INTERACTION OF FUNGI WITH CEMENT MATERIAL AND PROPERTIES THERE-OF

A thesis submitted
in partial fulfillment of the requirements for
the award of the degree of

MASTERS OF ENGINEERING
IN
STRUCTURAL ENGINEERING

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Candidate's Declaration

I hereby declare that the work being presented in the thesis entitled" ***Interaction of Fungi with Cement Material and Properties there of*** " in partial fulfilment of the requirements for the award of degree of Masters in Structures, Department of Civil Engineering, Thapar University, Patiala is my own laboratory work during the period of January 2013 to June 2013, under the conception and supervision of Dr. Maneek Kumar, Professor, Department of Civil Engineering and Dr. Sanjai Saxena, Associate Professor, Department of Biotechnology and Environmental Sciences (DBTES), Thapar University, Patiala. I have not submitted the matter embodied in this thesis for the award of any other degree.

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This is to certify that the above statement made by the candidate is correct and true to the best of our knowledge.

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This is to certify that the thesis entitled ***"Interaction of Fungi with Cement Material and Properties there of"*** being submitted by **Ms Rinki Verma (Roll No-801122014)** in partial fulfillment of the requirements for the award of degree of Master of structures in Civil Engineering, Thapar University, Patiala is a bonafide work carried out under the esteemed supervision and conception of Dr. Maneek Kumar and Dr. Sanjai Saxena and that no part of this thesis has been submitted for the award of any other degree.

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(RINKI VERMA)

ABSTRACT

The effect of induction of fungi in the cement mortar matrix has been investigated with regards to compressive strength. As nutrients are very necessary for the growth of fungi in any matrix, so rice husk (an organic material) was used for the purpose. 25 endophytic fungi were screened in different proportions of mortar mix having cement, sand, fly ash and rice husk. From all types of mixes the mix with 50% replacement of sand with rice husk and 50% replacement of cement with Fly Ash was the best for the growth of the Fungi. The cubes were prepared by volume with the best grown Fungi #21 CMSTITNEY, #31CMLPITNEY and #44 CMSTITNEY.

Also, it has been seen that although the growth of fungi was significant in the matrix providing a good bond, but use of rice husk, which is an organic material, has reduced the compressive strength of the material. Thus, there was only binding of fungi with the material but no increase in the compressive strength. Thus, there is need to find better nutrients on which the fungi can grow in the mortar matrix and which also do not hamper the strength of the composite.

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CHAPTER 1
INTRODUCTION

1.1 COMPOSITE MATERIAL

Composite material comprises of two or more than two basic materials possessing different properties which are mixed in different quantities. The idea behind developing composite materials is to best properties in the material being develop apart from knowing the strength of individuals component used in developing the composite material used in developing the composite material. In context of building materials and structure design in civil engineering the greatest advantage which composites provides is the strength of the material and stiffness with lightness. By selection of an appropriate combination of reinforcement and matrix material desired properties can be developed for a particular civil application.

Basically composites can be classified in two groups- particle type and fibre group. Fibre based composites are used for civil engineering applications. Composite materials provide design flexibility and can be moulded into complex shape. Common composite materials are concrete, fibre glass, mud bricks and natural composites are rocks and wood. In wood cellulose are held together by lignin. Only the bonding power of lignin makes the wood tougher.

Table 1.1 Benefits of the Products Produced by Composite Material

S. No	Benefits
1	High strength to weight ratio
2	Wear resistant
3	Fatigue life
4	Thermal insulation
5	Acoustical insulation
6	Corrosion resistant
7	Stiffness
8	Temperature dependent behavior
9	Thermal conductivity
10	Low electrical conductivity

1.2 BRIEF DESCRIPTION OF THE DIFFERENT COMPOSITE MATERIALS

1.2.1 Fibre Glass

GFRP or glass fibre reinforced plastic consists of two distinct materials, a fibres of glass (ceramic), which is the reinforcement and a polymer resin called polyester, that serves as the matrix. The polyester resin polymer alone is brittle and has a low strength but when fibres of glass are embedded in the polymer it becomes strong, tough, resilient and flexible. It is an ideal material to make boat hulls, swimming pool linings, car bodies, roofing and furniture. Fibre glass is inexpensive, easy to manufacture and possess high strength and stiffness with respect to plastics with which they are reinforced. Their low density, resistance to chemical attack and insulation capacity are some of its other characteristics. There are five major types of fiberglass.

A-glass (alkali glass) has good chemical resistance, but lower electrical properties

C-glass (chemical glass) has very high chemical resistance.

E-glass (electrical glass) is an excellent insulator and resists attacks from water.

S-Glass (structural glass) is optimized for mechanical properties.

D-glass (dielectric glass) has the best electrical properties but lacks in mechanical properties when compared to E and S glass.

E-glass and S-glass are, by far, the most common types found in composites. These types have good combinations of chemical resistance, mechanical properties and insulating properties. Of the two, E-glass offers the more attractive economics, and S-glass offers better mechanical performance.

1.2.2 Concrete

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. Concrete is the mixture of cement, sand, water and aggregates. Concrete is weak in tension but strong in compression. It can be strong in tension when metal rods, wire as a mesh is used with concrete. This is called reinforced concrete. There are many types of concrete available, created by varying the proportions of the main ingredients below. In this way or by substitution for the cementitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties. Aggregate consist of large chunk of material in a concrete mix. Generally, a coarse gravel or crushed rocks such as lime stone or granite along with finer material such as sand. Cement commonly portland cement, and other cementitious material such as fly ash and slag cement, serve as a binder for the aggregate. Water is then mixed with this dry composite, which provided a semi liquid that workers can shape (typically by pouring it into a form). The concrete solidifies and hardens to rock hard strength through a chemical process called hydration. The water reacts with water the cement, which bonds the other components together, creating a robust stone- like material. Chemical admixture is added to achieve varied properties. These ingredients may speed or slow down the rate at which concrete hardens, and impart many other harmful properties. Reinforcement are often added to concrete. Concrete can be formulated with high compressive strength, but always has lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension.

1.2.3 Mud Bricks

Some of earliest forms of buildings were built of mud bricks. Mud bricks were working well under compression. But it was easily broken when bent because of the tension force. To strengthen the brick in tension, mixing of straw was being done. Straw has good tensile strength. So it acts as reinforcement. The combination of mud and straw gives both compressive as well as tensile strength to the brick. So it is just because of the use of strength of both materials mud and straw that it is also called a composite material. The bricks made from composite material are called composite bricks.

1.3 UTILISATION OF WASTE MATERIAL IN COMPOSITE BRICKS

Waste material in the developing country is a gigantic problem. The impact of waste material on the environment is very dire. Thus, considering the consequences of improper disposal of these waste products on the environment and increasing demand of lightweight and low cost construction material, various researchers have successfully attempted the utilization of these materials in the building construction. There is abundance of waste material which can be easily used for the building construction. One of the very important components of building construction materials is bricks. So for the production of bricks different types of waste materials have been used by the researchers and investigated the effect of these materials on the properties of bricks. Waste materials have also being incorporated for brick manufacturing.

