge in a mortar the compressive strength reduces gradually whereas the use of stabilized sludge lead to increase in the compressive strength compared to control mix. The maximum compressive strength was achieved in 5% replacement level. The cement stabilized sludge mortar samples meet the required strength for structural as well as nonstructural applications. The water absorption, sorptivity decreases with increase in replacement level of stabilized textile ETP sludge.

Keywords: Textile ETP sludge, stabilization, mortar, compressive strength, low-grade MgO.

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LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BIS	Bureau of Indian Standards
CH	Calcium Hydroxide
CSH	Calcium Silicate Hydrate
E	Ettringite
EDS	Energy Dispersive Spectroscopy
ETP	Effluent Treatment Plant
GGBFS	Ground Granulated Blast Furnace Slag
ITZ	Inter Transition Zone
OPC	Ordinary Portland Cement
SEM	Scanning Electron Microscopy
UTM	Universal Testing Machine
w/c	Water to Cement Ratio
w/b	Water to Binder Ratio
XRD	X-Ray Diffraction

LIST OF UNITS

Units	Word(s)
kg	Kilogram
g	Gram
mg	Milligram
°C	Degree Celsius
%	Percent
m	Meter
cm	Centimeter
mm	Millimeter
µm	Micrometer
N	Newton
MPa	Mega Pascal
kg/m^3	Kilogram per cubic meter
N/mm^2	Newton per square millimeter
kN	Kilo Newton
hr.	Hour
min	Minute
sec	Second
l	Liter
ml	Milliliter
m/s	Meter per second
km/s	Kilometer per second
θ	Theta

CHAPTER 1

INTRODUCTION

1.1 GENERAL

'Save the earth to save the life' right from the establishment of urbanization and industrialization. It was realized with the time, environment and growth simultaneously important. We cannot ignore the environment in which we live. With the growth of science & technology, construction industries are rapidly increasing with time. The need for concrete's constituent material is also increasing. Cement and sand are major materials used for the composition of mortar and concrete but has its own environmental and social impacts.

1.2 NEED FOR SUPPLEMENTARY CEMENTITIOUS MATERIALS

The demand of building material in India would be around US$ 1333 million annually (Anon, 2002). Cement is a binder, a substance material which is used in construction that sets, hardens and stick to other materials and binding them together. The total production of cement worldwide is of the order of 4100 million metric tonnes. India, with nearly 270 million metric tonnes of cement production capacity (www.statista.com), India is the second largest cement producer in the world and accounts for 6.9 percent of world's cement output (www.ibef.org).

The activity of construction has increased in almost all the developing countries in the world. There has been a great effort for improving the standards and quality of the properties of concrete which is used as a construction material. Cost is also a factor which affects the growth. Increasing demand implies an increase in the cost of cement and during the production of cement CO_2 is produced which causes global warming. It is estimated that cement producing industry accounts for around 5% of global carbon dioxide (CO_2) emissions. By reducing cement consumption, environment can be protected. Thus, there is a strong need to find an eco-friendly substance in concrete as an alternate or a more environment friendly cement concrete for further developments without depleting the environment. Hence research has been carried out for cheap and easily available alternative material for cement by many researchers. Fly ash, silica fume, textile sludge, wood ash, Ground-granulated blast-furnace slag (GGBS or GGBFS), rice husk ash, glass powder etc. are used in mortar or concrete as partial replacement of cement. An attempt was made to partially replace of the cement with waste material like Textile sludge for use as structural as well as non-structural material. The different cemental materials that are attempted to be used replacement of cement are presented in following sections.

1.3 DIFFERENT ALTERNATIVE WASTE MATERIALS FOR CEMENT

There are two type of waste material non-reacting waste materials and chemically reacting waste materials. The material which does not chemically reacted with cement is called as noble or the non-reacting materials. Some of them are Plastic Waste, Metal Scrap Waste, Wood Waste, Rubber Waste, Rubble Waste, Coconut Fibers etc. It generally used as a filler material and these behave as nonbonding with cement concrete. The chemically waste material is defined as the materials which impact and take part in the hydration reaction of cement. Some of them are Bagasse Ash, Crushed Fine Waste Glass, Fly Ash, GGBS etc. All these materials affect the chemical reaction of cement hydration. Some of the chemically reactive and non-reacting waste material used as a partial replacement with cement are discussed below:

1.3.1 Coal Fly Ash

Coal Fly ash is a by-product of the combustion of pulverized coal. It is removed by the dust collection systems from the exhaust gases of fossil fuel power plants as very fine, predominantly spherical glassy particles and also from the combustion gases before they are discharged into the atmosphere. The size of particles is dependent on the type of dust collection equipment. Fly ash is generally finer than Portland cement. The diameter of fly ash particle size range varies from less than 1 um to 300 um. The components of fly ash differ, based upon the source and composition of the coal being burned, but all fly ash includes substantial amounts of silicon dioxide (SiO_2), calcium oxide (CaO) and aluminum oxide (Al_2O_3). It is found that fly ash is toxic in nature. Due to its pozzolanic and fineness and sometimes self-cementitious nature, fly ash is extensively used in cement and concrete. Based upon the collection system, varying from electrical to mechanical precipitators or filters and bag houses, about 85-99% of the ash from the flue gases in recovered in the form of fly ash. It accounts for 75-85% of the total coal ash, and the remainder is collected as boiler slag or bottom ash.

Due to its mineralogical composition, amorphous and fine particle size fly ash is generally pozzolanic and in some cases also cementitious whereas boiler slag and bottom ash are not pozzolanic in nature and they are much coarser. Therefore, it is important to understand that all the ash is not fly ash and the fly ashes produced by different power plants are not equally pozzolanic. The serious disadvantage of fly ash is its non-uniformity. Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, alumina. Iron and silica content in the ash. The chemical content of coal burned to fly ash affects the chemical properties of the fly ash i.e., anthracite, bituminous, and lignite. Fly ash can be gray to tan-gray, depending on its mineral and chemical constituents Fig 1.1 and Fig 1.2 shows the coal fly ash powder and scanning electron microscope (SEM) Image of the cross-section of the particle.

Presently India is producing 120-150 million tons per year of coal fly ash, in which 120 million tons is generated from existing coal-based thermal power plants. India is in the third position in the world of producing coal and thermal power plant installations. Concrete and Cement Industry accounts for 50% of Fly Ash utilization, the total utilization of which at present is around 30 million tons (28%).

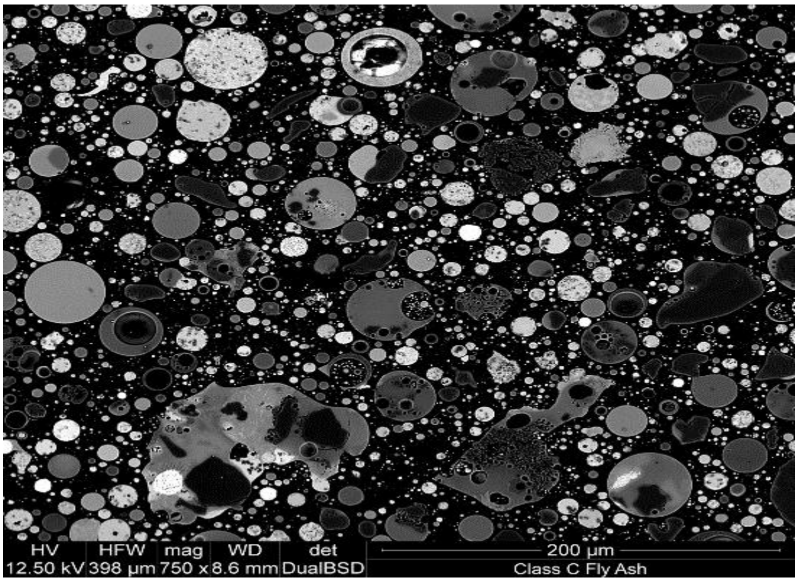


Fig 1. 1 Scanning Electron Microscope (SEM) Image of Cross Section of Particle (https://en.wikipedia.org/wiki/Fly_ash)

Fig 1. 2 The Coal Fly Ash Powder
(www.caer.uky.edu)

1.3.2 Ground-Granulated Blast Furnace Slag (GGBFS)

GGBFS is a blast furnace slag grounded has been quenched, either by granulation or palletization and then dried and ground to a fine powder. The raw material is a by-product of the iron making industry and comes from the iron blast furnaces. Presently, total productions of steel slag in India, are around 12 million tons per year. Primarily, the slag consists of calcium, magnesium, manganese and aluminum silicates in various combinations.

We can use GGBFS as a direct replacement for Portland cement, basis by weight. Replacement levels for GGBFS vary from 30% to 85%. Generally, 40 to 50% is used in most instances. GGBFS cement is used for its environmental benefits, improved appearance for exposed concrete and technical benefits, including resistance to sulfate and chloride attack and reduced heat of hydration. The specific gravity of the slag is 2.63. The bulk density of fine aggregate is almost similar to the bulk density of granulated slag. The water absorption of slag was found to be less than 2.60%. Silica content in the slag is about 26% which is advantageous since it is one of the constituents of the natural fine aggregate used in normal concreting operations. The fineness of slag is 2.37. GGBFS as an alternative construction material for natural sand in mortar application has been studied by the various researcher.

GGBFS is often found in ready-mix concrete, masonry, precast concrete, cement, concrete, floor leveling compounds and high-temperature resistant building products. By the use of GGBFS, we can improve workability and finish ability, flexural strength and high compressive strength and resistance to aggressive chemicals.

1.3.3 Silica Fume

Silica fume also knew as micro silica, is a non-crystalline polymorph of silicon dioxide, silica. it is a byproduct of producing silicon metal or ferrosilicon alloys. It is an ultrafine powder, consists of spherical particles diameter less than 1 um, approximately 100 times smaller than the average cement particle. The specific gravity of silica fume is 2.22. Due to its chemical and physical properties, it is a very reactive pozzolanic. Concrete which contains silica fume can have the very high strength and can be very durable.

As per Indian Ferro-Alloys Producers' Association (IFAPA), the total installed capacity of bulk Ferro-alloys Industry in India is estimated at 5.10 million tons per annum and for noble ferroalloys, it is 50,000 tons per annually. the color of silica fume usually premium white or greys colored powder shown in Fig 1.3, which is somewhat similar to Portland cement or some fly ashes. It can show both pozzolanic and cementitious properties. It is recognized as a pozzolanic admixture that enhances the mechanical property to a larger extent.

The compressive strengths of concrete are obtained by using the silica fume along with superplasticizer in order of 120-150 MPa in the laboratory. It improves the durability of concrete by reducing the permeability of concrete, refined pore structure, reduce calcium hydroxide content, which outcome in a higher resistance to sulfate attack. By improving durability property, it also improves the ability of concrete which content silica fume in it from embedded steel from corrosion (Siddique et al., 2011).

Fig 1. 3 silica fume (www.microsilica-fume.com)

1.3.4 Sugarcane Bagasse Ash

Bagasse is the fibrous matter that remains after sugarcane stalks are crushed to extract their juice. It is dry pulpy residue left after the removal of juice from sugar cane. The fibrous ash collected after the burning of bagasse in boilers during the cogeneration process is known as sugarcane bagasse ash (SCBA). Bagasse is used as a biofuel and building materials and in the manufacture of pulp. As temperature increases, the SCBA color changes from black to grey and white which indicates that the carbon content present in the SCBA is reasonably reduced.

India stands second producing sugarcane in the world. The total production in India was about 340 metrics million tones in the year 2010-11. It's around 15% contribution of India for producing sugar cane with respect to the world. Raw bagasse ash is composed mainly of silica, SiO2 (60-75 %), K_2O, CaO and other minor oxides including Al_2O_3, Fe_2O_3, and SO_3.SCBA is the result from the bagasse combustion and consists mainly of silica (SiO2), which has pozzolanic properties. SCBA has low specific gravity (1.8-2.1). it might be possible to use SCBA as replacement of cement and to reduce the cost of construction material.

1.4 ADVANTAGES OF USING WASTE IN CONCRETE

Waste management is a big issue arising in the world. These days as the development and requirement of material is increasing day by day. There has been a lot of efforts is made to utilize the waste in a better way. As the construction industry is growing at an exponential rate.so there is best option to use this waste material in concrete. By the use of waste material, we can reduce the land filling of hazardous material like textile sludge, Polychlorinated Biphenyl (PCB) etc.

Hazardous waste using in cement improves the physical and chemical properties of waste. It also decreases its toxicity and contaminants. Hazardous waste might help to adjustment of pH of concrete. It acts as an agent. the hazardous waste contains phosphate and sulfur reagents which reduce the setting or curing time and also reduce the leachability of contaminants. We can also reduce the carbon footprint by reducing the amount of cement in the concrete mix. Economically is beneficial for us. For low-cost housing projects, it is best-suited option to use the waste material in concrete.

It can also solve environmentally and waste management and economical construction issues. As the sustainability in the development is the need of this industry, hence, therefore, it is important to bring the waste material into concrete for research which needs to implement in the real world.

1.5 TEXTILE ETP SLUDGE

Textile is the most important sector in many developing countries like India, Bangladesh, and Pakistan. India is oldest and largest sector in the world. Out of 21076 units in India (Naik, 2001), there are more than about 700 large textile mills mainly concentrated in Bombay, Ahmadabad, Tirupur, Coimbatore, Kanpur, and Delhi. Various processes in textile industries converting a raw material into cloth material. It consumes the very large amount of water and produces hazardous waste effluents (Karthikeyan et al., 1999). About 150 million tonnes of waste per day in the form of textile sludge is generated in India. However, in some of the textile effluent treatment plants (ETP); sludge is disposed of in an engineered landfill. A large amount of the sludge is openly dumped, which lead to ground-water, soil and surface water contamination. So, with the use of textile sludge in building material we can also reduce to solve to some extent of landfilling of textile ETP sludge.

The textile ETP contains high calcium and magnesium, which comes predominantly from coagulating chemicals (lime and magnesium salts). The presence of high magnesium and calcium shows the possible use of the sludge as partial replacement of cement. The dry sludge was investigated in this research. By the analysis of textile ETP sludge, it was found that the sludge contains inorganic salts and heavy metals. The inordinate leaching out of heavy metals can have a toxic effect on soil and ground water. The steel of reinforced cement concrete (RCC) may be corroded by the inorganic salts. The treatment prior to the use of textile ETP sludge in partial replacement of cement is necessary. For the immobilization of heavy metals, the procedure of solidification/stabilization process is the often employed. Before landfilling, stabilization of textile ETP sludge helps in reduction of the amount of leaching of heavy metals to the lower layer of soil.

The treatment process of stabilization of sludge by means of chemical supplement that limit the solubility of contaminants is extremely cost-effective and is a good option for soils contaminated by heavy metals. In this research low-grade MgO is used for stabilization of textile ETP sludge. There are so many benefits in using MgO as raw material. It has a minimum environmental impact, high alkalinity, and low solubility. Increase pH value up to a limit of 10. which helps in neutralizing precipitate metals and acids (Teringo, 1987).

The definition given by Conner (Conner, 1990), for term stabilization is used to mention to a treatment with a stabilizer that has buffering forces in which the solubility of some heavy metal is minimized. There are so many alternatives for partial replacement of cement but few for stabilization of sludge. Some of them are discussed in following section

1.6 DIFFERENT METHODS OF TREATMENT AND STABILIZATION OF TEXTILE WASTE WATER AND SLUDGE

Innovative processes exist for treating industrial wastewater containing heavy metal. There are methods or removal processes and few alternative chemicals which may be effective for stabilization of textile ETP sludge and treatment of waste water. They are listed below:

1.6.1 Methods for Textile Waste Water Treatment

1. Adsorption
2. Membrane Filtration
3. Electrodialysis
4. Photocatalysis

A literature survey by M.A. Barakat (2011) of 95 articles (1999-2008) that the lime precipitation has been found as one of the extremely effective processes in which metal concentration is higher than 1000mg/L. Membrane filtration and adsorbents methods are the most studied and widely applied treatment of contaminated sludge and waste water for heavy metal removal. Photocatalysis is a new technique for a clean and efficient treatment. There is some parameter to select the most suitable treatment for heavy metal contaminated waste water such as initial metal concentration, Ph, the treatment performance compared to other technologies, economical parameter and environmental impact.

1.6.2 Stabilizing Chemicals

1. Low-grade MgO
2. Phosphate and carbonate mixtures
3. Hydroxyapatite
4. Lime

1.7 AIM AND SCOPE OF PRESENT INVESTIGATION

In this present work, textile ETP sludge has been used as a partial replacement of cement. It is known that the ETP sludge contains heavy metals. As we use this sludge in the structures the water penetrates to ground through the structure that will carry heavy metal which affects the ground water and soil. To encountered this problem Low-grade MgO is used to stabilize the textile ETP sludge. The objective of the study is to obtaining the percentage of MgO is to be used to further investigate the properties of mortar made from stabilized textile ETP sludge.

1.8 THESIS OVERVIEW

Chapter-1 deals with the basic introduction to waste material like textile sludge, use of waste material in concrete, objective and scope of the work.

Chapter-2 deals with the detailed review of published literature on replacement of industrial waste in the concrete and stabilization of material like soil.

Chapter-3 describes the scheme of material used, experiments and techniques adopted for testing.

Chapter-4 deals with the test results characterization of the material, properties of fresh mortar, durability and mechanical properties of hardened mortar. The test result of Scanning Electron Micrograph (SEM) and X-Ray diffractogram.

Chapter-5 deals with the conclusion and scope for further work.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

In this chapter the brief review on textile effluent treatment plant sludge in building material is discussed. Also, the leachability of heavy metals contaminated waste material is presented.

2.2 CHARACTERIZATION OF TEXTILE ETP SLUDGE

In this section, the physio-chemical properties of textile ETP sludge have been discussed. characterization of textile ETP sludge by the various researcher is listed in Table 2.1.

Table 2. 1 Physio-chemical property of textile ETP sludge

S. No.	Parameter	Balasubramanian et al. (2006)	Sundaram et al. (2006)	Patel et al. (2009)	Begum et al. (2013)
1.	pH	9.13	10.5	8.70	7.14
2.	Moisture content (%)	28.72	-	10.50	3.34
3.	Specific gravity	2.4	2.32	0.94	2.21
4.	Cadmium, (mg/kg)	3.96	5.6	5.17	-
5.	Copper, (mg/kg)	57.48	119	225.48	-
6.	Chromium, (mg/kg)	2.98	358	-	-
7.	Zinc, (mg/kg)	91.60	190	186.47	-
8.	Nickel, (mg/kg)	0.68	-	89.67	-
9.	Lead, (mg/kg)	12.1	-	44.75	-
10.	Calcium, (mg/l)	108.00	28.4 % (as CaO)	-	-
11.	Magnesium, (mg/l)	154.30	-	-	-
12.	Total hardness as CaCO3	905 mg/1	-	-	-

Balasubramanian et al. (2006) tested the specific gravity (Bureau of Indian Standard, 1980; BIS, IS: 4031(part11): 1980) of the cement used for the experimental work and obtained the value of 3.07, and for the sludge, the value obtained is 2.4. when the sludge is incinerated, it was observed that the volatile solids in sludge is around 32%. The large amount of volatile solids is due to the very high content of ash in the sludge.