Table 1.2 Waste Material Which have been Tried and Tested

S. No	Waste material	Reference
1	Fly ash	*Kute and Deodhar 2003*
2	Textile effluent treatment plant (ETP) sludge	*Balasubramanian et al.2006*
3	Industrial waste collected from industrial waste water treatment plant	*Weng et al.2003*
4	Granulated blast furnace slag	*Malhotra et al.1996*
5	Waste paper pulp	*Mucahit et al. 2009*
6	Limestone dust	*Halil et al. 2008*
7	Wood sawdust	*Turgut et al.2007*
8	Polyestryne foa	*Sohrab and Ali 2003*
9	Plastic fibre	*Hanifi et al.2005*
10	Straw	*Hanifi et al.2005*
11	Cigarette butts	*Aeslina et al.2010*
12	Cotton waste	*Halil et al. 2008*
13	Rice husk ash	*Rahman et al.1987*
14	Processed waste tea	*Demir et al. 2006*
15	Petroleum effulent treatment plant sludge	*Sengupta et al. 2002*
16	Welding flux slag	*Caroline et al.2009*

A few of the most preferred waste materials which have been successfully used or are being tested for use in building construction are discussed in the succeeding sub-sections.

1.3.1 Fly ash

Fly ash generated during the combustion of coal for energy production in an industry by product. It creates serious environmental, technical and economic problem. Fly ash consists of inorganic, incombustible matter present in the coal that has been fused during combustion into a glassy, amorphous structure. It is composed of glassy spheres and loops similar to cement. Fly ash is used in many applications to replace naturally occurring aggregate. Fly ash is of two types i.e. class C and class F. Fly ash provides later age strength to the structure due to its pozzolanic property and later stage strength is the main criteria to take the imposed load of the structure. So it becomes advantageous to use fly ash.

Table 1.3 Physical and Chemical Properties of Fly Ash (*Ismail et al. 2007*)

Physical Properties		Chemical Properties	
Characteristics	**Value**	**Compound**	**Content,% Wt**
Colour	Whitish gray	SiO_2	59
Bulk density (g/cm^3)	0.994	Al_2O_3	21
Specific gravity	2.288	Fe_2O_3	3.70
Moisture (%)	3.14	Cao	6.90
Average particle size	6.92	Mgo	1.40
–	–	SO_3	1

Malhotra and Dave (1999) studied the effect of the lime and fly ash on the properties of cement mortar. The composite mortars specimens consisting of both Portland cement and lime in different proportion improve the early age rheological properties, and once the setting and hardening has taken place, lime has little role to play in strength development. Thus, as a modification, certain part of lime was replaced with pozzolana such as burnt clay or fly ash. With this replacement, the mortar developed good early strength properties and strength at later stage also**.** The replacement of lime with fly ash, increases the reactivity which increase the compressive strength and ultimately final strength. Another aspect which is highlighted is the economy of the utilization of waste or by product like fly ash.

1.3.2 Limestone Dust and Wood Saw Dust

Limestone dust and Wood Saw Dust are accumulated in large amount from all over the world. These wastes causes environmental as well as health hazard problems. The use of these materials as a construction material has a great impact on the mechanical and physical properties of concrete mix. The compressive strength, flexural strength, unit weight, ultrasonic pulse velocity and water absorption value were investigated by Algin and*Turgut (2007).* They observed in the test that there is no sudden brittle fracture, a very high energy absorption and significantly low labour cost. The bricks are 65% lighter than conventional concrete bricks. Replacement of WSW was found to have given satisfied results as per BS: 6073.

1.3.3 Cotton waste (CW) and Limestone Powder Waste (LPW) as a Brick Material

Large amounts of cotton and limestone wastes are accumulated from the countries all over the world. The majority of cotton wastes (CW) and limestone powder wastes (LPW) is abandoned, and causes serious environmental problems and health hazards. *Algin and Turgut (2007)* presented a parametric experimental study, which investigated the potential use of CW–LPW combination for producing new low cost and lightweight composites as a building material. The physical and mechanical properties of concrete mixes having high level of CW and LPW are investigated. It was observed that the brick produced using CW and LPW is 60% lighter than the conventional brick. And 30% replacement of Cotton Waste has given satisfied results as per BS: 6073.

1.3.4 Use of Fly Ash (FA), Quarry Dust (QD) and Billet Scale (BS)

Shakir et al. (2013) found that the combination of fly ash, quarry dust and billet scale greatly affects the properties of brick. It was investigated that compressive strength and modulus of rupture increased with FA+BS. Water absorption decreased with increase in FA+BS and increased with increase in BS+QD**.** It was indicated that the bricks developed in this study can be used as an alternative to conventional bricks. There is neither any need to apply pressure on the mould having these constituents, nor high temperature for firing is required. Clay or shale was also not required to be mixed leading to environmental and ecological gain.

1.3.5 Use of Natural Fibre in Composite Bricks

Chan (2011) studied the effect of use of natural fibres like pineapple leaves and oil palm in his paper. The use of these fibres as a construction material would avoid the coverage of land with these natural wastes. The result showed that natural fibres have low unit weight and high porosity. Natural fibres improve the compressive strength, flexibility, thermal conductivity, acoustic insulation of finished product. *Chan (2011)* also examined the physical and mechanical properties of clay bricks made by adding two natural fibres to a clay-water mixture, with baked and non-baked conditions. The fibres were sourced from pineapple leaves (PF) and oil palm fruit bunch (OF), and added within the range of 0.25-0.75 %. Cement was added as a binder to the mixture at 5-15 %. The non-baked bricks disintegrated when submerged in water, while the baked ones displayed cement-dependent characteristics in water-absorption and density changes. Interestingly, further increase in fibre content did not cause significant density decrease in both the baked and non-baked bricks.

1.3.6 Use of Straw as a Brick Making Material

Rice straw is an organic waste product having low unit weight and high porosity. It is used as a thermal insulation. *Allam et al (2011**)*** performed different tests to evaluate the rice straw brick (R-brick) with proposed mix proportions. One and two hour's exposure tests were performed, with temperatures ranging between 300 and 800 °C. Both types of bricks did not suffer any significant loss in compressive strength when exposed to 300°C for 1hour. A loss of 70% in compressive strength of the rice-straw cement brick was reported when exposed to 800°C for 1 hour and 80% for 2 hours fire exposure. The economical investigation showed that the bricks under study cost 25% less than the standard cement brick. It was concluded that the proposed bricks provides an economical, light weight brick, with competing thermal insulation properties, while maintaining adequate mechanical properties, and fire resistance. The weight of brick is 25% lighter than the traditional ones.

1.4 ROLE OF MICROBES IN CONSTRUCTION MATERIAL

The use of microbes is continuously increasing in the area of construction materials and they have given worthy results regarding interfacial adhesion, strength properties, durability, elastic modulus, moisture resistance of cement mortar. Microbes are tiny organisms which comprise of bacteria, fungi and protozoa parasite found in air, soil, and water and is living in and on our body. Bacteria are single celled microorganisms without nucleus. Fungus is single celled or a multi-cellular organism. The cell structure is like in plants but fungi do not perform photosynthesis. A fungus depends on organic material for their food. The bacteria and fungi have a great value in construction field.

Ophiostoma ulmi is a plant pathogenic fungus which infects the elm tree and causes the *dutch elm* disease. However it has been recently exploited in the modification of hemp fibre as it improves the acid base interaction between fibre and resin thereby improving the interfacial adhesion. An added advantage of this method is improvement of moisture resistance, durability of composite get affected (*Ghulati et al .2006*)

To increase the application of microbes in construction materials, calcium forming bacteria had been exploited to improve strength property of cement sand mortar. *Arthrobacter crystallopoietes* KNUC403 is a calcite forming bacteria used to increase the compressive strength of cement mortar (*Sung-jin et al 2010*). Most of the researchers have conducted experimental studies on bacterial sources with mineral producing activity but without organic substance for improving the strength of cement mortar. *Exiguobacterium marinum* KNUC513 has given higher compressive strength as compared to mineral forming bacteria *sporosacrcina pastureii* and *Arthrobacter crystallopoietes* KNUC403 *(Sung-jin et al 2011*). Bioremediase, a unique protein from a novel bacterium BKH1, improved its compressive strength by more than 25% and tensile strength by more than 20%, and also improved the hardness and elastic modulus of cementitious material when used in cement sand mixture (*Biswas et al 2010*). The given examples fairly indicate that microbial system could be very helpful in the development of novel construction material with better properties and lesser environmental damage.

1.5 FUNGAL SYSTEMS AS NEW INTERVENTION FOR DEVELOPMENT OF BIO-COMPOSITE BRICK DEVELOPMENT- A NOVEL CONCEPT

Fungi are made up of filaments, called Hyphae. Each hyphae is essentially a tube. It elongates from the tip and is capable of growing indefinitely. The Cell walls of fungi are made of mostly of chitin. According to *Mayer et al (2010)* chitin resembles with cellulose having one hydroxyl group on each monomer replaced with an acetyl amino group. Due to this hydrogen, bonding gets increased between the polymers. This is called chitin polymer matrix that causes increase in the strength. So the composite produced by the chitin is stronger even more than the pure chitin. This will be stiffer and harder than chitin. So as a part of fungi, chitin plays a very important role for adhesive and enmeshment mechanism. In the structural stability (*Ritz et al. 2004*) and to improve the properties of concrete (*Kaur et al. 2012*) fungi has played a very good role in binding, filling the pores and to enhance the strength of cement mortar/concrete. According to *Kaur et al (2012)* fungi increases the reaction of cement with foundary sand used for their experimental work and has the ability to make C-S-H gel that is the main cause of increase in the strength of the mix. So the role of fungi in the composite formation is to improve the strength enhancement ability. According to *Jin et al (2010, 2011, 2012),* the use of Microbes (Fungi, bacteria) in the construction material is going to be the centre of attraction. *Ghosh et al (2005)* did his work on the inclusion of bacteria in the construction material. He found that there is a great effect on the strength properties of cement mortar and concrete also. Till date there exist no reports on exploitation of fungal system for biological composite material. Thus fungi can be used as a novel tool in building composite materials. The above examples fairly indicate that microbial systems could be very helpful in development of novel construction materials with better properties and lesser environmental damage.

CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL

Composite material comprises of two or more than two basic materials possessing different properties which are mixed in different quantities. The idea behind developing composite materials is to best properties in the material being develop apart from knowing the strength of individuals component used in developing the composite material. In context of building materials and structure design in civil engineering the greatest advantage which composites provides is the strength of the material and stiffness with lightness. By selection of an appropriate combination of reinforcement and matrix material desired properties can be developed for a particular civil application. So the bricks made of combination of two or more than two basic materials are called composite bricks**.** The advantages of these bricks are high strength to weight ratio, thermal insulation, acoustic insulation, temperature dependent behavior, thermal conductivity and low electrical conductivity. The disadvantages are low compressive strength, high water absorption, low density and low flexural strength. Many researchers have done work using composite materials they found the results within the limits after standard testing of the composite brick as per ASTM**.**

2.2 ROLE OF RICE HUSK IN COMPOSITE BRICKS

Shakir et al. (2013) investigated the production of bricks using fly ash, quarry dust, and billet scale. The procedure for producing the bricks included mixing the constituents along with cement and water, and then forming the bricks within molds without applying pressure over them. The Results of mechanical property and durability tests were hopeful. The optimum ratio of both billet scale to fly ash and billet scale to quarry dust was found to be 1:1. It was indicated that the bricks developed in this study could be used as an alternative to conventional bricks.

Yuzer et al. (2013) studied Compressive strength, density, ultrasonic pulse velocity, thermal conductivity and water vapor diffusion resistance factor of concrete under the effect of high temperature. The rice husk was replaced 1.5,3 and 5% of the weight of the cement. The objective of the study was to to check the viability of the rice husk by replacing it with polypropylene fibers in concrete. To increase its performance under high temperature and by utilizing rice husk, environment problem can be reduced considerably. To determine the compressive strength 150 mm cubes were prepared and tested. The results showed that the increase in replacement of cement with rice husk and high temperature caused the reduction in the compressive strength of concrete. As the temperature increases there will be evaporation of water caused differential expansion of the concrete. it reduced the ultrasonic pulse velocity. The density was reduced automatically when the porosity augmented with the addition of rice husk. The velocity decreased as the reduction in water vapor diffusion resistance of concretes containing RH reduced vapor pressure within the concrete and thus contributed to prevent the spalling of concrete. The thermal conductivity decreased with an increase in RH and the increased heating temperature also caused decrease in thermal conductivity.

Alonso-Santurde et al. (2012) studied the production of bricks by mixing green and core foundry sand with clay in proportions 0–50% and firing at 850–1050 °C. Brick specimens were prepared and evaluated physically and mineralogically. It was found that the clay–foundry sand bricks fired at 1050 °C had better physical property values while the mineralogy was not significantly affected. The optimum amount of foundry sand to produce bricks was found to be 35% green sand and 25% core sand.

B. lgin et al. (2012) founded that the amount of marble dust additive had positive effect on the physical, chemical and mechanical strength of the produced industrial brick .Waste material in different proportions was mixed with industrial brick mortar starting amount of 0 wt.% up to 80 wt.%. in 41 x 8 x 8 mm rectangular prisms for testing of physico-mechanical properties of the samples having different marble dust composition. These prepared prisms were pressed and sintered at three different temperatures 900, 1000 and 1100 °C. Flexural strengths of the test samples were given at three different temperature values of 900, 1000 and 1100 °C. It was found that the amount of marble dust additive had positive effect on the physical, chemical and mechanical strength of the produced industrial brick.

Sutas et al.(2012) have studied the effect of Rice Husk and Rice husk ash on the properties of brick and concluded that Comparative adding between rice husk and rice husk ash were varied by 0 -10% by weight. The results shows that with the increase of rice husk compressive strength and density of specimens decreased and the porosity increases.