Sundaram et al. (2006) studied the sludge after drying at 105˚C temperature. The color of the material is brown. due to the contribution of the significant amount of iron oxide which is about 9.1% present in the material. Due to the addition of excess lime which was added during the treatment process makes calcium oxide (28.4%) which is a major constitute present in the sludge and it is also responsible for its pH value (10.5). The particle size measured by the sieve analysis which was about 0.285 mm.

Patel et al. (2008) investigate the physio-chemical parameters of textile chemical and printing clusters waste water from four common effluent treatment plants (CETPs). the plant is situated in Balotra and Pali in Rajasthan and Manikapuram and Mannarai in Tripura and Tamilnadu respectively. The sludge was collected in the form of semi-dried cakes. The sludge was generating after the physio chemical treatment of waste water. The data indicate that the sludge is highly alkaline in nature and also has high electrical conductivity values. The methods used for testing various parameter is shown in Table 2.2 and the results of physio chemical parameters is presented in Table 2.3.

Patel et al. (2009) tested the physio-chemical Parameters and heavy metal by a standard method such as American Public Health (APHA), Bureau of Indian Standards (BIS) and central pollution control board (CPCB) solid waste manual.

Begum et al. (2013) tested the sludge in dried condition.it was observed by the researcher the volatile content in sludge is very high. To determine the pH of sludge by taking a sample and distilled water in the ratio of 1:10. The sample was agitated mechanically for 30 min. After agitation, the sample was filtered and the pH was determined.

Table 2. 2 Analytical methods used for chemical sludge sample analysis (Patel et al. (2008))

S. No.	Parameter	Reference	Method No.
1.	pH	CPCB solid waste manual (2002)	-
2.	Moisture content (%) and dry solids	APHA standard methods (1998)	2540 G
3.	conductivity	CPCB solids waste manual (2002)	-
4.	Volatile and fixed solids (%)	APHA standard methods (1998)	2540
5.	Total organic carbon (%)	Walkley Black method (1935) in CPCB solid waste manual (2002)	-
6.	Calorific value	Bureau of Indian Standards (BIS)	IS:1350 (part11)1970
7.	Specific gravity & density	APHA standard methods (1998)	2710 F
8.	Heavy metals (Cr, Cu, Ni, Cd, Zn, Co, Pb)	APHA standard methods (1998)	3030 D & E & 3111A & B
9.	Hexavalent Chromium	International organization for standardization (ISO)	ISO 11083 :1994

Table 2. 3 Comparatively range of study data (Patel et al. (2008))

S. No.	Parameter	Data Range of Samples	Literature range
1.	pH	8.02 - 9.0	6.8 - 9.4
2.	Electrical conductivity (mS/cm)	2.12 - 6.63	11.5 - 11.6
3.	Moisture Content (%)	5.40 – 66.65	4.6 - 94.6
4.	Dry solids (%)	33.35 – 94.60	5.4 - 95.4
5.	Volatile solids (%)	34.30 - 48.37	24.2 – 80.0
6.	Fixed solids (%)	51.63 – 65.70	20.0 – 75.8
7.	Total Organic Carbon (%)	1.23-17.82	12
8.	Calorific value (Kcal/Kg)	Nil – 2066.33	495 - 498
9.	Specific gravity	0.84 – 1.07	0.86 - 2.4
10.	Density (g/cm3)	843.80 – 1065.40	1110 -1120
11.	Cd (mg/kg on dry wt. basis)	4.248 – 5.409	0.10 - 396
12.	Cu (mg/kg on dry wt. basis)	39.806 – 389.831	9.9 – 57.48
13.	Zn (mg/kg on dry wt. basis)	73.480 – 386.939	0.65 – 306
14.	Ni (mg/kg on dry wt. basis)	23.729 – 88.745	0.68 – 0.42
15.	Co (mg/kg on dry wt. basis)	12.119 – 13.559	2.29 – 6.61
16.	Cr (III) (mg/kg on dry wt. basis)	32.004 – 316.326	4.7 - 199
17.	Cr (VI) (mg/kg on dry wt. basis)	BDL	4.7 – 14.00
18.	Pb (mg/kg on dry wt. basis)	20.314 – 52.044	0.50 – 27

Iqbal et al. (2014) investigated the physio-chemical properties of textile sludge from selected industrial units in Bangladesh. The sludge sample was incinerated at different temperature and different time intervals. The maximum temperature attained by the electrical incinerator was for 1000˚c. It was observed that the sludge sample reduces their volume as well as mass. The sludge was stabilized by clay or cement. It was observed by the result that some of the heavy metal is decreased as we incinerate the sludge which was shown below in tabulated form. The evaluated properties of textile sludge are tabulated in table 2.4 and table 2.5. S1, S2, S3, S4, S5, and S6 refers to 6 different textile industries effluent sludge samples. The sludge collected from treatment plants of various textile units located at Savar, Gazipur, and Narsingdi.

Table 2. 4 Primary analysis of sludge of different industrial units (Iqbal et al. (2014))

Parameters	S1	S2	S3	S4	S5	S6
pH	6.56	7.82	6.5	6.6	6.25	6.63
Moisture content (%)	90	89	90	91	90	90
Alkalinity as $CaCO_3$, (mg/kg)	98.66	107.7	98.2	96.33	93.33	100
Cadmium, (mg/kg)	19.43	14.43	18.8	5.3	10.8	9.2
Copper, (mg/kg)	265	211	145.1	130	210	140
Chromium, (mg/kg)	382.3	392.3	451.1	367	301.8	285.6
Zinc, (mg/kg)	328	348	317.28	229	390	510
Nickel, (mg/kg)	66.2	54.9	65.1	229	65	76
Lead, (mg/kg)	189.4	109.4	192.6	113	28.9	23.2
Arsenic, (mg/kg)	1.6	1.45	1.6	1.1	1.8	1.56
Mercury, (mg/kg)	0.9	0.7	0.1	0.12	0.1	0.1
Organic content (%)	67.6	68	67.3	76	69	69
Ash content (%)	19	17.6	19	15.5	17.9	18.5
Silica, (mg/kg)	157	212	157	187.3	172.3	189
Sulphate, mg/kg	3400	4700	3540	4522	4508	5105

Table 2. 5 Heavy metal concentration in ash sample (Iqbal et al. (2014))

S. No.	Parameters	S1	S2	S3	S4	S5	S6
1.	Cadmium, mg/kg	9.93	7.2	4.2	1.3	3.1	4.6
2.	Copper, mg/kg	664.7	411.5	282.9	249	410.5	273
3.	Chromium, mg/kg	850	1059.2	1019.2	831.2	685	648.3
4.	Zinc, mg/kg	980	761	636	480.9	764	1126
5.	Nickel, mg/kg	168.6	126	151	186	155	175
6.	Lead, mg/kg	19.1	45.2	47	38.5	14.9	12
7.	Arsenic, mg/kg	0.8	0.79	0.9	1.2	1	1.2
8.	Mercury, mg/kg	0.08	0.07	0.07	0.01	0.01	0.01

2.3 INFLUENCE OF TEXTILE SLUDGE ON FRESH PROPERTIES

From the time of mixing until the mortar or concrete sets this duration refers to the fresh state. During this time concrete or mortar is handled, transported placed and compacted. Fresh state properties are very important because of these influences the quality of its hardened state. Fresh concrete or mortar properties like consistency, workability, settlement, and bleeding etc. Some of the property of fresh concrete and mortar with the addition or replacement of textile sludge by the various researcher are discussed below.

Balasubramanian et al. (2006) tested and studied that the consistency limit which was tested by IS: 4031 (part 4):1990 and found that the consistency of cement is 31% and consistency limit of cement with different percentage of sludge was increasing with increasing the percentage of sludge which was shown in Fig 2.1. The water to cement ratio was also increasing between 0.45 to 0.7 up to 35% substitution of textile sludge for cement. It was observed that the setting time delays because of the presence of an organic fraction in the textile sludge. Proportionality saw between delay of the organic fraction contained in the textile sludge.

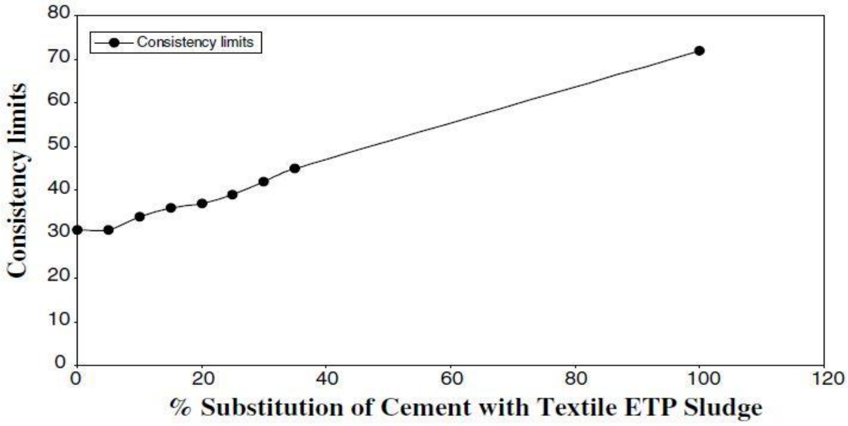


Fig 2. 1 consistency limits for mixture of textile ETP sludge and cement, (Balasubramanian et al. (2006))

Kulkarni et al. (2012) tested the fresh property of M20 grade concrete. The concrete is combination of different percentage of textile mill sludge (TMS) and fly ash and it was observed that the slump value of concrete as an increase in the percentage of TMS and fly ash simultaneously the slump value was decreasing, which is shown in Fig 2.2.

Table 2. 6 Slump value for varying percentage of sludge and fly ash (Kulkarni et.al (2012))

Sludge %	Slump Values (mm)			
	5% Fly Ash	10% Fly Ash	15% Fly Ash	20% Fly Ash
0	140	145	150	150
4	135	145	150	150
8	130	130	130	130
12	95	90	90	90
16	40	45	40	40
20	15	15	10	10
24	0	0	0	0

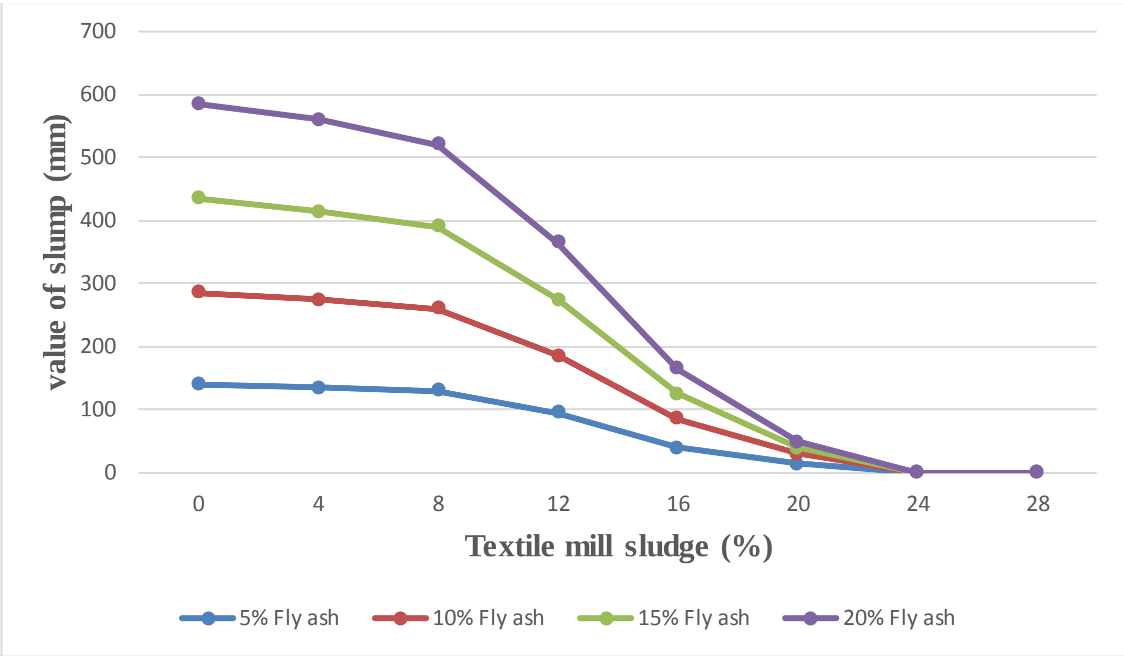


Fig 2. 2 Consistency limits for mixture of textile ETP sludge and cement, (Kulkarni et.al (2012))

Sandesh et al. (2014) investigate the fresh concrete properties of 3 series of mixes, which is S1, S2, and S3. S1 consists of 5 different mixes (S1M1, S1M2, S1M3, S1M4, S1M5) in which cement content is constant (320 kg/m^3) and water content was varying (140, 160, 180, 200 and 208 liters). For each mix, replacement of cement by sludge is 5%. For S2, and the S3 difference was cement content which is 340 and 360 kg/m^3 all other parameters are same like S1. from table 2.7 reported by the researcher that the as we increasing the w/b ratio the slump value was increasing in all the series. The reason behind was due to the fine state of division of sludge.

Rahman et al. (2017) studied and found that the setting time delays due to the presence of organic fraction in the sludge and this delay are directly proportional to the organic fraction contained in the sludge. The salinity of sludge was found to be 0.264 mg/kg. Which is within the acceptable range for building material. It was reported by the researcher that the sludge has high water absorption capacity and this is not a desirable property of sludge for use in building materials in durability point of view.

Table 2. 7 Slump value for varying percentage of sludge and fly ash (Sandesh et al. (2014))

S. No.	Mix	W/B	Slump (mm)
1.	S1M1	0.43	10
2.	S1M2	0.50	13
3.	S1M3	0.56	16
4.	S1M4	0.62	35
5.	S1M5	0.65	75
6.	S2M1	0.41	10
7.	S2M2	0.47	17
8.	S2M3	0.53	42
9.	S2M4	0.59	75
10.	S3M1	0.39	11
11.	S3M2	0.44	15
12.	S3M3	0.50	30
13.	S3M4	0.55	64

2.4 EFFECT ON MECHANICAL PROPERTIES

2.4.1. Compressive Strength

Compressive strength refers to resistance to failure under the action of compressive forces of any material. The compressive strength of concrete and mortar cubes are generally decreased when textile ETP sludge was used as partial replacement of cement and aggregate substitution. Some of the published research describing the reduction in strength are discussed below.

Swamy et al. (2000) studied and reported on the use of municipal waste water sludge as a partial replacement of cement and found that there is a reduction in compressive strength as an increase in the percentage of textile ETP sludge. It was concluded by the researcher that the partial use of sludge does not provide the required compressive strength for construction and structural application.

Balasubramanian et al. (2006) reported reduction in compressive strength with the substitution of cement with Textile ETP sludge in the mortar cubes. It is recommended that as much as 30% of Portland cement can be replaced by textile ETP sludge in the preparation of building components. In this study, it is found that the sludge content in the composition of building materials depends on desired properties of the building materials. Up to 5% replacement of cement with ETP sludge there is a slight decrease in compressive strength but beyond 5% replacement, there is a gradual reduction in strength. The trend is shown in Fig 2.3.

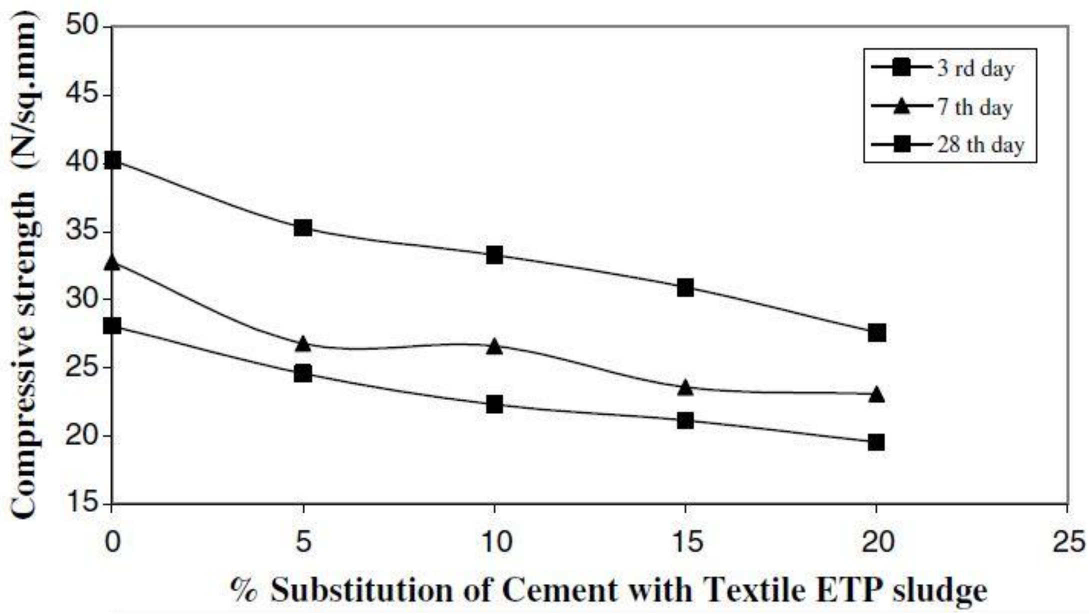
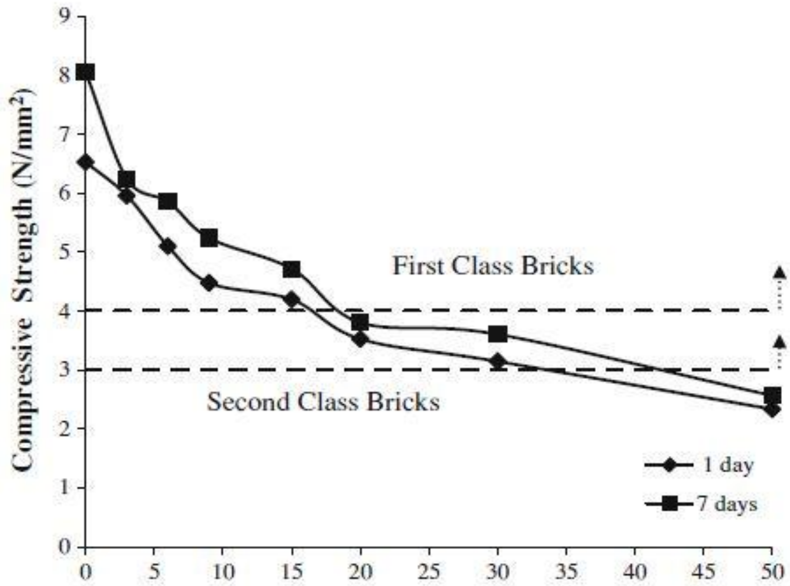


Fig 2. 3 Compressive strength of mortar versus textile ETP sludge, (Balasubramanian et al. (2006))

Kumar et al. (2008) studied a solid waste of various industries (textile, glass and thermal industries) in the utilization of building material. From the test result, it was concluded that the solid waste sludge replaced up to a limit of 20 to 30% for production of bricks and for concrete blocks limit suggested was 45 to 50%. The bricks made with 25-30% replacement with sludge obtained good compressive strength and water holding capacity.