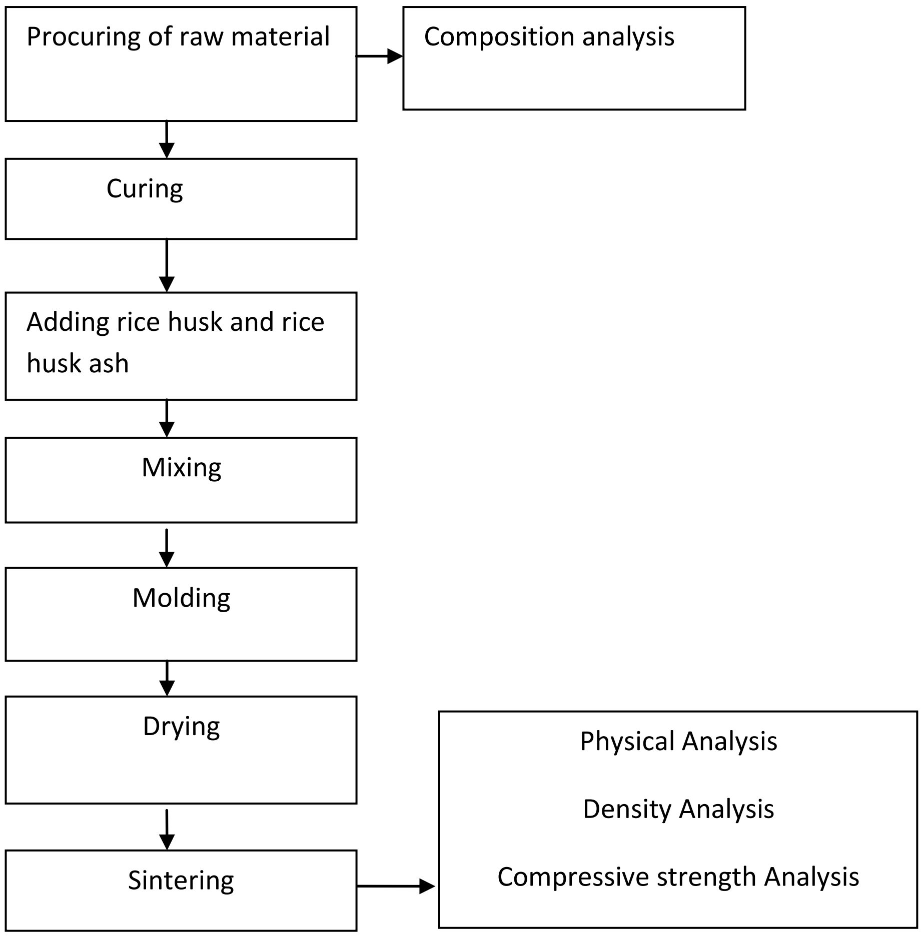

Fig. 2.1 Schematic Diagram of Experiment

The varying %age of weight from 0 to 10 of rice husk and rice husk ash was added. The component was mixed, moulded and casted. The size of the bricks was 10x15x30 cm. The bricks were placed into the kiln fired bricks at about 700°C. The compressive strength, density, %age of water absorption and structure analysis by scanning electron microscope (SEM) were investigated. The mix with rice husk has a less bulk density as compared to the mix with rice husk ash because larger the size of organic matter content greater the porosity. With the increase in the porosity the water absorption increases. At the addition of 2% of rice husk ash, the maximum of water absorption was 15.20%. The compressive strength decreased with the increase of rice husk addition, because of higher porosity and low bulk density. Rice husk ash was added 2% by weight show maximum of compressive strength is 6.20 MPa, because it is a pozzolanic material which has silica dioxide about 90% leads to increase in the compressive strength.

Allam et al. (2011) founded that with the use of straw in the brick construction there is a loss of compressive strength of the brick it can be used for insulation purpose only and for lightweight construction purposes. These bricks have low wt and low density. Mix proportions are shown in the table given below.

Table 2.1 Mix Proportion for Rice Straw-Cement Bricks/1000 Bricks

Type of mix	Fine aggregate (m^3)	Coarse aggregate (m^3)	Chopped rice straw (Kg)	Cement(Kg)
A	0.9	0.9	40	400
B	0.85	0.4	70	400
C	0.85	0.2	90	400

The compressive strength reduced due to the partial loss of bond among the mix component as a result of excessive amount of straw in the mix. The comparison of the straw added brick and cement brick showed that at 400 to 800 °C there was a loss of 25% but with rice straw it Was 70% due to one hour fire exposure. In 2 hour exposure this loss in cement brick was 50% and for straw it was 80%.

Chan (2011) examined the physical and mechanical properties of clay bricks made by adding two natural fibres to a clay-water mixture, with baked and non-baked conditions. The fibres were sourced from pineapple leaves (PF) and oil palm fruit bunch (OF), and added within the range of 0.25 - 0.75 %. Cement was added as a binder to the mixture at 5-15 %. Although the two fibres had different effects on the bricks produced, cement appeared to control the compressive strength. The non-baked bricks disintegrated when submerged in water, while the baked ones showed cement-dependent characteristics in water-absorption and density changes

Table 2.2 Chemical and Physical Properties of Clay

Chemical properties		Physical Properties	
Al_2O_3	27.65	%age passing 63 µm seive	44.7%
CaO	0.18	Specific Gravity	2.71
$Fe_2\ O_3$	3.66	Natural water content	73.10%
K_2O	1.96	Liquid limit	45.85%
MgO	1.09	Plastic limit	22.38
SiO_2	59.10	Plasticity index	23.47
TiO_2	0.63	Soil description	Grayish colour
Na_2O	0.39	--------------------------------	
SO_3	5.25		

It was concluded that both cement-PF and cement-OF specimens, baked (B) or non-baked (NB) displayed similar strength characteristics with regard to cement addition. Cement generally increased the compressive strength in non-baked specimens, but caused a significant strength reduction in the baked specimens.

Sisman et al. (2011) investigated the properties of concrete after replacing the natural aggregates with varying %age of rice husk i.e. 5, 10,15,20,25 and 30%. The cubes of 15x15x15 cm were prepared and cured. The compressive strength and unit weight were found after 7 and 28 days and the water absorption, freezing thawing and thermal conductivity were found out after 28 days only. The results concluded that after 7 and 28 days the compressive strength was reduced with the increase in the %age of rice husk in the mix. The unit weight of the sample gets reduced with the increase in the rice husk. The water absorption of the sample was decreased. Thermal conductivity was increased with the increase in unit wt so using an aggregate replacement with rice husk thermal conductivity also gets reduced.

Turgut (2010) studied the production of masonry blocks using limestone powder (LP) waste and class C fly ash (FA), without the addition of Portland cement. LP was mixed with FA at respectively 10%, 20% and 30% by volume, wetted and compressed under a pressure of 20 MPa in a steel mold for 1 min to produce block samples. The formed blocks were cured at room temperature for 48 h, in water tank at 22 °C for respectively 7, 28 and 90 days, and then dried in ventilated oven at 105 °C for 24 h. Tests were conducted on the produced blocks to evaluate their compressive and flexural strengths, ultrasonic pulse velocity (UPV), density, water absorption and thermal conductivity. The results indicated that masonry blocks could be produced using LP, FA and water.

Turgut et al. (2008) examined the potential use of crumb rubber to partially replace sand aggregate for producing low cost and lightweight composite concrete bricks with improved thermal resistance. The physico-mechanical and thermal insulation properties of the rubber-added concrete bricks were investigated. The obtained compressive strength, flexural strength, splitting strength, freeze–thaw resistance, unit weight and water absorption values met the relevant international standards. The experimental observations also showed that high level replacement of crumb rubber with conventional sand aggregate did not exhibit a sudden brittle fracture even beyond the failure loads, led to high energy absorption capacity, reduced the unit weight considerably and introduced smoother surface.

Turgut et al. (2007) studied compressive strength, water absorption, unit weight, ultrasonic pulse velocity and flexural strength. In the experimental work 105x90x75mm steel moulds were used for the water absorption, unit wt and compressive strength test. For flexural strength the size of the mould was 105x225x75. After the mixing of LPW-WSW and cement as per the table given below 60 moulds were prepared. It was observed during the test that the bricks can be used for lightweight buildings. The compressive strength of the bricks was inversely proportional to the WSW replacement.

Table 2.3 Mix Proportions

Mix No.	Cement (g)	Water(g)	LPW(g)	WSW(g)	Total(g)	Pressure (p) MPa
Control mix	376	188	2936	_	3500	17
LW-10	376	188	2706	54	3324	8
LW-20	376	188	2405	108	3077	4
LW-30	376	188	2117	162	2843	2

30% replacement of WSW reduced the strength by 71%. But the average strength results satisfied the BS 6073.There was no sudden brittle fracture, high energy absorption. The bricks were 65% lighter than conventional concrete bricks. 30% replacement of WSW has given satisfied results as per BS6073.

Malhotra et al. (1999) investigated that initial strength properties of the mortar such as workability, bond strength and plasticity can be increased by the replacement of some part of cement with lime. This was the conventional modified mortar in which mix gains only initial strength. But for the final strength some part of lime was replaced with pozzolana material i.e fly ash. gives later age strength to the mortar. Material used for this mortar was cement, sand, lime and Fly Ash.

Table 2.4 Physical and Chemical Properties of Fly Ash (Ismail et al.2009)

Physical Properties		Chemical Properties	
Characteristics	Value	Compound	Content,% Wt
Colour	Whitish gray	SiO_2	59
Bulk density (g/cm^3)	0.994	Al_2O_3	21
Specific gravity	2.288	Fe_2O_3	3.70
Moisture (%)	3.14	Cao	6.90
Average particle size	6.92	Mgo	1.40
_	_	SO_3	1

The mortar was prepared and filled into the 50 mm size cube mould and covered with grease plate for 48 hours. Curing was done at 50±2°C for 8 days then the cubes were tested. It was found that with the replacement of lime with fly ash water retention was higher. It increases bond strength, increase the reactivity which increases the compressive strength almost doubles of the conventional mortar. Fly ash is a waste product so its utilization made the mortar economic.

Salas et al. (1987) studied the characteristics of the lightweight insulating concrete. The rice husk used for the study was natural or with 5% lime treated. The sand and gravel were replaced with rice husk. Two cases were considered in which HPG 2 and 40 to 45 no. mixes were in natural state and HPG 2 and 46 to 50 were treated. The sample 150x300 mm was prepared to determine the compressive strength. These were placed for curing in a curing chamber and tested at 3,7,28 and 60 days resp. in both cases the increase in compressive strength was very less after 7 days. Rice husk tends to retain the water vapour in the atmosphere and increasing its weight significantly. It was observed that the compressive strength was greater in case of treated husk and the lightweight concrete having a 28 days strength equal to or greater than 17.5 require the quantity of cement double than the actual calculated quantity. It was also concluded that the strength get reduced even with the low amount of rice husk. To achieve greater strength it was observed husk should be replaced only with sand rather than gravel. Low weight and insulating properties are the only properties of rice husk otherwise it does not help to increase the strength properties.

Salas et al. (1987) The three types of mix were prepared i.e L, C, M and one was standard mix named as HPG-2. the hollow concrete blocks of 40 x 20 x 20 cm of density 1100 kg/m^3 were prepared using rice husk a waste product and fly ash a by product from the industries. The three mixes L, C, M were prepared. From which L was prepared as a standard material without any replacement. In mix C 25% and in mix M, 54% of the weight of cement was replaced with the natural fly ash. The blocks were prepared with varying water/ cement ratio for L type mix and water /cement +ash ratio for C and M type of mix. These blocks were tested after 7, 28, 60 days respectively. The results concluded that the most suitable water cement ratio for the L type mix was 0.60, the water/cement ratio 0.65 causes segregation and reduce the strength. M 0.60 was the acceptable limit. It was concluded that there was an increase in compressive strengths with respect to mix M, savings in cement was approximately 30% with respect to mix M, since 4.78kg of cement were used per block instead of 3.38 kg. A negligible increase in weight,with respect to mix M, was of the order of 3%.

2.3 EFFECT OF MICROBES ON PROPERTIES OF CONCRETE

Siddique et al. (2012) studied that waste foundry sand after treated with *Aspergillus* spp (fungi) had increased the compressive strength. The replacements of fungus treated waste foundry sand was 0, 10,15 and 20%. The utmost compressive strength of fungal treated WFS specimen increased by 15.6% as compared to control specimen at the replacement of 20%. The reason behind this was the ability of making C-S-H gel of fungal treated specimen as compared to controlled specimen. This formation of C-S-H increases the strength of concrete. The result was concluded that 15.6% compressive strength increases with fungal treated WFS. Water absorption and porosity decreases 45 and 68% respectively as compared to controlled specimen.

Ritz et al. (2000) showed that Fungi have an important role to play in underwriting the sustainable management of soils into this sterile environment. With sufficient substrate, the fungal biomass increases, as does the production of exudates .Within a short time, probably within a day or so, the microstructure is altered both in geometry and with increased stability. The fungi at this stage act as interior architects, and painters and decorators painting proteins onto the walls of pores and altering the pores shape and design. This will have an immediate impact on the pore geometry and connectivity which will lead to a significants alteration in the structure's ability to retain water and the rate at which fluids and gases as transported through the system. Thus, they make their own environment. These concepts provide a clear demonstration of the principle was provided by Meadows *et al*. (1994), who showed that *Pencillium chrysogenum* significantly increased the slope stability of experimentally inclinable beds of sand, and when slopes failed, hyphal trails enmeshing sand were visible.

Sung-Jin et al. (2012) have studied that biofilm forming microorganisms can increase the compressive strength of cement sand mortar. In this study 13 Alkaliphilic biofilm forming bacteria (ABB) were isolated from a cement tetrapod block in west sea. using 16S RNA, ABB were partially identified as *Bacillus algicola* KNUC501 and *Exiguobacterium marinum* KNUC513. It was presumed that alkaliphilic bacteria would be useful for this purpose. The mature biofilm covered the mineral particles in the cement construction structure. It was concluded that bacteria biofilm can be used as a binder in cement mortar and can improve the strength of mortar.

Sung-Jin et al. (2012) investigated that the durability of cementitious material can be improved by deposited an organic-inorganic composite on the surface of cement paste. B subtilis 168 was used for this study. It showed considerably less water than non treated. Compressive strength was increased .it was concluded B. subtils 168 can serve as a multifunctioning agent for the cracks remedies, prevention of water penetration and strength improvement that is used as sealing and coating agent to improve strength and water resistant of concrete.