Kulkarni et al. (2012) found that the Textile ETP sludge (32%) and fly ash (20%) can be successfully used as building material by adding it in M20 grade of concrete. The values of compressive strength obtained with the addition of 32% sludge and 20% fly ash are 20.22 N/mm^2.

Begum et al. (2013) tested on the bricks as per IS 3495 (part 1-2):1992 and found that the compressive strength of bricks after1 and 7 days which are shown in Figure 2.4. Immersion in water was greater than that of the bricks immersed in water for 1 day. As the increase in the replacement level of textile sludge in the brick the reduction in compressive strength examined. About 50% replacement with sludge the compressive strength of brick was found to be 2.5 N/mm^2 as suspected to reference brick it is 8 N/mm^2. There is a decrease in the compressive strength with increase in the percentage of sludge due to the increase in pore volume of bricks. The maximum amount of waste sludge that can be added lies in the range of 3–15 % corresponding to the compressive strength between 5.62 and 4.19 N/mm2 for textile sludge bricks. The mix up to 15 % satisfies the requirements of first-class bricks as per the Indian Standards. The sludge mix ratio of 20 and 30 % satisfies the requirements of second class bricks.



% Replacement of ETP sludge

Fig 2. 4 Compressive strength of bricks (Begum et al. (2013))

Akram et al. (2015) reported that when e-plastic alone was used, it was found by that there is a decrease in strength but when 10% fly ash was added results comparable to control specimen it was increased even when 15% proportion of e-waste used.

Rahman et al. (2017) tested the mortar cube of size 50.8×50.8×50.8 and the procedure followed as per ASTM standards. The partial replacement of textile ETP sludge for both cement and sand are tested. The ratio of replacement for sludge with cement was 0, 10, 20, 30, 40 and 50 % and for sand the replacement level was 20, 40, 60 and 80 % was used.it was found that the 5wt% replacement of Portland cement by sludge in the composition of mortar reduces compressive strength by 15% compared to the mortar made of cement alone. For a sludge content of 10 % of Portland cement in the mortar, the compressive strength decreases sharply from 27 to 14 MPa. This sharp reduction in strength might be due to higher heterogeneity in the microstructure of the mortar which is shown in figure 2.4. As the sludge is substituted by fine aggregate in the composition of mortar it was found that the 25 % replacement shows decrease the compressive strength of 25 %, while 50 % replacement of sludge shows 45 % reduction in compressive strength compared to that of the mortar specimen as shown in Fig 2.5. The reduction in strength due to the addition of sludge can be explained by heterogeneity in the microstructure. Further addition of sludge up to 80 % of sand also decreases the compressive strength but the rate of reduction in strength decreases.

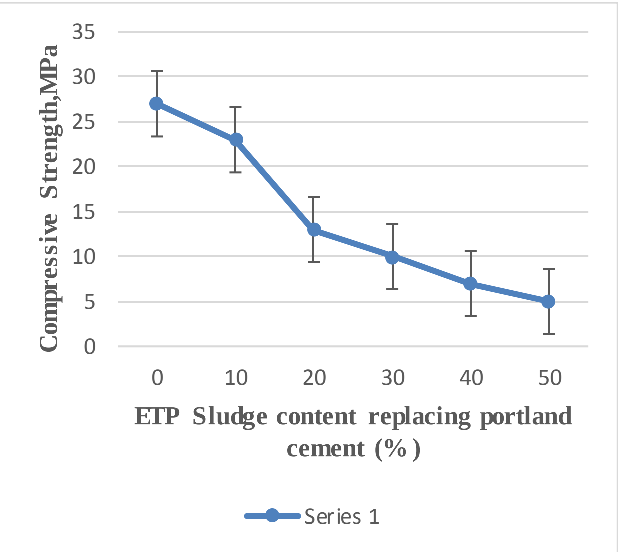


Fig 2. 5

Effect of ETP sludge content (replacement with cement) on the compressive strength of mortar, (Rahman et al. (2017))

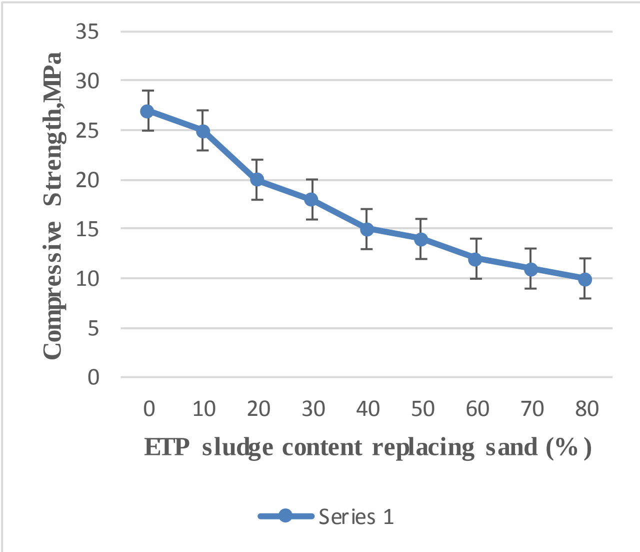


Fig 2. 6

Effect of ETP sludge content (replacement with sand) on the compressive strength of mortar (Rahman et al. (2017))

2.4.2. Flexure Strength

Textile ETP sludge shows a similar trend in the development of flexure strength as developing in compression strength. The published research shows that the decrease in the flexure strength on the substitution of cement and sand in mortar as well as concrete. The flexure strength strongly depends upon the quality of paste in mortar mixture. As we increase the percentage of substitution of sludge in a mortar, the paste becomes more weak and porous and due to this, the microstructure of mortar becomes porous also. As such textile ETP sludge mortar mixture shows lower strength.

Sandesh et al. (2014) investigate the 3,7 and 28 days flexure strength of concrete mix has decreased by 21% with respect to control mix. The 28 days flexure strength of control sample was obtained as 6.12 whereas with 5% replacement of textile ETP sludge with cement the obtained flexure strength was to be 5.17.

Arul et al. (2015) studied and found the flexural strength of M20 and M30 grade of concrete at 0%, 5%, 10%, 15%, 20%, 25% and 30% and observed that the as an increase in the percentage of ETP sludge the specimen gradually gives higher. For M20 grade concrete the value of flexure strength obtained was 6.84, 8.64, 9.30, 9.60, 10.56, 10.98 and 11.04 N/mm^2 at 28 days and for M30 grade of concrete the value obtained was 6.60, 7.14, 7.08, 7.32, 7.20, 7.56 and 7.44 N/mm^2 at 28 days. the increase in the flexure strength of concrete cube is because of cohesive nature of textile ETP sludge.

Rahman et al. (2017) tested the mortar with size 304.8mm× 25.4mm× 25.4mm. the Flexural strength of different composition of mortar specimens with the increasing sludge content is tabulated in Table 2.8. Portland cement mortar without sludge the flexural strength was found to be 10 MPa. For mortar with 10%, 20%, 30%, 40% and 50wt% sludge replacing cement the flexural strength was found to be 4.5, 4.0, 3.0, 3.5 and 2.0 respectively. The reduction of strength is due to higher heterogeneity in the microstructure of the mortar.

Table 2. 8 Porosity, density and flexure strength of mortar (Rahman et al. (2017))

S. No.	Types of mortar	Porosity (%)	App. density (gm/cc)	True density (gm/cc)	Flexural strength (MPa)
1.	Portland cement mortar without sludge	7.50	2.19	2.37	10.0
2.	Mortar with 10wt% sludge replacing cement	7.70	1.98	2.10	4.5
3.	Mortar with 20wt% sludge replacing cement	10.1	1.87	1.97	4.0
4.	Mortar with 30wt% sludge replacing cement	13.45	1.83	1.84	3
5.	Mortar with 40wt% sludge replacing cement	15	1.8	1.82	2.5
6.	Mortar with 50wt% sludge replacing cement	18	1.78	1.8	2.0

2.4.3. Split Tensile Strength

The split tensile strength of textile ETP sludge mortar sows trend in the similar manner as that of normal mortar. It has less influence on the development of split tensile strength as compared to compressive strength. On the use of textile ETP sludge as cement and sand replacement in a mortar, split tensile strength decreases.one of the main reason behind the reduction of strength is an increase in the porosity and distribution of pores in the sludge. With the use of chemical admixture, we can improve the microstructure of sludge and this may result in improving the split tensile strength.

Sandesh et al. (2014) investigate the split tensile strength-duration of 3,7 and 28 days. It was observed that the split tensile strength was decreased as increase the percentage of sludge which is shown in Fig 2.7. The 3 days tensile strength was decreased with 49.5%, 59.38% and 60.4% with control mix and for 7 days the reduction of 32.8%, 37.5% and

41.8% and 28 days reduction with respect to control mix of 28 days results are 27.6%, 35.1% and 39.6%.

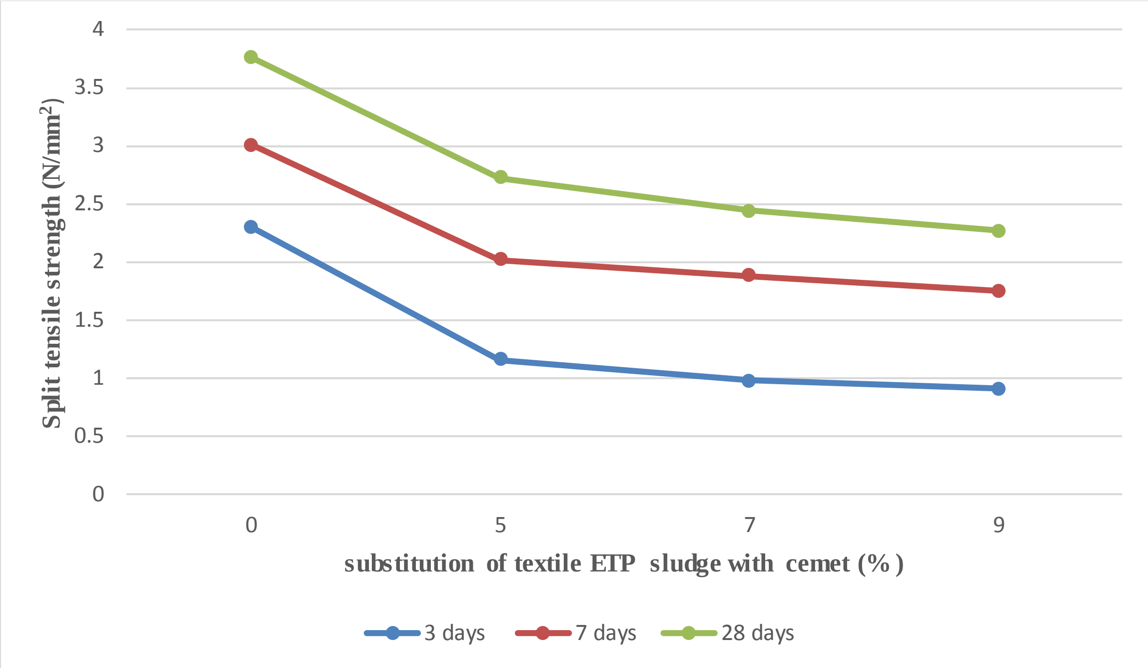


Fig 2. 7 Split tensile strength of mixes (Sandesh et al. (2014))

Arul et al. (2015) studied and found the split tensile strength of M20 and M30 grade of concrete cylinder specimen at 0%, 5%, 10%, 15%, 20%, 25% and 30% and observed that the as increase in the percentage of ETP sludge the specimen gradually gives higher split tensile strength. For M20 grade concrete cylinder specimen the value of split tensile strength obtained was 2.6, 2.7, 3.06, 3.12, 3.34, 3.42 and 3.32 N/mm^2 at 28 days. For M30 grade of the concrete cylinder, the value obtained was 4.14, 3.82, 3.73, 3.74, 3.76, 3.72 and 3.58 N/mm^2 at 28 days· the increase in the split strength of concrete cube is because of cohesive nature of textile ETP sludge.

Joseph et al. (2017) investigated the split tensile strength of cylinder specimen of diameter 150 mm and length 300 mm. The duration of the testing specimen was 7 and 28 days. As the percentage of sludge and quartz powder increases with substitution with cement, the split tensile strength reduces which shown in Table 2.9. In this table S refers for replacement of sludge in concrete as replacement of cement and Q refers to quarts powder.

Table 2. 9 Split tensile strength of mortar (Joseph et al. (2017))

S.NO.	Mix Combination	Split-Tensile Strength(N/Mm^2)	
		7 DAYS	28 DAYS
1	Control Concrete	2.108	3.137
2	S0Q5	1.2	2.68
3	S0Q10	1.84	3.81
4	S0Q15	0.84	1.32
5	S5Q0	1.25	2.1
6	S10Q0	1.686	2.509
7	S15Q0	1.44	1.52
8	S5Q10	1.23	1.84
9	S10Q10	1.17	2.1
10	S15Q10	1.1	1.8

2.4.4 Leachability

Rahman et al. (2017) conducted leaching test for mortar and concrete samples. The procedure followed by Japan Society of Civil Engineers (JSCE) standard. By the leachate analysis, it was found that the pH of water increases. The Ph value of the sludge when used is around 4.5-5.0, which indicates it was acidic in nature. Due to the presence of Portland cement, the sludge acidity is neutralized during the hydration process. Conductivity was increasing with time which is shown in Table 2.8. Heavy metals like As and Cr content in leachate are on higher side whereas the content of Cu, Pb, Hg, and Zn are quite lower (limit specified by Department of Environment (DoE), Bangladesh). The investigation indicates that some of the elements are leaching out from the cement matrix but most are confined in a cement matrix.

Table 2. 10 Test result of leaching at different periods (Rahman et al. (2017))

S.NO.	Parameter	Leaching period (days)				DoE standard for inland surface water
		7 days	20 days	35 days	60 days	
1.	pH	7.5	7.5	8.0	8.0	7–9
2.	Conductivity (ppm)	1600	4000	5000	5300	–
3.	SO_4^{-2} (ppm)	51	52	300	904	–
4.	TDS (ppm)	500	1587	2000	2397	2100
5.	Cr (ppm)	–	–	–	0.73	0.50
6.	Cd (ppm)	-	-	-	BDL	0.01
7.	BOD (mg/L)	-	-	-	95.01	50
8.	COD (mg/L)	-	-	-	107.10	200

2.5 MICROSTRUCTURE

Begum et al. (2013) studied the SEM images with three different combinations of bricks. The three combinations are pure clayey soil, textile sludge, and clay replaced with 15% textile sludge. It was observed that the pure clayey soil consists of granular material.in the textile sludge sample, there are materials are not homogenous and fibrous. In third combination, it was noticed that the mixture is granular and fibrous as well. More compact structure in the pure clayey soil in comparison of textile sludge. More voids observed in textile sludge contains bricks and the specific gravity is higher than that of clay. The SEM images shown in Fig 2.9 (a), 2.9 (b) and 2.9 (c).

Rahman et al. (2017) study the morphology property of sample was studied, according to their research mortar (Portland cement and sand) exhibits homogenous and dense structure, whereas with the addition of textile sludge in the composition displays higher heterogeneity of the structure. The comparative images are shown in Fig 2.8 (a) and 2.8 (b).

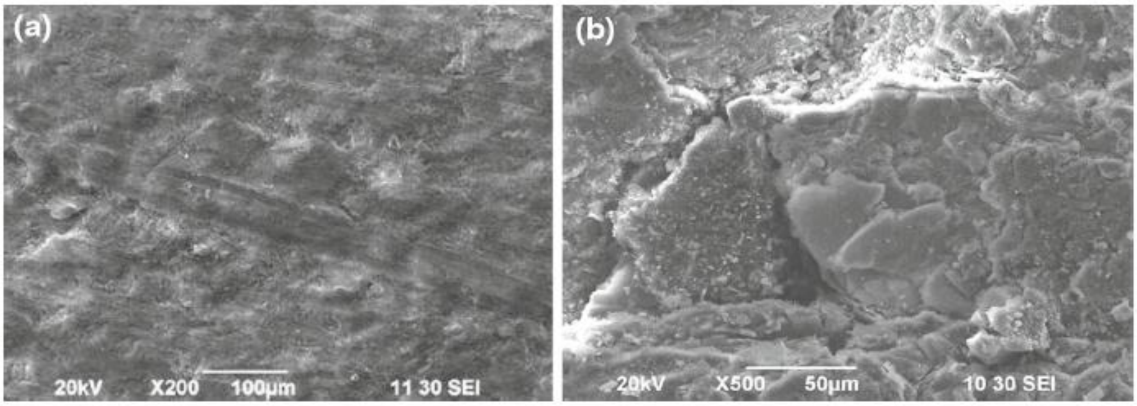


Fig 2. 8 Scanning electron microscope (SEM) image: (a) mortar specimen containing Portland cement and sand at the ratio of 1:3, and (b) mortar specimens containing Portland cement, sand and textile ETP sludge at the ratio of 1:3.51:0.50. (Rahman et al. (2017)).