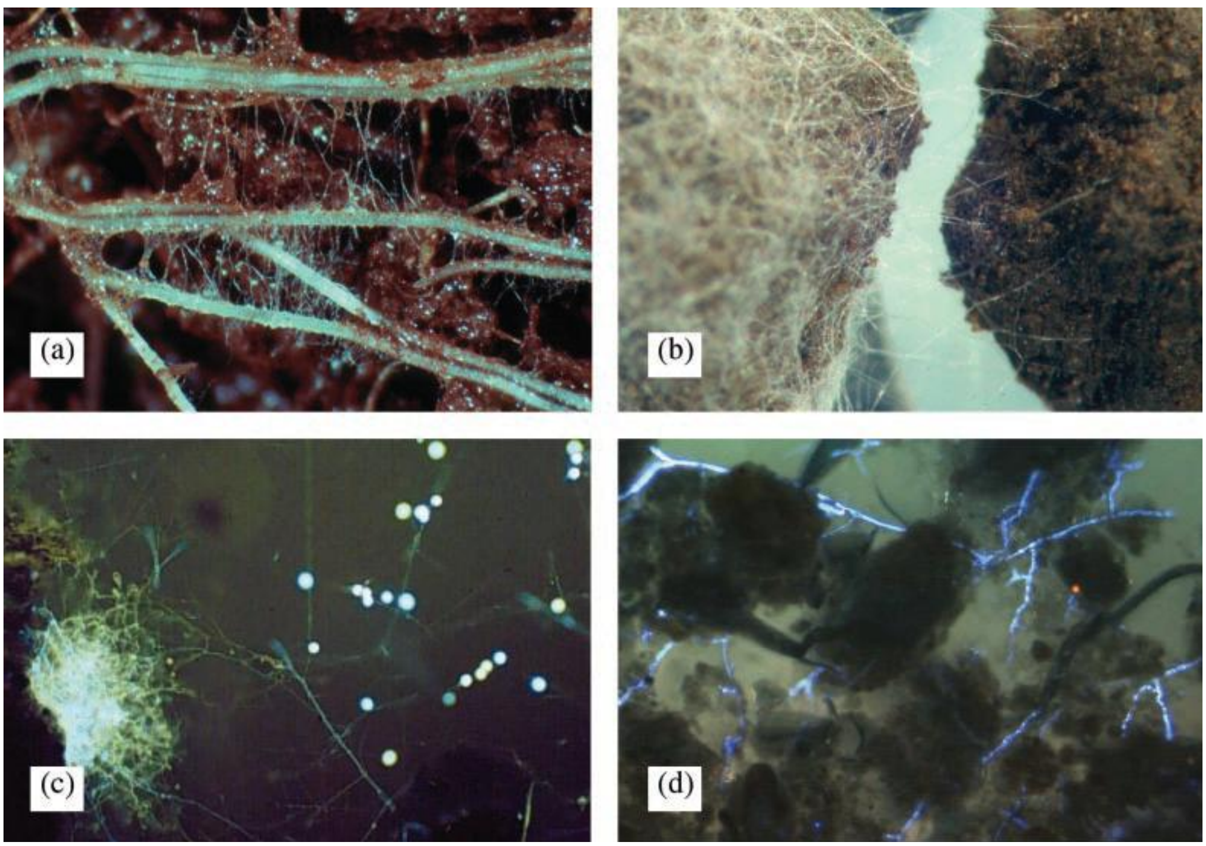

Fig.2.2. Fungal mycelia in the soil environment. (a) Unidentified hyphae bridging roots of *Plantago lanceolata* growing in non-sterile field soil. Note abundance of mucilage films. Image width = 2 cm. (b) Hyphae of *Fusarium oxysporum* f. sp. *raphani* colonisinga pair of adjacent soil aggregates. Aggregate on left is sterile, hence extensive mycelial development. Aggregate on right is non-sterile; reduced mycelial growth is due to competitive effects of indigenous microflora and reduced nutrient levels therein.Image width = 1 cm. (c) Unidentified mycelium growing in soil pore, visualised in thin-section of undisturbed

pasture soil,stained with Fluorescent Brightener 28. Note proliferation of hyphae on pore wall in left of image. Bright spherical objects are sporangia. UV epifluorescent illumination. Image width = 150 µm. (d) Mycelium of *Rhizoctonia solani* growing in sterilized arable soil, visualised in thin-section stained with SCRI Renaissance 2200. UV epifluorescent illumination. Image width = 150µm. (Image sources: the authors)

Biswas et al. (2010) studied the strength improvement of the cement mortar/concrete with the use of Bioremediase a unique protein from a novel bacterium BKH1.The isolation of pure strain was done. Pure culture of bacterial strain was obtained by serial dilution techniques from enrichment culture. The growth parameters such as pH and temperature, the morphology and Gram's staining of the bacterium were studied to observe some phenotypic characters of the isolate. After the isolation cubes of cement mortar of size 70.6x70.6x70.6 were prepared by mixing different bacterial cell concentration (0, 10^4,10^5,and 10^6) cells/ml of water used.water cement ratio was 0.4. The sample was tested after 28 days of curing. The result concluded that the bacterial strain BKH1 increase the compressive strength and tensile strength of cement paste and mortar. The bioremediase protein is stable within temperature 50-80°C. The durability and quality also can be increased.

Sung-Jin et al. (2010) studied that calcite forming bacteria improve the compressive strength of the mortar.in this study 4 CFB isolated. 16S rRNA genes were used and CFB be partially identified as *Sporosarcina soli* KNUC401, Bacillus massiliensis KNUC402, *Arthrobacter crystallopoietes* KNUC403 and *Lysinibacillus fusiformis* KNUC404. KNUC403 was selected as an ppropriate bacterial sealing agent to improve the compressive strength of concrete. The addition of CFB greately affects the compressive strength.

2.4 SEM/EDX Analysis

Wang et al. (2000) studied the concrete prepared from cement and fly ash (25% fly ash and 75% cement by weight), which covers coal fly ash and biomass fly ash. All the fly ash concrete has the statistical equal strength from one day to one year after mix .Scanning electron microscopy (SEM), Energy dispersive X-ray (EDX) and environmental scanning electron microscopy (ESEM) analysis presented for both coal and biomass fly ash particles undergo significant changes of morphology and chemical compositions in concrete due to pozzolanic reaction. Although biomass fly ash differs significantly from coal fly ash in its fuel possessions. Fly ash particles have higher reactivity due to their higher relative surface areas. Fly ash particles with high iron contents (>50% mol) can have significant pozzolanic reactivity.

Fig. 2.3 shows the crystal of CH, the product of cement hydration and the reactants of pozzolanic reaction, which has a laminar morphology in (a) and supported by EDX analysis in (b) . The fly ash particles in the concrete mix reacted slowly with CH to form C–S–H gels and fill the pores. Fig. 2.4 shows the barely reactive Class F fly ash particles in a 56-day-old concrete sample because the particles' surfaces are quite smooth, which are only partially coated concrete mix of 573-day. The shell and inner components come from different resources and have different compositions, which are verified by the EDX spectrum.