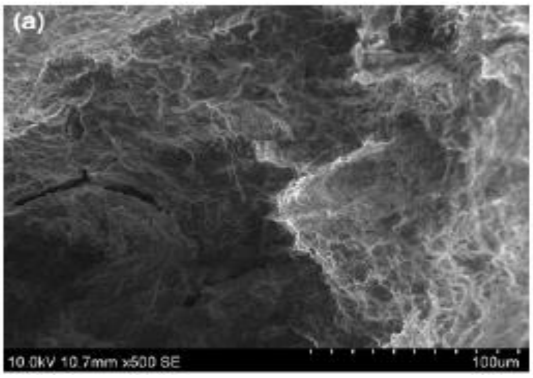


Fig 2. 9 (a) SEM images of pure clay soil sample

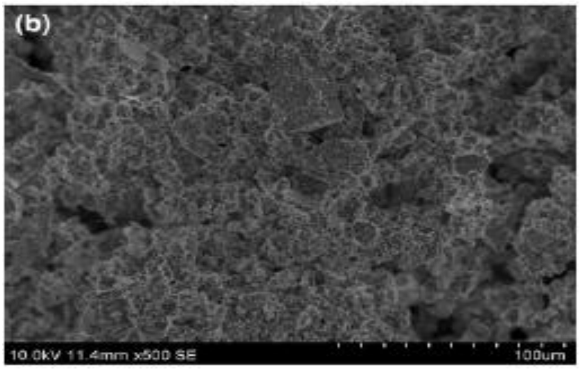


Fig 2. 9 (b) SEM images of textile sludge sample

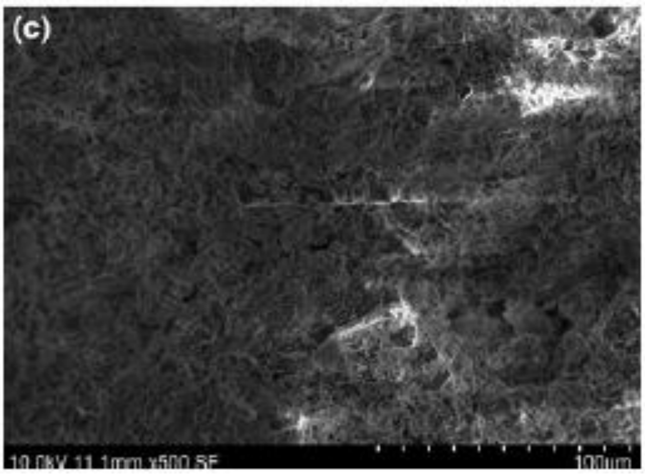


Fig 2. 9 (c) SEM images of specimen replaced With 15% textile sludge

2.6 STABILIZATION

Sludge contained heavy metal which polluted soil and ground water which may be harmful to human and other organisms due to the high toxicity of these metals. To remove these metals at the certain desirable limit, stabilization/solidification treatment process is most cost-effective and promising option by means of chemical additives.

Garcıa et al. (2004) investigate the use of low-grade magnesium oxide to stabilize the heavy metals in highly contaminated soils. It was observed the use of LG-MgO act as a reactive medium which ensures greater than 80% of metal fixation. Greater than the use of 10% LG-MgO as stabilizer agent, it provides long-term stabilization due to the alkali reservoir and also without varying the pH Conditions.

Zhan et al. (2015) used lime as a stabilizing agent to remove ammonia in textile effluent sludge which effects the compressive strength of concrete blocks and also bad odor. The researcher studied on concrete block, the ratio of an aggregate and cement was used as 6,10 and 12. Replacement of fine aggregate with pretreated textile effluent sludge at a ratio ranging from 0 to 30 percent by mass was used. It was observed that ammonia content and compressive strength reduced as the increase in percentage of lime.

2.7 CONCLUDING REMARKS

It was concluded from the literature survey that the use of textile ETP sludge as replacement of cement and sand in the concrete as well as mortar reduces the compressive strength of the mix. This reduction was mainly due to heavy metal contained by the ETP sludge and uncontrolled pH of mix. The major issue of using textile ETP sludge in building materials is leachability of heavy metal which directly affects the compressive strength, human health and ground water. One of the options to improve properties of sludge is its stabilization. It has not been attempted on textile sludge.

CHAPTER 3

EXPERIMENTAL PROGRAM

3.1 GENERAL

This chapter describes the experimental test method applied in this research work for characterization of material used in the making of mortar and evaluation of the effect of textile ETP sludge as a replacement of cement on properties of concrete.

The test procedure is divided into two parts. In the first part, the object was to stabilize the textile sludge by using low grade MgO. Further in the second part the preparation of mortar made by using stabilized sludge is investigated. The schematic diagram of experimental program of part-2 are shown in Fig 3.1. The material used in testing procedure for both parts are discussed in the following section.

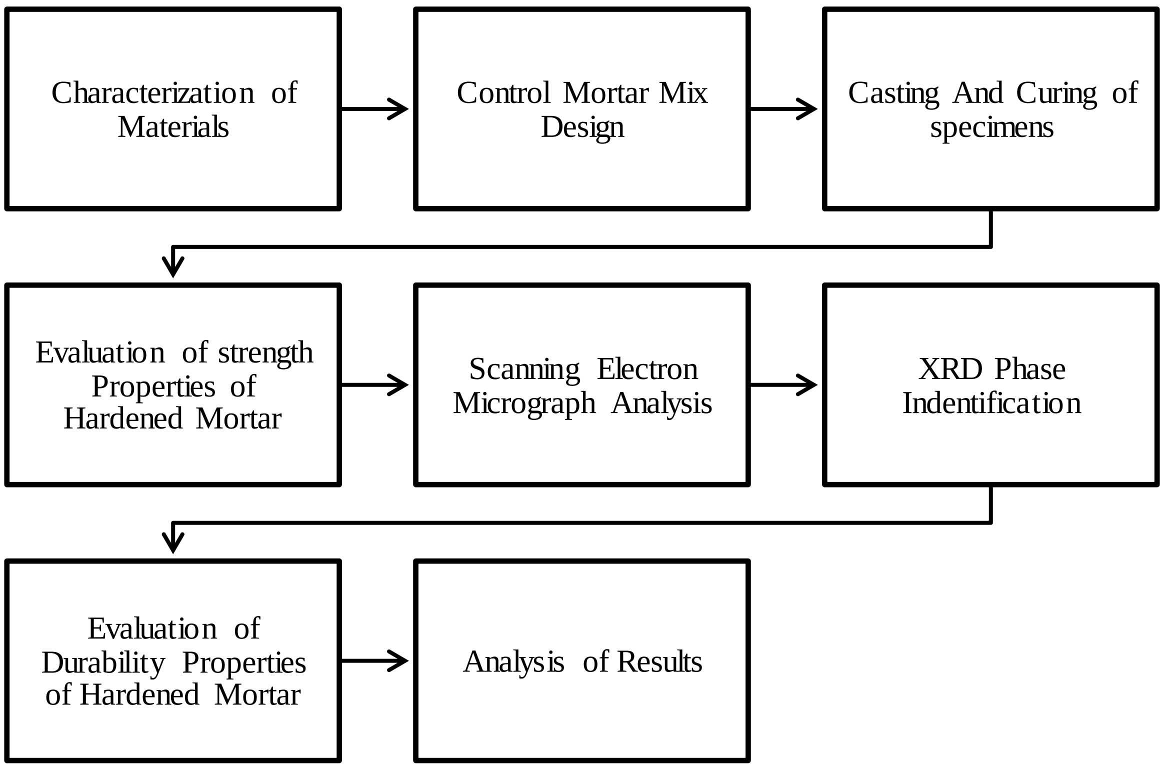


Fig. 3. 1 The schematic diagram of experimental program

3.2 STABLIZATION

Part one of the study is based on stabilization of ETP sludge by low grade MgO. The divided experimental program for stabilization is presented in the following sections.

3.2.1 Material Used

The properties of various materials used for stabilization are described below:

3.2.1.1 Textile ETP Sludge

The textile ETP sludge was collected from Partap industries Ambala, Haryana .it was blue in color, which is shown in Fig 3.2. The generalized chemical properties of ETP sludge are shown in Table 3.1.

Fig. 3. 2 Fresh raw textile ETP sludge

Table 3. 1 chemical Properties of Textile ETP sludge

Parameter	Constituent (%)
SiO_2	22
Al_2O_3	5.93
Fe_2O_3	2.5
CaO	63
MgO	2.86
K_2O	1.2
Na_2O	0.30
SO_3	2.12
TiO_2	0.36

3.2.1.2 Low-grade magnesium oxide

The low-grade MgO used as a stabilizing agent for textile ETP sludge. It was product of Nice®. It was white in color, which is shown in Fig 3.3. The chemical properties are shown in Table 3.2.

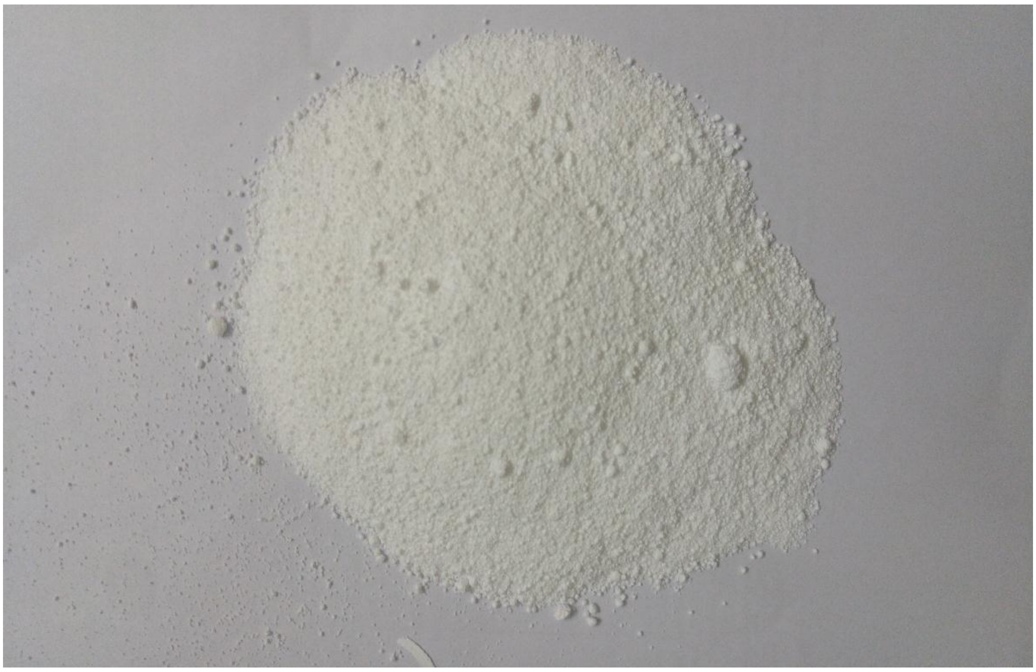


Fig. 3. 3 Low-grade magnesium oxide

Table 3. 2 Chemical Properties of LG-MgO

Parameter	**Constituent (%)**
Assay	98 min
Chloride	0.15 max
Sulphate	0.5 max
Arsenic	0.0003 max
Heavy metals (as Pb)	0.002 max
Iron	0.05 max

3.2.1.3 Miscellaneous Material

Deionized water was used for stabilization as well as measurement of pH of sludge. For filtration of sludge after striation 0.45 um filter was used. HNO_3 was used for acid digestion.

3.2.2 Stabilization Methodology

The chemical characterization of the contaminated Textile ETP sludge was determined after performing total acid digestion (HNO_3/$HCLO_4$) of the samples. The leachates were analyzed by inductive coupled plasma atomic emission spectrometry (ICP-AES) to determine the non-metallic species metals and heavy metals. The methodology used for stabilizing the heavy metal from sludge with the use of LG-MgO was as per DIN (Deutsches Institut für Normung e.V., German Institute for Standardization) 38414-S4. there are following steps for conducting this test the procedure as described below:

1. The raw sludge was dried for a period of 1 day maintaining the temperature of 150± 2°C before use. After that, the raw sludge was crushed and sieved at 90-micron sieve. The passing material was used for further testing.
2. 100 gm of dry sludge was taken in a flask with 1 liter of deionized water. The mixture was mixed thoroughly. For stabilization with LG-MgO different percentage of MgO were taken in order to study the effect of different dosages on stabilization i.e. for 5% stabilization, combination is 100 gm dry sludge, 1 lit deionized water and 5 gm of LG-MgO.
3. After proper mixing of components, the magnetic needle was put in the mix and after that, the flask was properly sealed with aluminum foil paper. The mixed sample is shown in Fig 3.4.
4. The sample was kept upon magnetic stirrer with continuous stirring (3-5 rpm) at room temperature duration of 24 hours. The setup for this investigation for stirring is shown in Fig 3.5.
5. After striations, the resulting suspension was filtered through a membrane filter of size 0.45 um.
6. The filter sludge was dried and used as a replacement for cement.

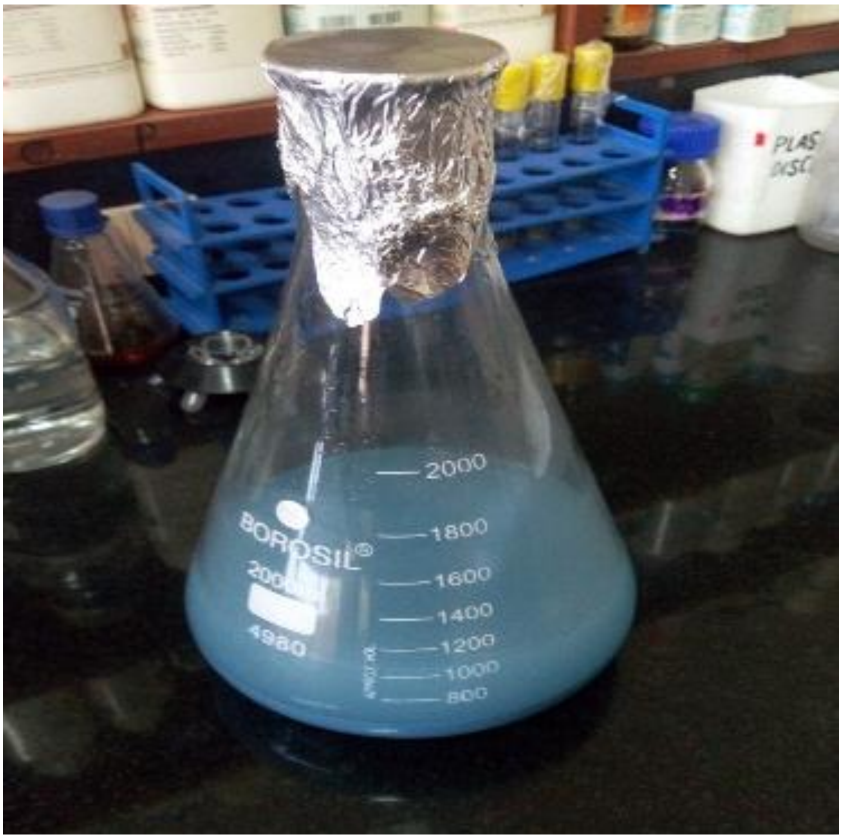


Fig. 3.4 Flask containing sludge

Fig. 3.5 Magnetic stirrer

3.2.3 Test

Various tests were conducted on the dried sludge samples as explained here under:

3.2.3.1 Inductive Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)

ICP-AES is the effective method of finding the heavy metal concentration in the leachate. In this study, Sample was prepared with 1 liter of deionized water taking 100 gm of stabilized sludge. The sample was kept in striation for 24 hr. and after that leachate was taken out from centrifugation of samples. It was around 2 mg of the sample taken from centrifugation for further analysis. The sample was digested with acid. After total acid digestion of textile ETP sludge with HNO_3, the leachate was further analyzed with the method of ICP-AES.

3.2.3.2 pH

pH is an important parameter for concrete or mortar from a strength point of view. In this study, pH was measured by pH meter. Fundamentally, a pH meter consists of a voltmeter attached to a pH-responsive electrode and a reference (unvarying) electrode. 100 gm of ETP sludge, 2 liters of deionized water and varying percentage of low grade MgO was taken, for the measurement of pH. After proper mixing, the solution was tested by pH meter. Before and after striations readings were taken.

3.3 MATERIAL USED FOR MORTAR SPECIMEN

The laboratory tests were done as per Indian standard code under control condition for determining the properties of the material used for making mortar. The characterization of material for all major ingredients of cement mortar was carried out. Characterization is required to check for their acceptance as per Indian standardization to achieve the particular required strength. The properties of various materials for mortar like cement, sand, and water are described in following sections:

3.3.1 Ordinary Portland Cement (OPC)

cement is the major active component for concrete as well as mortar. Due to its fineness, it fills the voids and makes concrete and mortar impermeable. Cement has binding properties which enable mortar to get higher strength. OPC is categorized in three grades 33, 43 and 53 grades depending upon its 28 days compressive strength. It is generally grey in color.

In this investigation, OPC 43 grade is used for entire duration of the investigation. The primary investigation of cement was carried out and observed that it was fresh and free from lumps. The physical properties of cement tested in the laboratory with Indian standard specification (BIS:8112-2013) which is shown in Table 3.3 and the generalised chemical properties of cement is shown in Table 3.4. OPC 43 grade compressive strength is presented in Table 3.5.

Table 3. 3 Physical properties of OPC

Parameter	Obtained values	Standard Values (As per IS 8112:1989)
Manufacture	Ultra tech	-
Grade of cement	43	-
Specific gravity	3.1	-
Standard consistency	23 %	30
Initial setting time	123 minutes	30 minutes (Minimum)
Final setting time	270 minutes	600 minutes (Maximum)
Fineness	255 m^2/kg	225 m^2/kg (Minimum)

Table 3.4 Chemical Properties of ordinary Portland cement (OPC)

Constituent	OPC 43
SiO_2	21.65
Al_2O_3	4.69
Fe_2O_3	3.38
CaO	63.15
MgO	1.88
K_2O	1.48
Na_2O	0.35
SO_3	2.87
LOI	2.25

Table 3. 5 Compressive Strength of OPC (Grade 43)

S. No.	Days of Curing	Compressive Strength (MPa)
1	3 days	25.72
2	7 Days	36.45
3	28 days	46.20

3.3.2 Fine aggregates

Fine aggregate is defined as the aggregate which passes through the IS sieve 4.75mm. It is generally composed of crushed stone or natural sand. The aggregate has been divided into four grading zones according to their particle size distribution by IS 383-1970. Testing is done by Indian standards measurement of sieve size analysis and physical properties are shown in Table 3.6 and Table 3.7 respectively.

Table 3. 6 Sieve analyses of fine aggregates

Weight of sample taken =1000 gm

Sieve size	Mass Retained (gm)	mass retained (%)	Passing (%)	Cumulative percentage mass retained
4.75 (mm)	31	3.1	96.9	3.1
2.36 (mm)	137	13.7	86.3	16.8
1.18 (mm)	238	23.8	59.4	40.6
600 microns	168	16.8	42.6	57.4
300 microns	316	31.6	11.0	89.0
150 microns	65	6.5	4.5	95.5
Pan	45			
			∑ %age retained =302.4	

Fineness modulus= 302.4/100 = 3.02

Table 3. 7 Physical properties of fine aggregates

Properties	Results obtained
Grading Zone	Zone II
Specific gravity	2.64
Water absorption (%)	0.87
Fineness modulus	3.02

3.3.3 Water

The water used in this investigation is from concrete lab at Thapar Institute of engineering and technology.it was clean and fresh tap water. From primary investigation, it was observed that the water is free from silt, oil, organic matter, sugar, acidic material and chloride as per Indian standard. Quality of water plays important role in setting time of cement. impurities may cause straining of the concrete surface which may lead to corrosion of main reinforcement.

3.4 MIX DESIGNATION

The mix has been designed as per Indian standards IS 269-1976. The proportion of control mortar mix ratio, as determined is 1:3 with water cement ratio of 0.50. Further, in the control mix. Cement was partially replaced by variable percentage of textile sludge. The replacement levels were fixed at 5%, 10% and 15% respectively. Four types of sludge were used; namely unstabilized sludge, sludge stabilized with 5% MgO (S5), sludge stabilized with 10% MgO (S10) and sludge stabilized with 15% MgO (S15). According the nomenclature of resultant mixes was finalized. It is presented in Table 3.8. For instance, S5M10 means a mix in with 10% of cement is partially replaced with sludge stabilized by using 5% MgO.

Table 3. 8 Mix Designation

S. No.	Nomenclature	Cement Replace by sludge (%)	MgO used for Stabilization (%)	Mix Proportion (gm)			
				Cement	Sand	Textile Sludge	Water
1.	M0	-	-	200	600	0	100
2.	M5	5	-	190	600	10	100
3.	M10	10	-	180	600	20	100
4.	M15	15	-	170	600	30	100
5.	S5M5	5	5	190	600	10	100
6.	S5M10	10	5	180	600	20	100
7.	S5M15	15	5	170	600	30	100
8.	S10M5	5	10	190	600	10	100
9.	S10M10	10	10	180	600	20	100
10.	S10M15	15	10	170	600	30	100
11.	S15M5	5	15	190	600	10	100
12.	S15M10	10	15	180	600	20	100
13.	S15M15	15	15	170	600	30	100

3.5 BATCHING, MIXING AND CASTING OF SPECIMEN

A careful procedure was adopted in the batching, mixing and casting operations. The quantity of cement, sludge, aggregate, and water for the casting of mortar for each batch were determined by weight. The fine aggregates were weighed first with an accuracy of 0.5 grams. OPC having 43 grades was used in casting. Proportions of cement are replaced with sludge and thoroughly mixed. Then water was added carefully so that no water was lost during mixing. The constituents were mixed in the DIGI mortar mixer. Mixing period should not less than two minutes. Six clean and oiled moulds for each category were prepared. As per the specification of IS:10086-1982 the mould for test specimen were used for casting of cement mortar cubes as specify in the code.

The dimension of the cube was 70.5x70.5x70.5 mm. The mould which was used for casting is taken care of as soon as operable after mixing. It was taken care that all the moulds were cleaned and oiled properly before filling and also securely tightened to correct dimensions. The vibrator used for compaction was table vibrator. It should be taken care after mixing and compaction of mortar paste it keeps on dry place where relative humidity at least 90% was maintained and also temperature 27$\pm$ 2°C for 24 hours, after that they were demoulded with care so that edges are not broken. After demolding, the specimen was cured in the curing tank which filled with water for the required duration. The Duration of testing for compressive strength after curing period was 7 and 28 days.

3.6 TEST CONDUCTED

Table 3.9 shows the list of tests performed and the codes that were followed while doing the tests.

Table 3. 9 Tests and codes

Test	Code
Compressive strength	BIS 516-1959
Sorptivity	ASTM C1585
Scanning electron microscopy (SEM)	-
X-Ray Diffraction (XRD) Analysis	-
pH	-

3.6.1 Compressive Strength

Cubical specimens of size 70.5 mm were cast for conducting compressive strength test for each mix. The compressive strength test was performed as per BIS: 516-1979. For this test, six cubes from each mix were prepared and tested. The test was carried at the end of 7 and 28 days of curing taking 3 specimens at each testing age. The average of three cubes for any mix was taken as compressive strength of mortar. It should be taken care that the cube was placed in such a manner in a machine that load was applied to the opposite sides of the cube as cast. The load was applied gradually with a loading rate of 1.5 kN/sec until failure.

The compressive testing machine is shown in Fig 3.6.

Fig. 3. 6 Compression Testing machine

3.6.2 Sorptivity

This test is done to check the durability properties of hardened mortar mix. Water Sorptivity of mortar specimens was measured as per ASTM C 1585-04. For every mix, three specimens were tested for the water Sorptivity test. The aim of this test was performed to determine the vulnerability of an unsaturated mortar or concrete specimen to the penetration of water. The specimens were initially oven dried at a controlled temperature of $50 \pm 2^{o}C$ for 3 days. After this duration, the specimen was placed in a sealable container for almost 7 days. At the succeeding duration, the weight of specimen was measured to nearest 0.01gm and sides were sealed with epoxy. The average diameter of three specimens was measured and recorded as initial weight. as shown in Fig.3.7, the specimens were placed in the drinkable water and stop watch was started. The weight of specimen was recorded at an interval of 60sec, 5 min,10min, 20min, 30min, 1hr, 2hr, 3hr, 4hr, 5hr, 6hr, 1days, 2days, 3days. 4days, 5days, 6days, 7days and 8 days. The absorption was calculated as follows:

$$I = Mt/ [a \times d]$$

Where,

I = the absorption

M_t = the average increase in specimen mass in gm, at time t

a = the exposed area of the specimen, in mm^2

d= the density of the water in g/mm^3

Fig. 3. 7 Experimental set up for measuring Sorptivity of mortar

3.6.3 Scanning Electron Microscopy (SEM)

SEM plays a vital role in resolving the microstructure of mortar or concrete. It provides both compositional and topographical analysis of materials. The application of SEM amplifies the ability to characterize the mortar microstructure and helps in finding out the factors affecting the hardened and durability properties of mortar. The fractured pieces of mortar generated from the compressive strength test were used for notice the scanning electron micrographs.

3.6.4 X-Ray Diffraction (XRD) Analysis

The X-Ray diffraction method was used for identification of various phases present in the hardened textile sludge mortar as well as control mortar cube sample at the age of 28 days. It is a non-destructive method by which X-Ray of a defined wavelength is passed through a sample to the identified crystalline structure. It is the most renowned technique used for unraveling the materials in thin and bulk film forms. The nature of wave in the X-Ray means that they are diffracted by the core of the crystal which gives a unique pattern of peaks of reflections at different angles and different intensity. It moves around the samples and measures the intensity as well as the position of these peaks. The sampling was done in the powdered form for each mix. The cement pastes were separated from mortar samples and were sieved through 90 µm sieve. The data were analyzed for all samples at room temperature in the range of $20^\circ \leq 2\theta \leq 80^\circ$. the scan speed was 5°/min.

3.6.5 pH

pH of mortar mix was taken by digital pH meter. 3 gm of crushed mortar sample diluted with deionised water, after that reading was measured by digital Ph meter. In general, pH values of hardened concrete increase gradually over time. The pH of ordinary Portland cement concrete is usually between 12.5 and 13, but it can decrease due to deterioration mechanisms such as chloride ingress, carbonation or acid attack. Chloride ingress into concrete can result in a pH reduction due to the formation of hydrochloric acid.

CHAPTER-4

RESULT AND DISCUSSION

4.1 GENERAL

This chapter describes the observations and details of the results from the different tests conducted on chemical, physical and mechanical properties of mortar, which are associated with finding the usability of textile ETP sludge in cement mortar. Micro-structure analysis of scanning electron microscopy and Inductive coupled plasma atomic emission spectroscopy for heavy metals detection are discussed in this chapter. A Comparative study of properties of durability, strength properties of hardened mortar made with textile ETP sludge as partial replacement of cement is presented. The results and discussion of both Part-1 and Part-2 of the explained previously are presented in the following sections.

4.2 PROPERTIES OF STABILIZED ETP SLUDGE

Before and after stabilization of textile ETP sludge various properties are studied to decide the effectiveness of procedure. These Parameters are discussed in following sections:

4.2.1 Inductive Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)

Five samples were prepared for ICP-AES. To analysis the leachate behavior of textile ETP sludge with the LG-MgO. Table 4.1 shows the concentrations of heavy metal in textile ETP sludge with or without stabilization. It was observed by the results obtained from the ICP-AES that some of the metal like Cr, Pb, Cd, Zn decreasing with the increase in stabilization of textile ETP sludge with LG-MgO. The metal concentration getting from ICP-AES was with in regulatory limit as per specified by central pollution control board (CPCB) New Delhi. Lesser amount of heavy metal in leachate, metals are controlled from contaminating the ground water resources. Some of the metals which effect the mechanical and durability properties of concrete with the use of textile ETP sludge as replacement of cement have also been reduced. So ICP-AES, confirms the effectiveness of stabilization.

Table 4. 1 ICP-AES Results

Sample	Cd	Cr	Fe	Pb	Zn	S
TEXTILE ETP SLUDGE	0.62	1	2.623	0.51	1.062	96.475
SLUDGE+5%LG-MGO	0.23	0.924	2.198	0.07	0.559	96.126
SLUDGE+10%LG-MGO	0.14	0.413	1.623	0.02	0.369	86.475
SLUDGE+15%LG-MGO	0.12	0.262	1.234	ND	0.259	84.278
SLUDGE+20%LG-MGO	ND	0.2	0.965	ND	0.149	84.192
CPCB Standards	0.25	2.0	3.5	0.1	5.0	100

ND MEANS LESS THAN 0.01 PPM

4.2.2 pH

pH is an important parameter for mortar from strength point of view. Table 4.2 shows the value of pH of sludge with deionized water before and after stirrer. Table 4.3 shows the value of pH after 28 days of casting of mortar cubes. It can be concluded by reading of pH mentioned in Table 4.3, initially without stabilization the pH was increasing as the increase in percentage of sludge replace with cement whereas with stabilization at 5% and 10%, pH was lies within the control specimen. The main reason for the increase of the pH value is the release of more alkalis followed by further dissolution of tricalcium aluminate phases which react with available sulphate and result in precipitation of ettringite. The hydroxide concentration and pH values are slightly increased over time due to continued hydration of the clinker phases which results in releasing almost constant amount of alkalis in the solution.

Table 4. 2 pH of Textile ETP sludge with LG-MgO

S. No.	Parameter	Before stirrer	After stirrer
1	Textile ETP sludge	8.32	-
2	Stabilize Textile ETP sludge with 5% LG-MGO	10.23	10.98
3	Stabilize Textile ETP sludge with 10% LG-MGO	12.10	12.26
4	Stabilize Textile ETP sludge with 15% LG-MGO	12.25	12.32

Table 4.3 pH of mix

S. No.	Mix	pH
1.	M0	12.98
2.	M5	13.23
3.	M10	13.18
4.	M15	13.72
5.	S5M5	12.70
6.	S5M10	12.84
7.	S10M5	12.10
8.	S10M10	13.02
9.	S15M5	13.12
10.	S15M10	13.25

4.3 PROPERTIES OF MORTAR SPECIMEN

The compressive strength and Sorptivity of control, partial replacement of cement with textile ETP sludge and partial replacement of cement with stabilized textile sludge mortar was studied in the following sections:

4.3.1 Effect of Untreated ETP Sludge on Compressive Strength

Present study shows the effect of textile ETP sludge on compressive strength of mortar. It was observed from the test results presented here in Fig 4.1 that with increase in the percentage of replacement of textile ETP sludge with cement the compressive strength of mortar in comparison with control sample was decreasing gradually at 7 days as well as 28 days. This decrease in strength is explained by **Patel et al. (2012)**, according to the test results, it might be due to the presence of certain compounds like salts of zinc and lead in the sludge which might have deleterious effect on the hydration reactions responsible for the strength development. The decrease in the compressive strength at 5% ,10% and 15% of replacement to cement at 7 days was 0.35%, 21.21 %, 28.28% and for 28 days 3.80%, 5.75%, 24.32% respectively as compared to control mix.

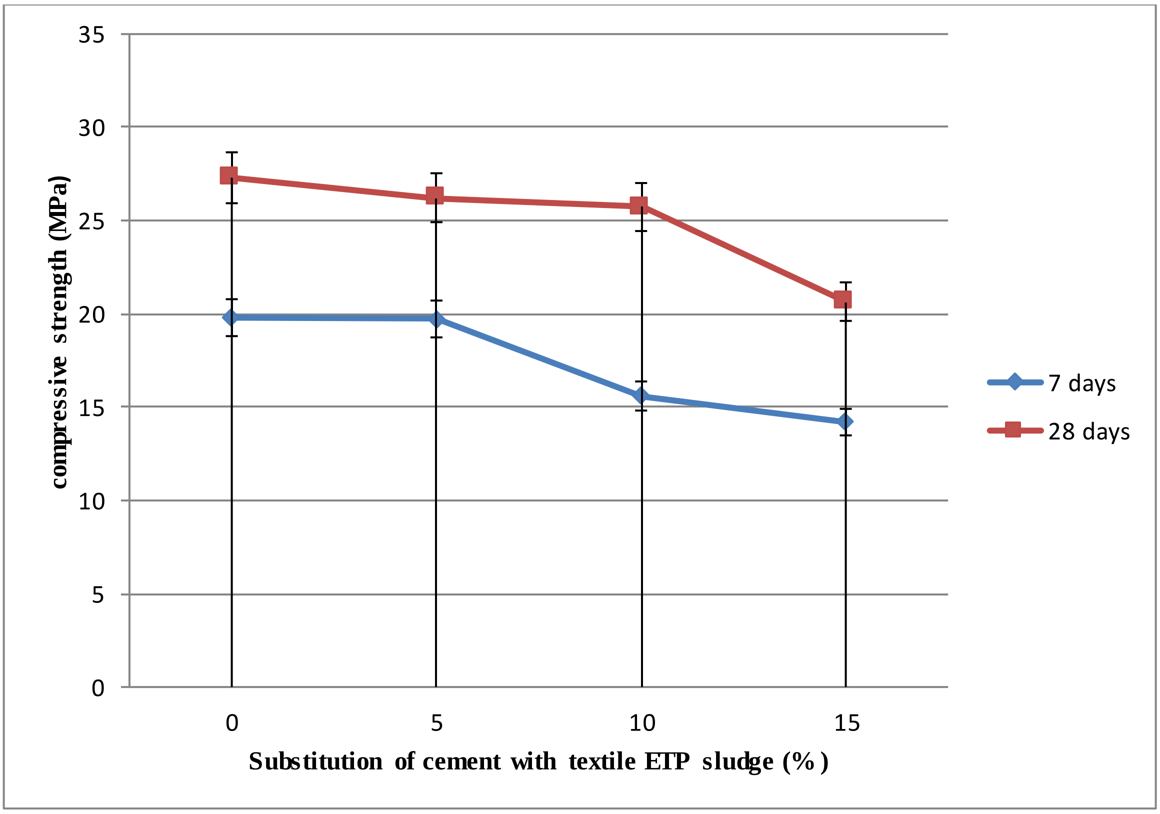


Fig 4. 1 Average compressive strength for mixtures of cement and textile ETP sludge

4.3.2 Effect of Stabilized ETP Sludge on Compressive Strength

The sludge was stabilized using 5%, 10% and 15% of low grade MgO. The sludge is referred to as S5, S10 and S15 respectively. Further each treated sludge was used as partial replacement to cement. The percentage replacement level was varied from 5% to 15% at an increment of 5%. Fig 4.2 represents the effect of S5 sludge at all replacement level at both 7 days and 28 days. Similarly, Fig 4.3 and Fig 4.4 represent compressive strength results for S10 and S15 stabilized ETP sludge samples.

In Fig 4.2 it was observed that when the 5% stabilized textile ETP sludge was used as replacement of cement at different percentage. The 7 days compressive strength was increased by 8.58% and 28 days compressive strength was increased by 3.80% at 5% replacement level of cement as compared to control mix.

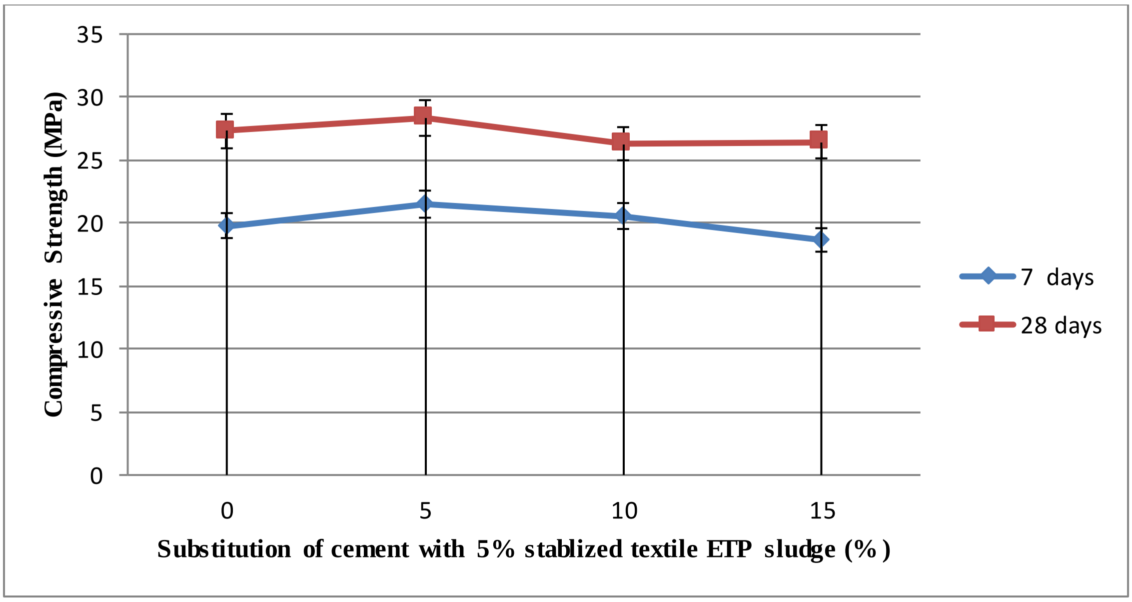


Fig. 4. 2 Average compressive strength for mixtures of cement and 5% stabilized textile ETP sludge

In Fig 4.3 it was observed that when the 10% stabilized textile ETP sludge was used as replacement of cement at different percentage. The 7 days compressive strength was increased by 20.85%, 13.20% and 28 days compressive strength was increased by 11.35%, 7.80% at 5% and 10% replacement of cement as compared to control mix.