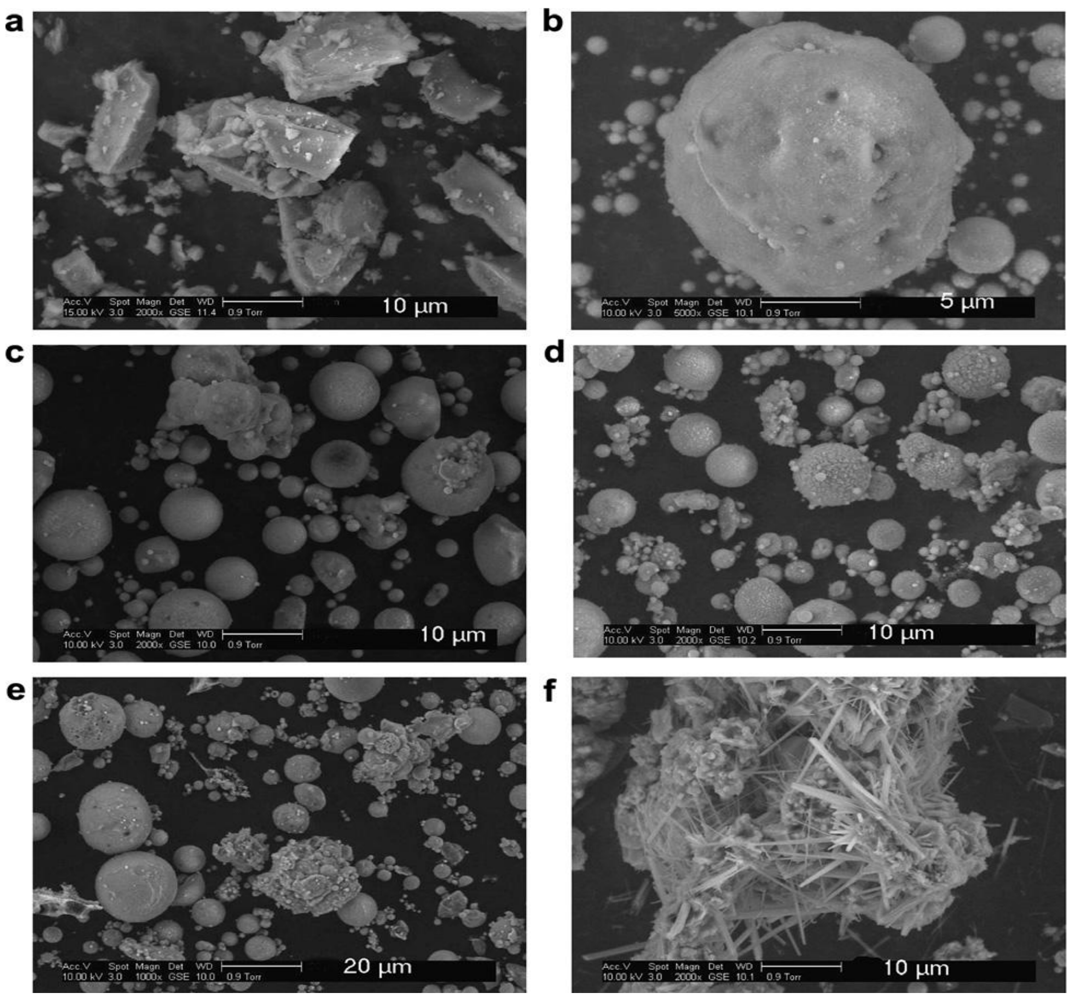

Fig 2.3 Scaning Election Micrographs (Sems) of Cement and Fly ash (a) Cement (B) Class C (c) Class F (D) Sw$_1$ (E) Sw$_2$ And (F) Wood

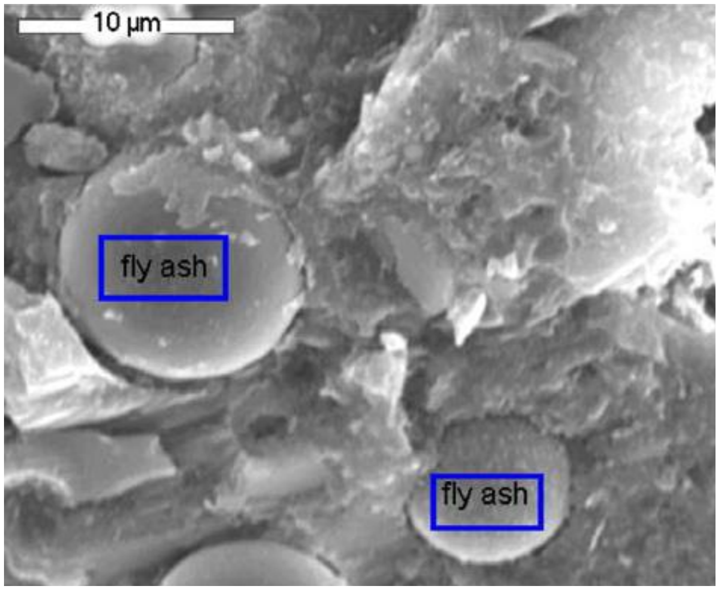

Fig. 2.4 Barely Reactive Fly Ash Particle of Class F Mix (56-Day)

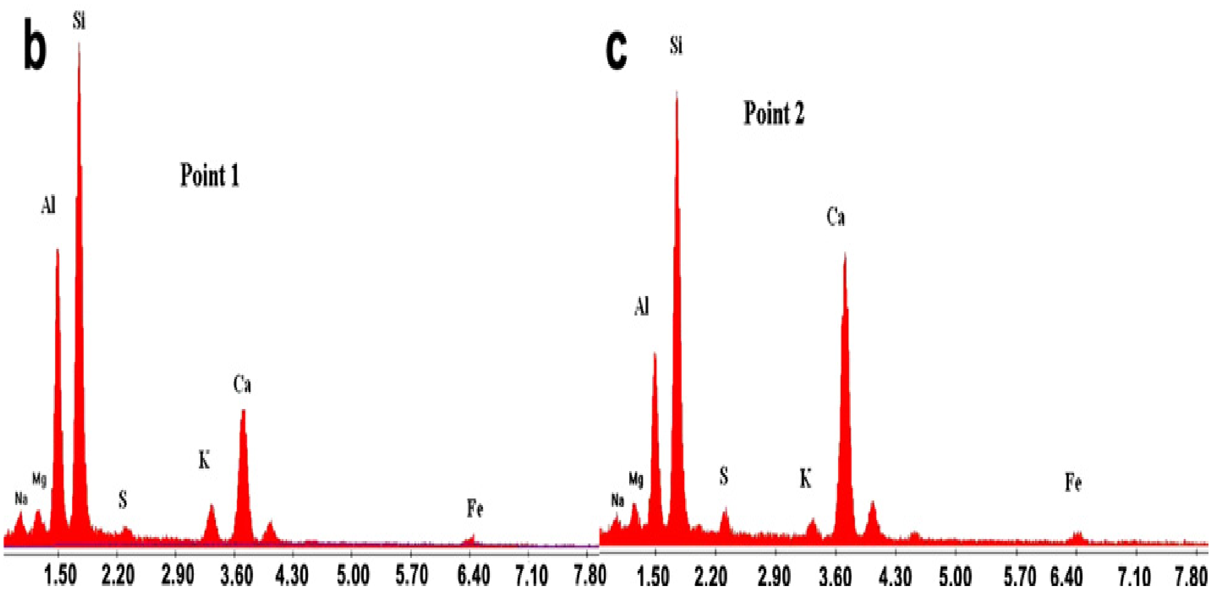

Fig.2.5 The Spectrum of Reactive Fly Ash Particle in SW_1 Mix (573-Day). (A) SW_1 Fly Ash Particle; (B) EDX Point 1 and (C) EDX Point 2

CHAPTER- 3
MATERIALS AND METHOD

3.1. SUB CULTURING AND MAINTENANCE OF PURE CULTURES

This involved preparation of Potato Dextrose Agar (PDA) plates, sub culturing of the endophytic fungal cultures on PDA plates and long term preservation of pure isolates.

3.1.1. Preparation of Potato Dextrose Agar (PDA) Plates

39.0 g of PDA (Hi Media) was dispensed in liter lukewarm single distilled water and stirred thoroughly. This was then dispensed in 250 ml Erlenmeyer Flasks and autoclaved at 121°C, 15 psi for 15 minutes. Glass Petri plates were sterilized at 121°C, 15 psi for 20 minutes. Then under sterile conditions 25 ml of the autoclaved PDA was dispensed in sterile 90 mm Petri plates and allowed to solidify at room temperature. The plates were stored in incubator at the temperature 26 ± 2°C until further use.

3.1.2. Sub Culturing of the Test Endophytic Cultures

Endophytic fungi isolated from *Aegle marmelos, Cinnamomum malabaricum, Cinnamomum Zeylanicium, Cinnamomum camphora, Piper nigrum* and *Tinospora indica,* were aseptically subcultured on sterile PDA plates and incubated at 26°C for 7-10 days under 12 hrs of photo period. The pure cultures thus obtained were transferred and maintained on PDA slants at 28°C. Sub culturing was done after regular intervals of time. The endophytic cultures were preserved on PDA slants with 15 % glycerol for long term storage at 28° C.

3.2 MATERIALS USED FOR PREPARING BIOLOGICAL COMPOSITE BRICKS

3.2.1. Cement

Cement is a fine gray powder. It is mixed with water and sand to make a cement mortar. Ordinary Portland Cement (OPC) of 43 Grade (JK cement) from a single lot was used throughout the course of the investigation. The cement was of uniform in color i.e. gray with a light greenish shade and free from any hard lumps. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture. The various tests conducted on cement are initial and final setting time, specific gravity, fineness and compressive strength The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 8112:1989 are listed in Table 3.1.