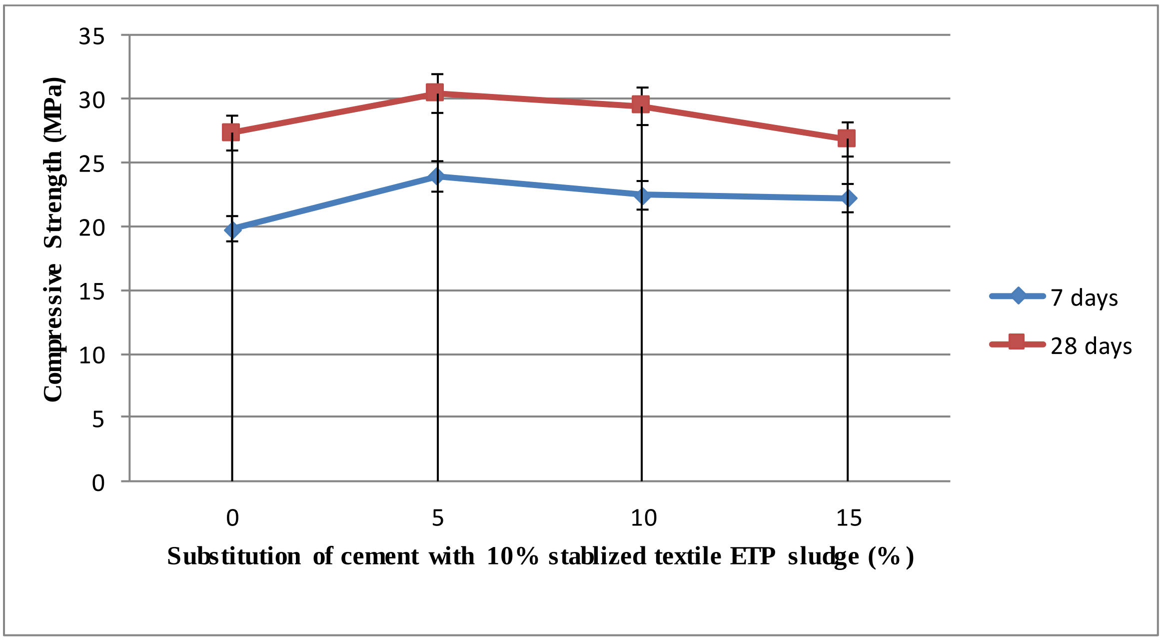


Fig. 4. 3 Average compressive strength for mixtures of cement and 10% stabilized textile ETP sludge

In Fig 4.4 it was observed that when the 15% stabilized textile ETP sludge was used as replacement of cement at different percentage. The 7 days compressive strength was increased by 33.33%, 31.96% and 28 days compressive strength was increased by 10.62%, 8.42% at 5% and 10% replacement level of cement as compared to control mix.

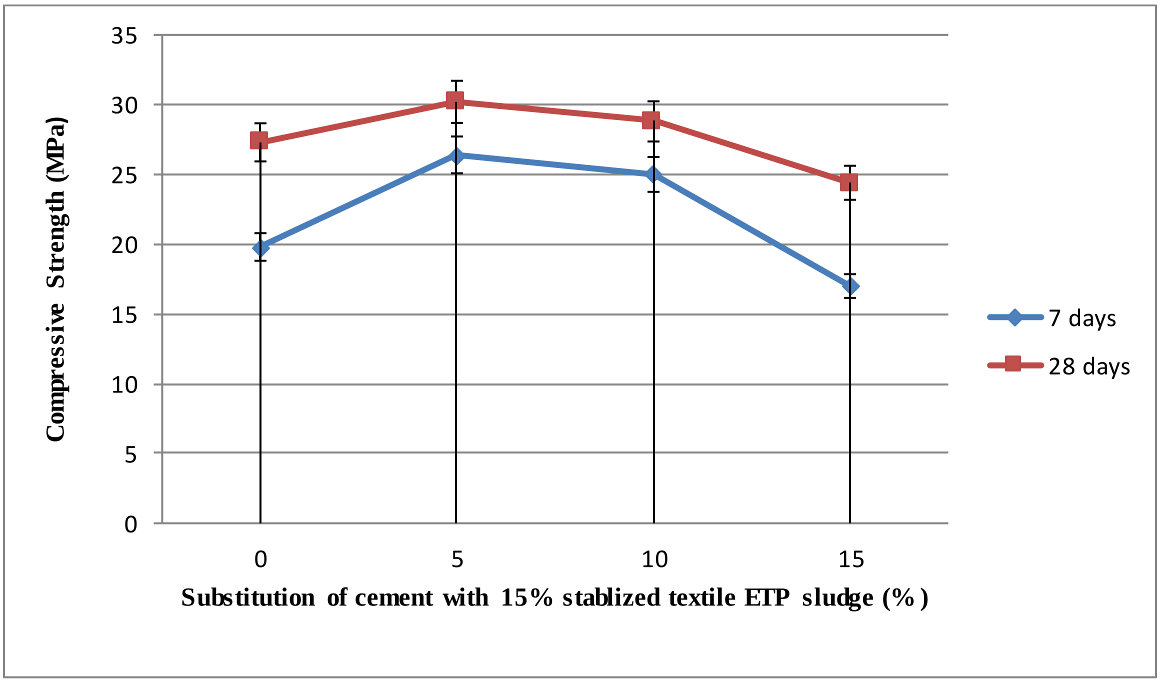


Fig. 4. 4 Average compressive strength for mixtures of cement and 15% stabilized textile ETP sludge

From all the figure it can be observed that at both 7 days and 28 days, the compressive strength of mixes having stabilized sludge is greater than that the compressive strength of control mix.

The comparative 7 and 28 days average compressive strength results were shown in Fig 4.5 and Fig 4.6. It clearly shows that the stabilized sludge is improving the mechanical properties of mortar. Zhan et al. (2015) states that the compressive strength of the concrete blocks increases with reducing the content of ammonia level by stabilization with lime in textile effluent sludge (TES) content. Ammonia level in TES was the main cause of the weakening effect. Similarly, with the low grade MgO the heavy metal concentration also reducing by stabilization. So, this may be one of the reason of improving the compressive strength of mortar cubes.

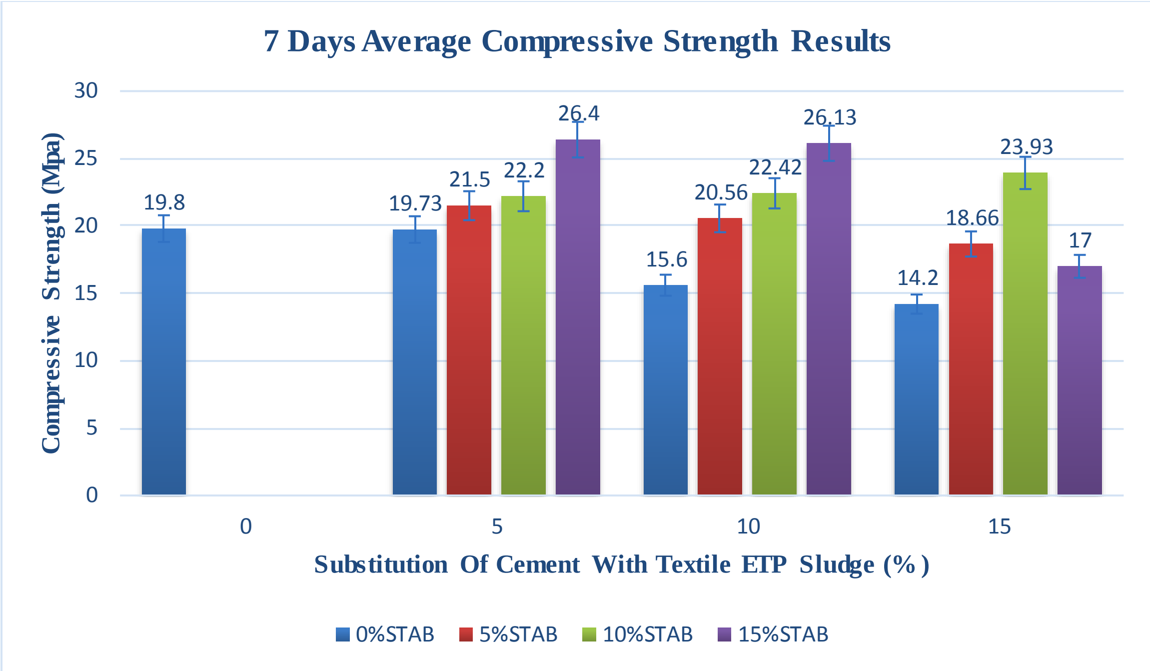


Fig. 4. 5 compressive strength v/s % substitution of cement with textile ETP sludge at 7 days

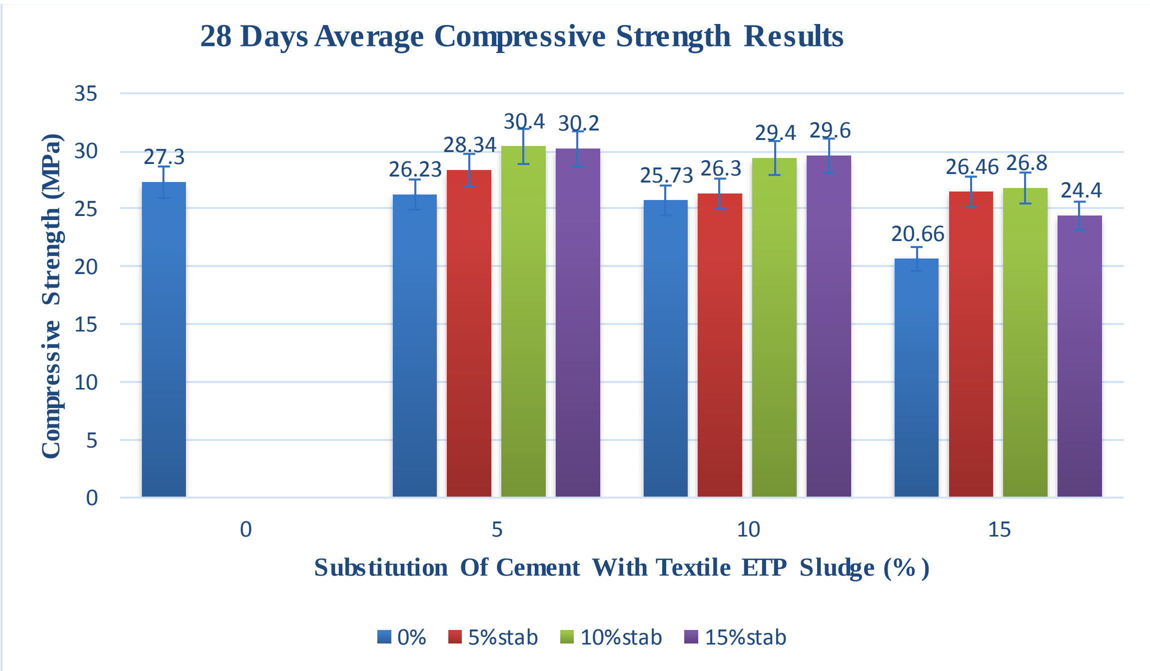


Fig. 4. 6 compressive strength v/s % substitution of cement with textile ETP sludge at 28 days

4.3.3 Sorptivity

Sorptivity test results are shown in Fig.4.7. In this figure seven series are presented they are defined as M0 represent as control sample. M5, M10, M15 are represented as replacement of ETP sludge with cement at a percentage of 5%, 10% and 15%. S10M5, S10M10, and S10M15 are represented as stabilization of ETP sludge at 10% and replacement of cement at 5%, 10% and 15% respectively. The slope of the line between was taken as sorptivity of each mix, which is presented in Fig 4.7. It was observed by the graph without stabilization shows higher water absorption as compared to control as well as stabilized sample. As the increase in the percentage of stabilized sludge in samples the water absorption decreases, this also satisfies the increase in compressive strength results of stabilized sludge mortar cubes as compared to without stabilized sludge mix.

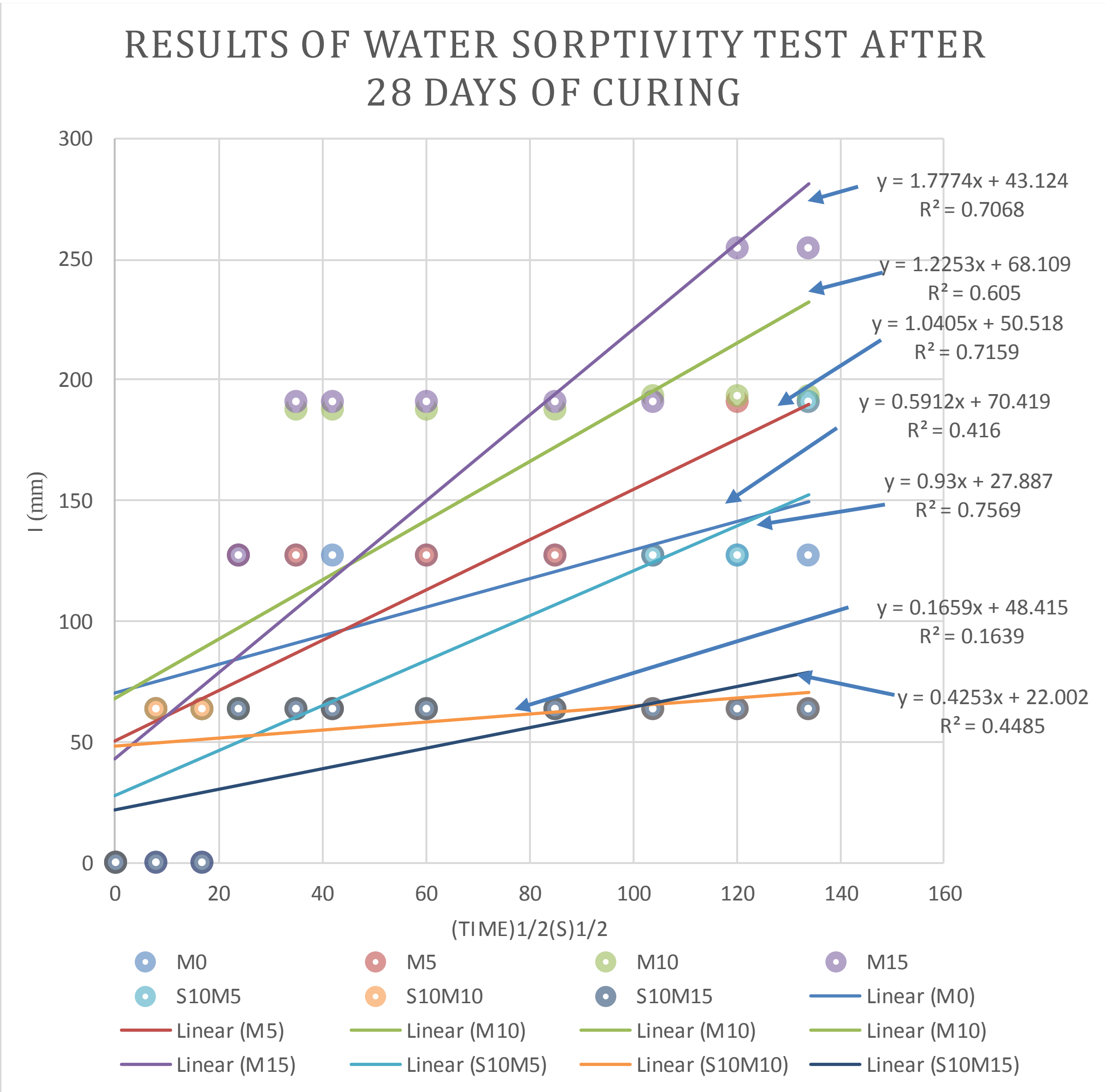


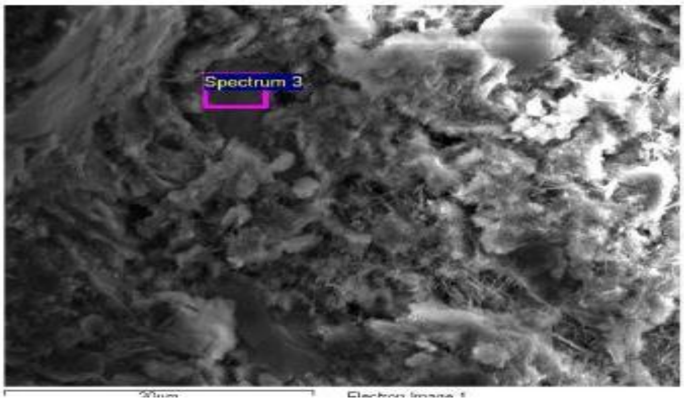
Fig. 4.7 Effect of textile ETP sludge on water Sorptivity of mortar

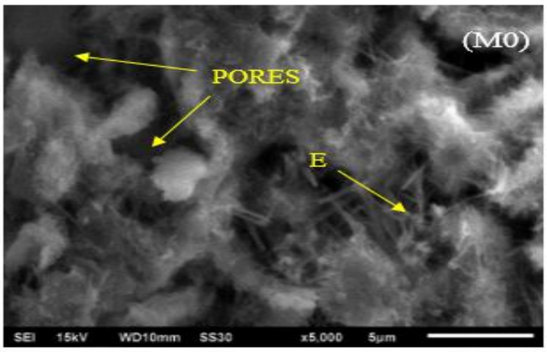
4.4 SEM-EDS

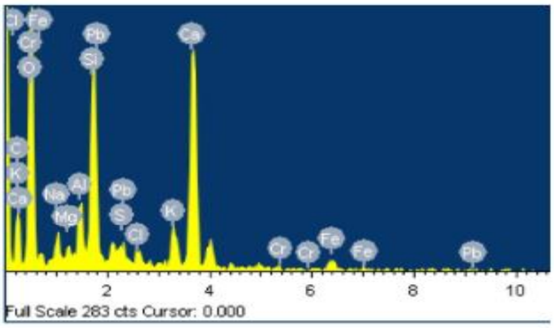
Scanning electron micrographs (SEM) of mortar mixtures after 28 days of immersion in normal water was taken and analysed for different mixes. In this study, fractured pieces of mortar were mounted on the SEM stubs and images were obtained by Secondary electron (SE) image mode. The mortar specimen was coated with a very thin layer of gold to make them electric conductive before keeping in SEM stem. Figs 4.8 shows the SEM analysis of control sample of mortar (M0) and 5%, 10%, 15% (M5, M10, M15) replacement of cement with textile ETP sludge in mortar. Figs 4.9 shows the SEM analysis of 5%, 10% and 15% (S5M5, S10M5, and S15M5) stabilized textile ETP sludge replacement of cement with 5%.

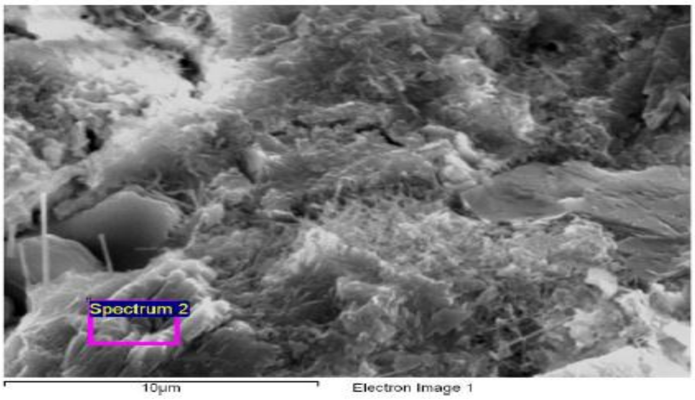
The SEM micrography of the untreated sludge shows that with the increase in replacement percentage of sludge with cement, the voids become larger as compared to control sample. Also, the formation of ettringite increases with varying percentage of ETP sludge. The results of EDS-mapping analyses of the untreated sludge also reveals that calcium and iron were distributed over the particle uniformly, but zinc was rarely detected.

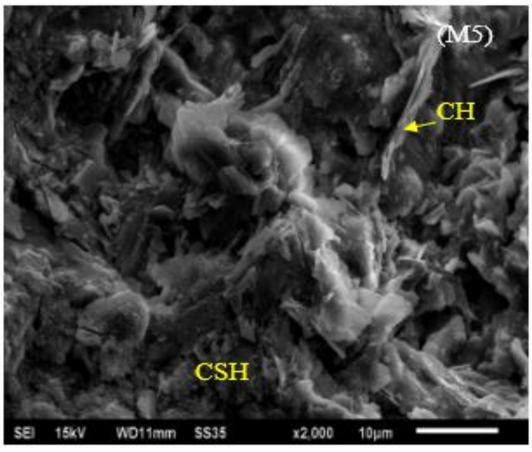
The SEM micrography and EDS- mapping analyses of the stabilized textile ETP sludge revelled that calcium is the major element in the treated ETP sludge. The reduction in the peacks of heavy metal is also shown in S5M5, S5M10 and S5M15 as compared to M0, M5, M10 and M15. The concentration of iron, sulphide and oxides is also evenly distributed in both untreated and treated sludge.

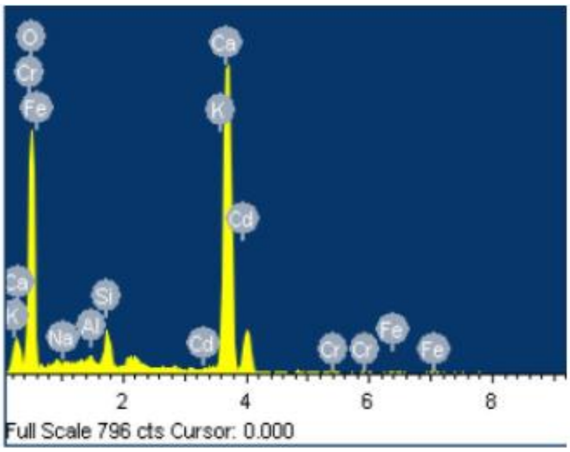

Spectrum 3


(M0)
PORES
E
SEI 15kV WD10mm SS30 x5,000 5µm


Cl Fe Cr O Pb Si Ca
Cr K Ca Na Mg Al Pb S Cl K Cr Cr Fe Fe Pb
2 4 6 8 10
Full Scale 283 cts Cursor: 0.000


Spectrum 2
10µm
Electron Image 1


(M5)
CH
CSH
SEI 15kV WD11mm SS35 x2,000 10µm


O Cr Fe Ca K Cd
Ca K Na Al Si Cd Cr Cr Fe Fe
2 4 6 8
Full Scale 796 cts Cursor: 0.000

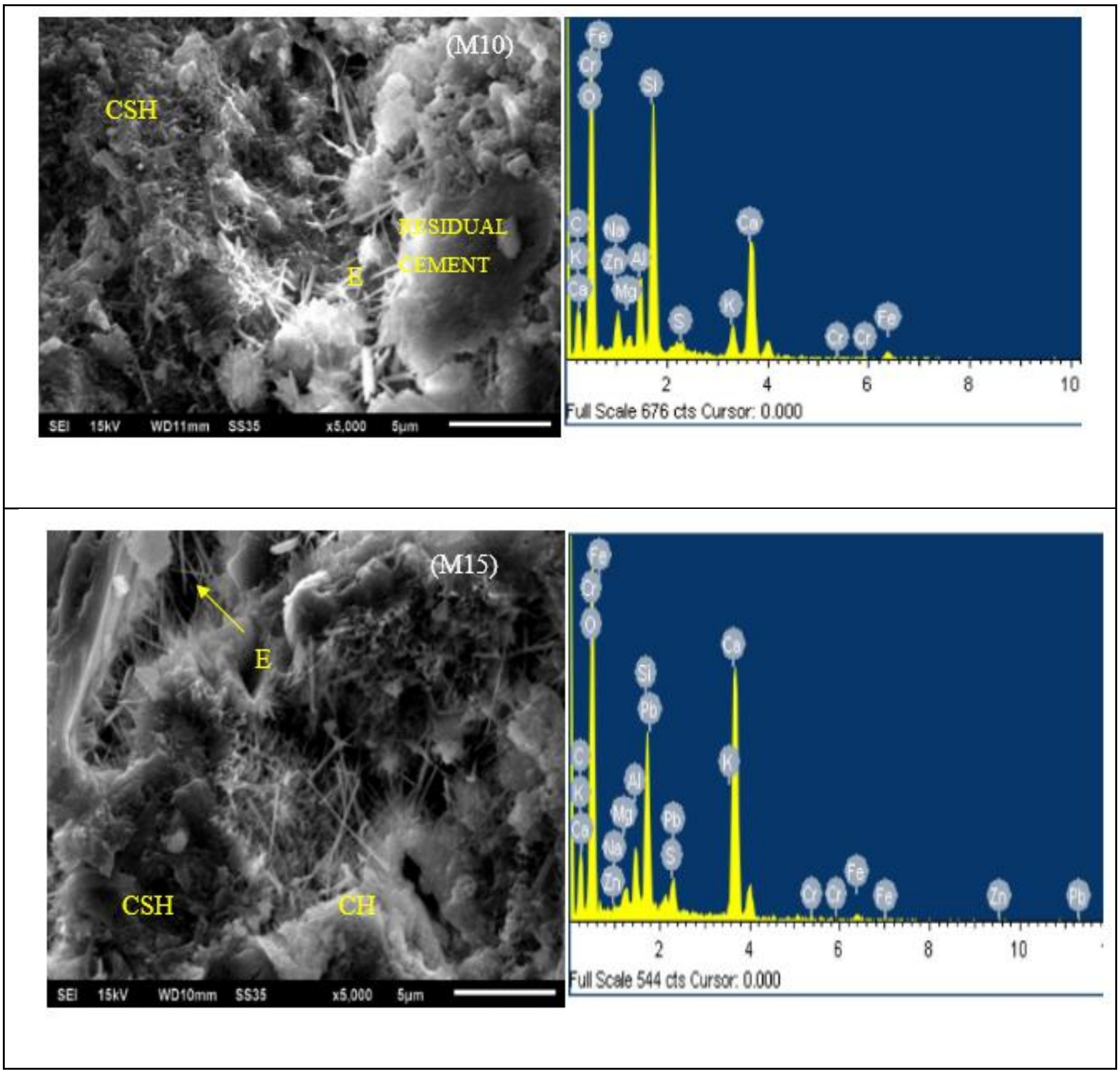
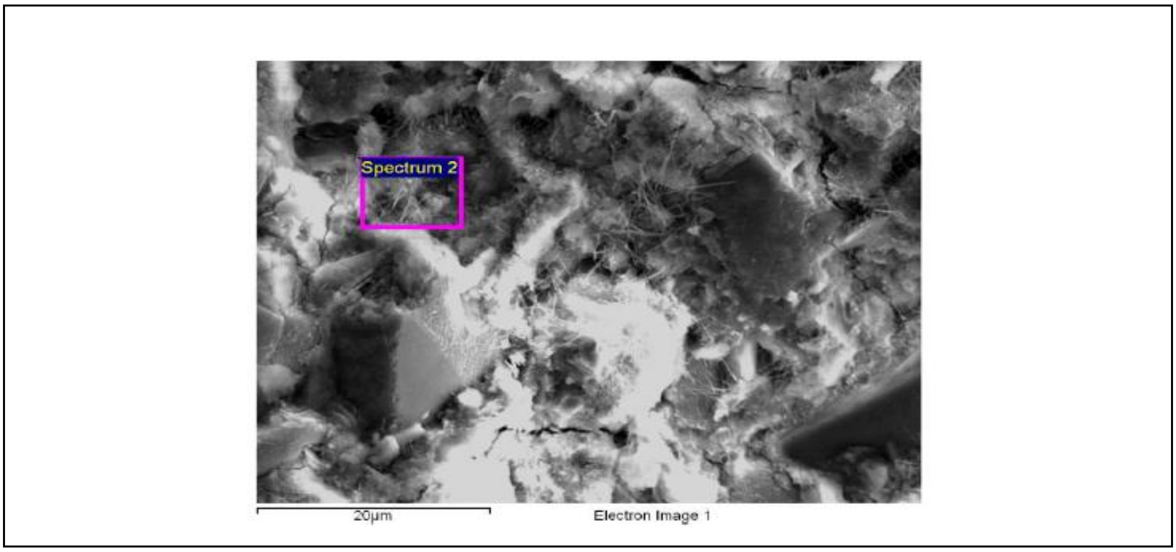
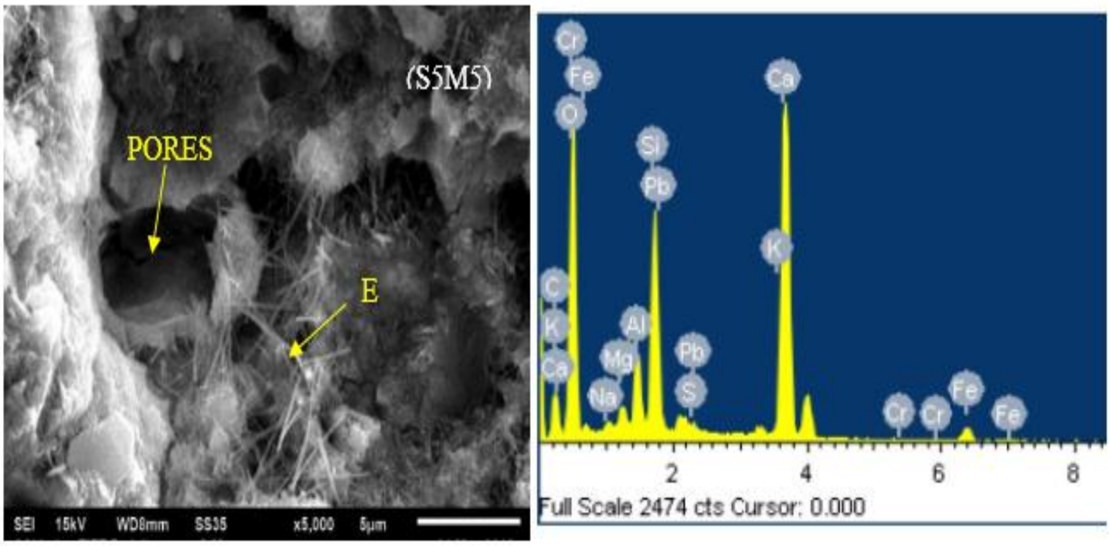
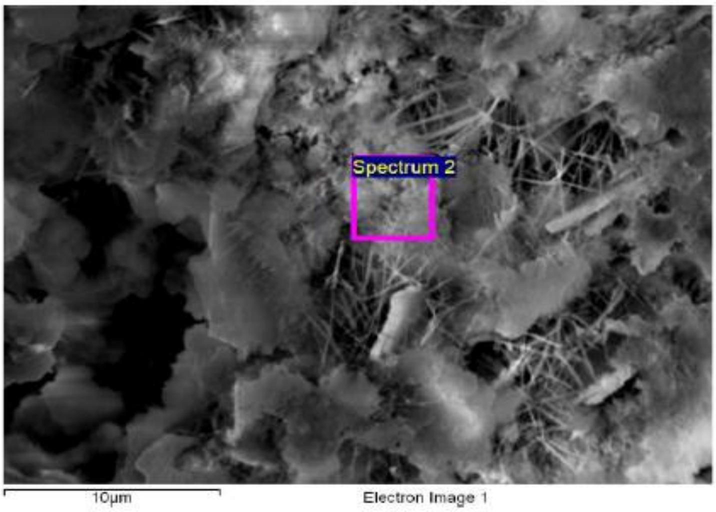
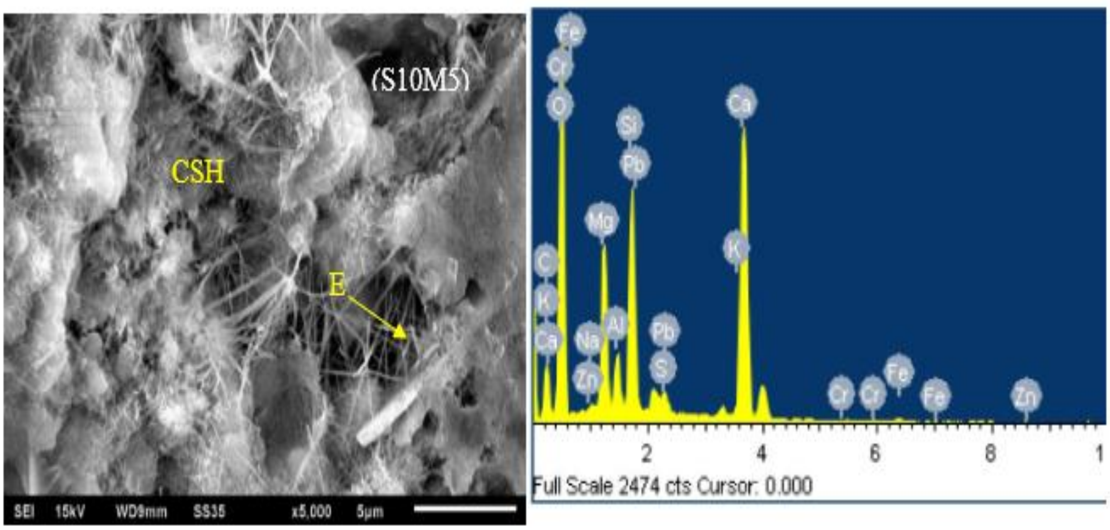


Fig. 4.8 Scanning electron micrograph and Energy dispersive spectrometer of control mortar(M0) and Replacement of cement with textile ETP sludge (5%,10%,15%) mortar (M5, M10, M15) after 28 days of curing.




(S5M5)
PORES
E
SEI 15kV WD8mm SS35 x5,000 5µm
Cr
Fe
O
Ca
Si
Pb
K
C
K
Ca
Al
Mg
Na
Pb
S
Cr
Cr
Fe
Fe
2
4
6
8
Full Scale 2474 cts Cursor: 0.000


Spectrum 2
10µm
Electron Image 1


(S10M5)
CSH
E
SEI 15kV WD9mm SS35 x5,000 5µm
Fe
Cr
O
Ca
Si
Pb
Mg
K
C
K
Ca
Na
Al
Zn
Pb
S
Cr
Cr
Fe
Fe
Zn
2
4
6
8
1
Full Scale 2474 cts Cursor: 0.000

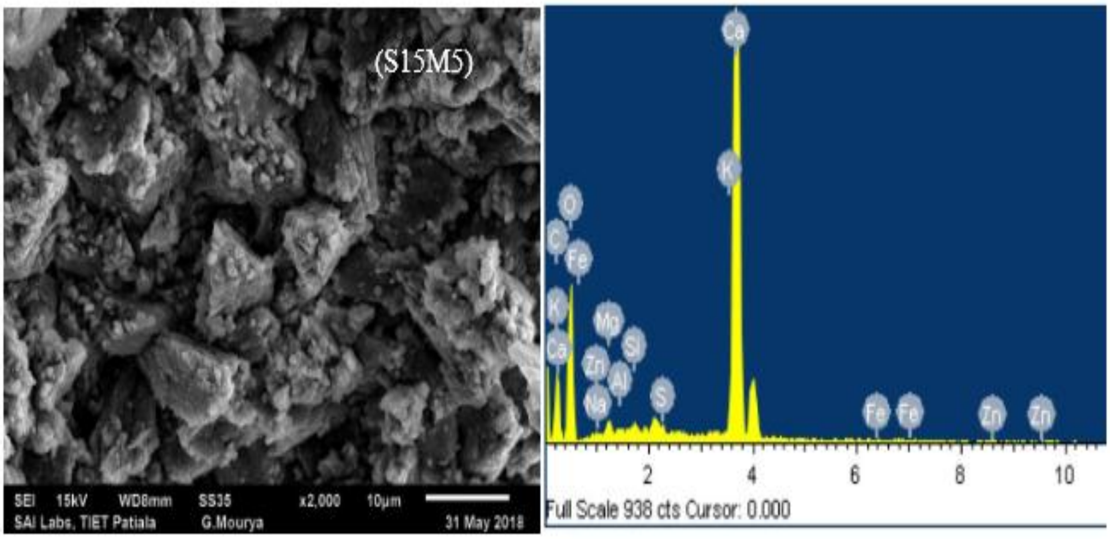
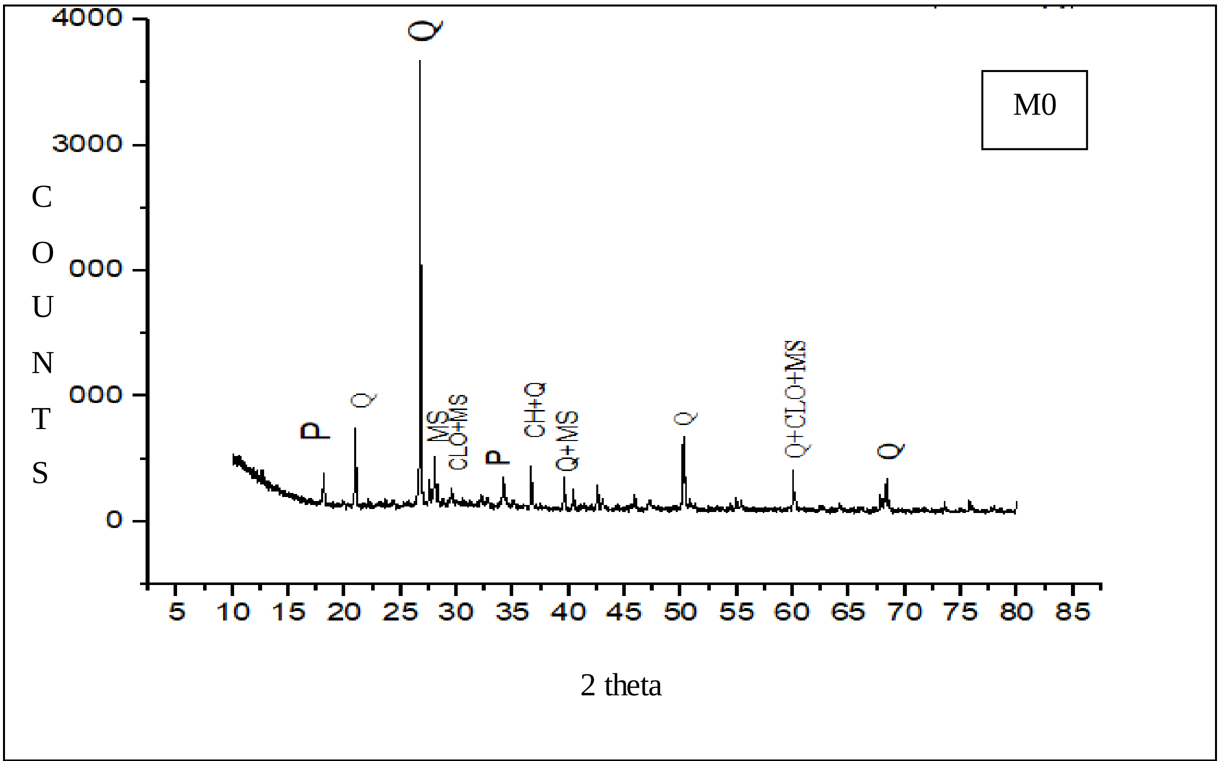


Fig. 4.9 Scanning electron micrograph and Energy dispersive spectrometer of stabilized textile ETP sludge mortar of 5% replacement of cement with 5%,10%, and 15% of stabilization (S5M5, S10M5, S15M5) after 28 days of curing.

4.5 XRD ANALYSIS

XRD spectrum of mortar mixes after 28 days of curing are shown in Fig 4.10 and Fig 4.11. The cement pastes were separated from the mortar samples and were sieved through a 90µm sieve. The XRD analysis was performed for diffraction angle ranged between 10˚to 80˚ in steps of 2θ=0.017˚. The diffraction pattern of intensity of diffraction peaks was prepared. From the XRD analysis of the control mix, peaks of portlandite, quartz, Magnesium silicate, cadmium lead oxide were obtained in the mix. On addition of untreated sludge, major peacks of lead oxide silicate, silicon sulfide, cadmium lead oxide, lead aluminum silicate were observed, indicating presence of heavy metal in the mix. With the increase in the percentage of untreated sludge heavy metal was increased. With the stabilization of sludge, the major components formed were portlandite, calcium silicate hydrate, quartz, cadmium lead silicate. Cadmium lead oxide. On treatment of sludge, heavy metals have been leached out as observed in the XRD spectrums. This is similar to what was observed in compressive strength test. Where the mix with treated sludge showed higher strength as compared to the mix with untreated sludge.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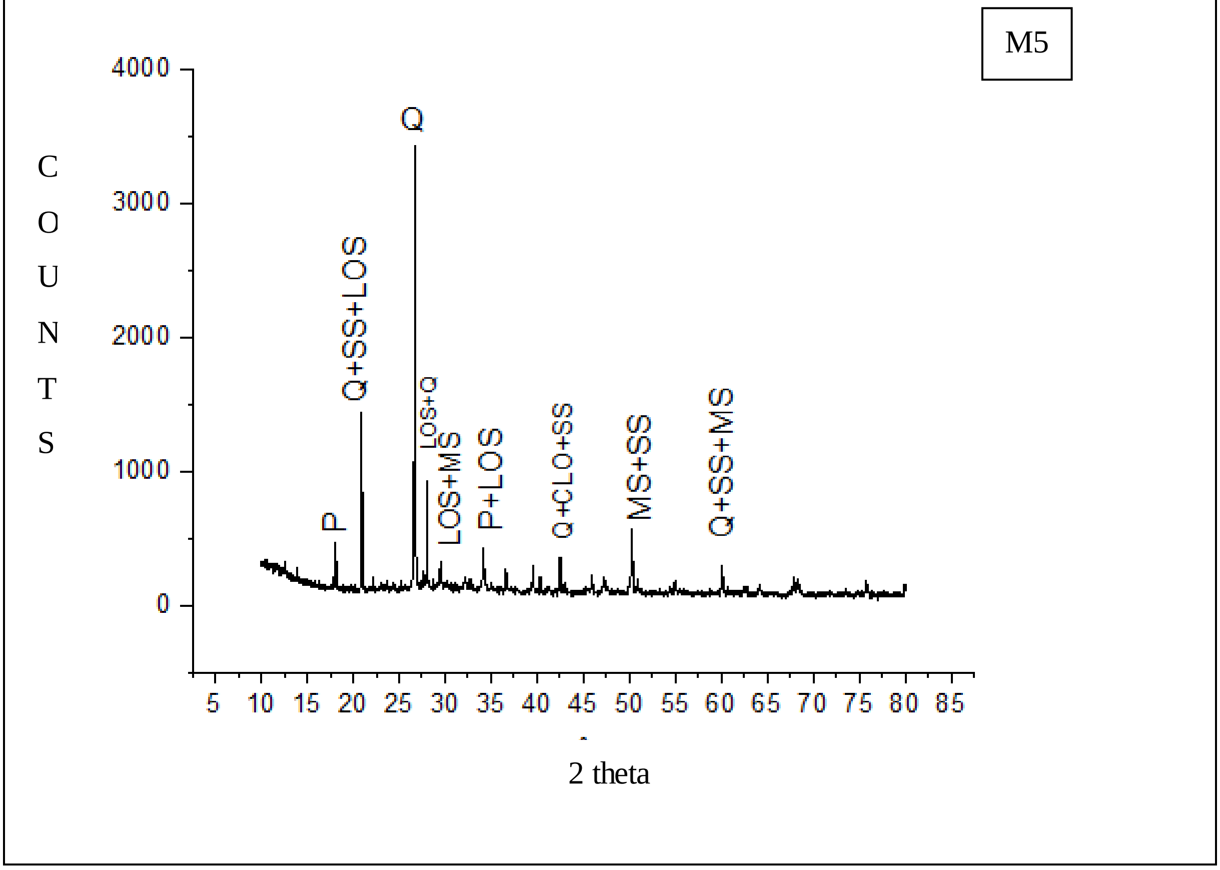
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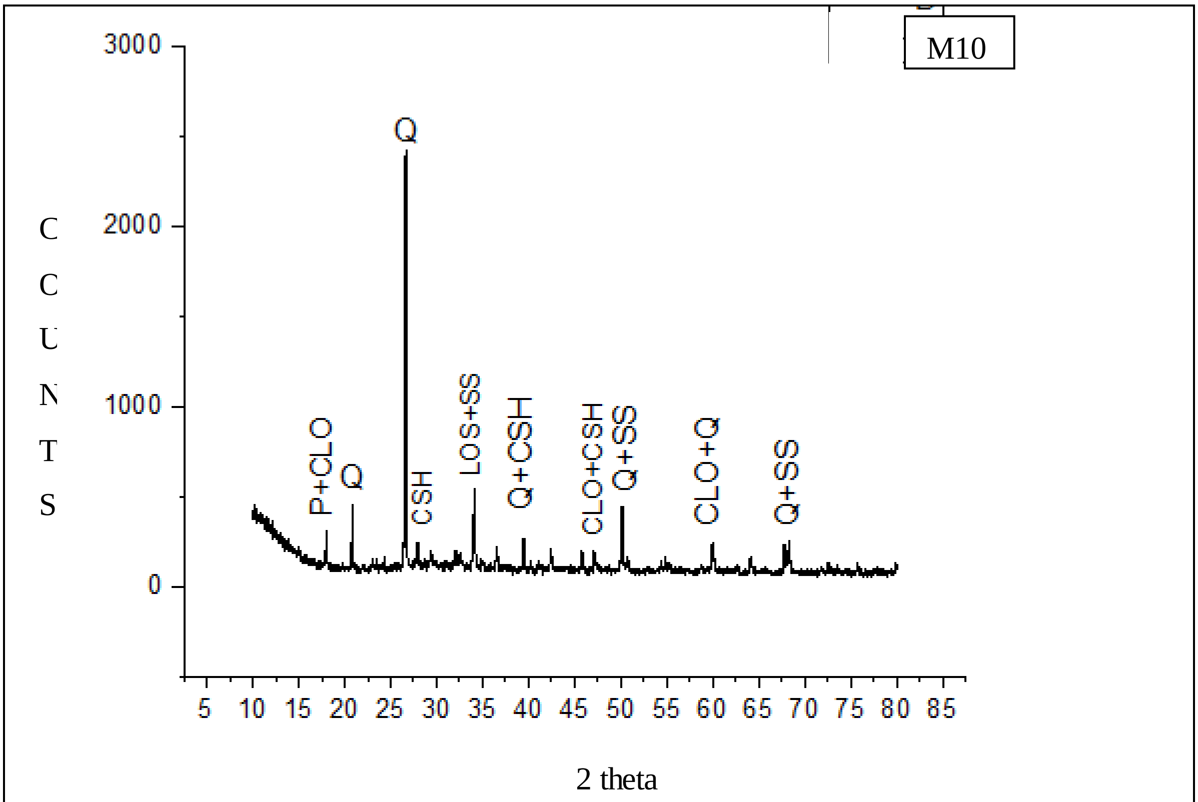

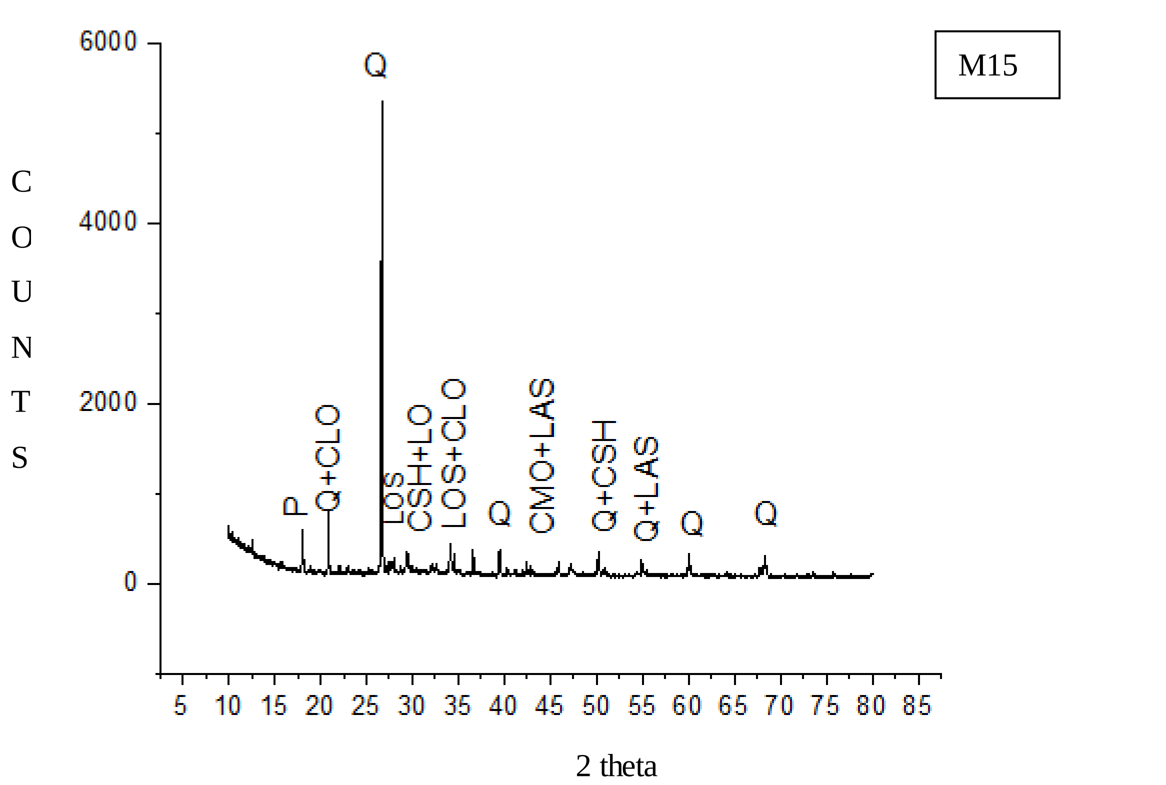

Fig. 4.10 XRD spectrum of control mortar(M0) and Replacement of cement with textile ETP sludge (5%,10%,15%) mortar (M5, M10, M15). (P=Portlandite; Q=Quartz; CSH=Calcium

Silicate Hydrate; SS=Silicon sulfide; CLO= Cadmium Lead Oxide; LO=Lead Oxide; LAS=Lead Aluminum Silicate; CCO=Cadmium Chromium Oxide; MS= magnesium silicate).

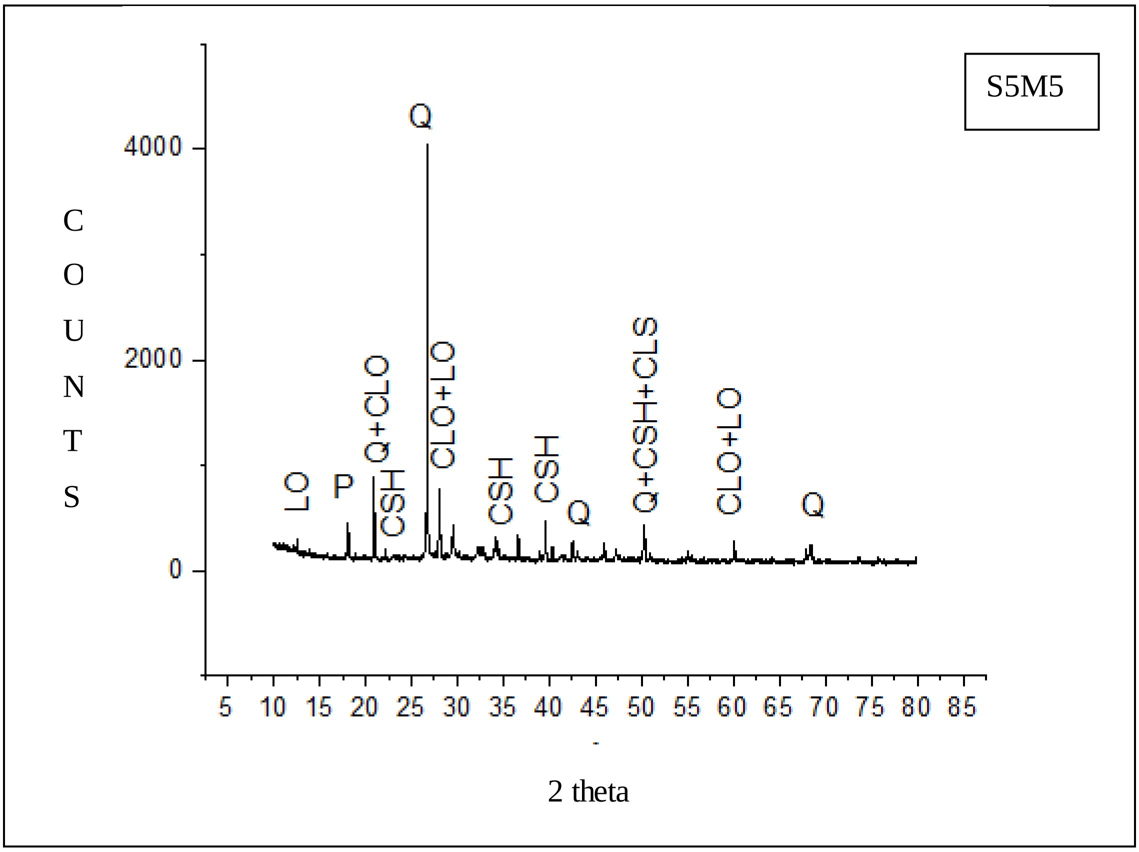

Fig.4.11 XRD spectrum of stabilized textile ETP sludge mortar of 5% replacement of cement with 5%of stabilization (S5M5) (P=Portlandite; Q=Quartz; CSH=Calcium Silicate Hydrate; CLO= Cadmium Lead Oxide; MCO=Manganese chromium oxide; CLS=Cadmium Lead Silicate; LO= Lead oxide)

CHAPTER-5

CONCLUSION & SCOPE OF FURTHER STUDY

5.1 CONCLUSION

In this research work, the study findings highlight the leachability of heavy metals stabilized with low-grade magnesium oxide are successful and possible to be a partial replacement of cement by the DIN procedure to treat the heavily contaminated textile ETP sludge. Following conclusions are drawn from this study they are as follows:

5.1.1 Stabilization

1. The use of LG-MgO as a reactive agent for treatment of sludge contaminated by heavy metals confirm the significant rates of reduction of metals are achieved.
2. LG-MgO provides an alkali reservoir that allows long-term stabilization without varying the pH conditions.
3. The use of low-grade MgO may be an economically useful alternative in the stabilization of heavy metals in heavily contaminated textile ETP sludge.
4. With stabilization, textile ETP sludge may be possible to use as a structural material.

5.1.2 Compressive Strength

1. The compressive strength of mortar decreased with the increase in cement replacement with different replacement levels of textile ETP sludge whereas it increases with the use of stabilized textile ETP sludge in comparison of control mortar mix.
2. The decrease in the compressive strength at 5% ,10% and 15% of replacement to cement at 7 days was 0.35%, 21.21 %, 28.28% and for 28 days, it was decreased by 3.80%, 5.75%, 24.32% as compared to control mix with the use of untreated ETP sludge.
3. With treatment of ETP sludge, the maximum compressive strength was achieved in 67.5% at 7 days in mix S10M10 in comparison with mix M10 and 29.74% at 28 days in mix S15M10 in comparison with mix M15.
4. The maximum compressive strength was achieved in 10% Stabilization with 5% stabilization level with respect to control mix. Thus, for optimum mix was S10M5.

5.1.3 Sorptivity

1. Initial rate of absorption (sorptivity) of mortar mixtures increased on inclusion of ETP sludge.

5.1.4 Microstructure

1. The reduction in the peacks of heavy metal is observed in S5M5, S5M10 and S5M15 as compared to M0 (Control mix), M5, M10 and M15.
2. Mortar (Portland cement and sand) exhibits homogenous and dense structure, whereas with the addition of textile sludge in the composition displays higher heterogeneity of the structure.

5.1.5 XRD Phase Analysis

1. Phase composition of powdered mortar paste did not change qualitatively, however change in phase proportions were observed on use of textile ETP sludge on mortar.
2. XRD analysis showed the peak of portlandite (CH), calcium silicate hydrate (CSH), quartz (Q), cadmium lead oxide (CLO), silicon sulphide (SS), Cadmium Lead Silicate (CLS), Lead oxide (LO).

5.2 SCOPE FOR FURTHER WORK

Although there is large-scale availability of textile ETP sludge in the world. There is need of use of this waste material in the construction industry to save the environment and also it is important to stabilize this hazardous waste in a most economical way to save the ground water for contamination. There is need of research on textile ETP sludge use as a structural as well as non-structural material. It may also possible use of textile sludge in bricks, blocks, and flooring tiles.

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