Table 3.1 Properties of Cement

S. No.	Characteristics	Value obtained	Indian standard (IS:8112 1989 values)
1	Consistency	32%	------------------------
2	Initial setting time, minutes	105	Not less than 30 minutes
3	Final setting time, minutes	160	Not more than 600 minutes
4	Specific gravity	3.12	---------------------
5	Fineness(retained on 90 micron sieve)	4%	10%(max)
Compressive strength			
6	7 days	40 N/mm^2	33N/mm^2
	28 days	48 N/mm^2	43 N/mm^2

3.2.2. Fine Aggregates

The fine aggregate may be described as coarse, medium and fine sands according to size,. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The sand used for the experimental work was locally procured and conformed to Indian standard Specifications IS: 383-1970. The sand was first sieved through 4.75 mm and then washed to remove the dust. Properties of the fine aggregate used in the experimental work as tabulated in the Table 3.2

Table 3.2 Physical Properties of Fine Aggregate

S. No.	Characteristics	Value
1	Specific gravity	2.54
2	Bulk density (kg/l)	1.4
3	Fineness modulus	2.36
4	Water absorption	0.85
5	Grading zone	Zone III

The fine aggregate was sieved through a set of sieves to obtain sieve analysis and the same is presented in the Table 3.3. The fine aggregate belong to Zone III.

Table 3.3 Sieve Analysis of Fine Aggregate

S. No.	Sieve Size.	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained(C)	Percentage Passing (100-C)
1	4.75	63.5	6.35	6.35	93.65
2	2.36	35	3.50	9.85	90.15
3	1.18	132.5	13.25	23.10	76.90
4	600	128.5	12.85	35.95	64.05
5	300	282	28.20	64.15	35.85
6	150	327	32.70	96.85	3.15
7	Pan	31.5	3.15	**SUM C = 236.25**	

3.2.3 Rice Husk

Rice husk is one of the most widely available agricultural wastes in many rice producing countries around the world. Rice husk was used as a supplementary material for making bio composite material. It was purchased from the local grain market. Rice husk in powdered form and in coarse form was used in experiment work. Specific gravity and water absorption test were conducted before the experimental work. The values of various properties of rice husk in coarse state are shown in table 3.4 and in powdered form in Table 3.5.

Table 3.4 Properties of Rice Husk (a) Coarse

Coarse Rice husk		
S. No.	**Characteristics**	**Value**
1	Specific gravity	1.37
2	Water absorption	0.50%

Table 3.4 Properties of Rice Husk (b) Powdered Form

Powdered Rice Husk		
S. No.	**Characteristics**	**Value**
1	Specific gravity	1.21
2	Water absorption	0.97%

3.2.4 Fly Ash

Fly ash is finely divided mineral residue resulting from the combustion of coal in electric generating plants. Fly ash used in the study consists of inorganic, incombustible matter present in the coal that has been fused during combustion into a glassy, amorphous structure. Fly ash particles were generally spherical in shape and range in size from 2-10 µm. They consist mostly of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3).The water absorption and other tests for finding other properties were conducted before the use and the value of tests is shown in table 3.6. The value of physical and chemical properties are shown in Table 3.5

Table 3.5 Physical and Chemical Properties of Fly Ash

Physical Properties		**Chemical Properties**	
Characteristics	**Value**	**Compound**	**Content,% Wt**
Colour	Whitish gray	SiO_2	59
Bulk density (g/cm^3)	0.994	Al_2O_3	21
Specific gravity	2.288	Fe_2O_3	3.70
Moisture (%)	3.14	CaO	6.90
Water absorption	0.17%	MgO	1.40
Specific gravity	2.288	SO_3	1

3.2.5 Water

Water, which is used for drinking generally, is used for making the concrete. No sampling is required in case of water used from lake and stream contained marine life. The potable water is generally considered satisfactory for mixing and curing of concrete. Tap water is used for casting the cubes. Water that is suitable for drinking is used for the experimental work. Water was free from deleterious material, salts and wastes.

3.3 PREPARATION OF FUNGAL COMPOSITE MATERIAL

Biological composite material was prepared by using consortia of rice husk, fly ash, cement and sand. The endophytic fungi were screened for their composite strength by inoculating and incubating it over the different mortar preparation at 26±2°C for 30 days. The fungal growth was regularly monitored. The fungi used during the study are listed in Table 3.7 with their host plant and taxonomic identification. The different mortar preparations used during the screening studies are listed in Table 3.8. The entire tests were performed in triplicates.

Table 3.7 Different Types of Fungi used

S.No	Culture Code	Host Plant	Common name	Taxomonic identification
1.	#44 CMSTITNEY	*Cinnamomum malabaricum*	*Dal chini*	*Fusarium* sp
2.	#1 CCSTIDD	*Cinnamomum camphora*	Kapur	Mycelia sterile
3.	#2 CCSTITD	*Cinnamomum camphora*	Kapur	Mycelia sterile
4.	#1 CSSTOT	*Camellia sinensis*	*Tea*	*Schizophyllum* sp
5.	#4 CMBANEY	*Cinnamomum malabaricum*	*Dal chini*	*Lasiodiplodia* sp
6.	#96 CMSTITNEY	*Cinnamomum malabaricum*	Dal chini	Unidentified
7.	#21 TICSTITPLM	*Tinospora indica*	Giloy	Unidentified
8.	#2 CMLNEY	*Cinnamomum malabaricum*	*Dal chini*	*Fusarium* sp
9.	#2 PNLNEY	*Piper nigrum*	*Kaali mirch*	*Alternaria* sp
10.	#31 CMLPITNEY	*Cinnamomum malabaricum*	*Dal chini*	*Fusarium* sp
11.	#21 CMSTITNEY	*Cinnamomum malabaricum*	*Dal Chini*	*Fusarium* sp
12.	#55 CMSTITNEY	*Cinnamomum malabaricum*	*Dal chini*	*Artheminium* sp
13.	#1003 AMSTITNEY	*Aegle marmelos*	*Beal*	*Botyrosphaerea* sp
14.	#30 CZBAG	*Cinnamomum zeylanicum*	*Tez patta*	*Alternaria* sp
15.	#31 CZBAG	*Cinnamomum zeylanicum*	*Tez patta*	*Alternaria* sp
16.	#79 CMSTITNEY	*Cinnamomum malabaricum*	*Dal chini*	*Alternaria* sp

3.4 BIOLOGICAL COMPOSITE BRICKS

70.6 mm acrylic cubes were used for the study. The composite material consists of cement, sand, fly ash and rice husk. Different compositions of the above mentioned material were used. 50% of cement was replaced with 50% of fly ash whereas 50% of sand was replaced with similar amount of rice husk. The standard mixture consists of cement: 200g, sand 600 g, and Water-cement ratio: 0.5, Water absorption 90%. Whereas the replacement mixture for biological composite by weight consist of cement :100 g, fly ash 100 g, sand 300 g and rice husk 300 g under controlled conditions. By volume, the replacement mixture consists of cement 100 g, fly ash: 67 g, rice husk 139 g, sand 300 g. In both the composite material 3 discs of actively growing fungus was inoculated and incubated at 28±2°C for next 30 days. The cubes were cured at regular interval of 3 days. The cubes thus obtained were subjected for their compressive strength test using universal testing machine. Table 3.8 represents the different mortar mix used for compressive strength.

Table 3.8 Different Mortar Mix used for Compressive Strength

S. No	No. of cubes	Composite material	Composition in (g)
1	9	controlled mix (CM)	cement- 200, sand - 600
2	9	50 % replacement of cement and sand with fly ash and rice husk	cement- 100, sand- 300,fly ash-100 rice husk- 300,
3	6	1/6 th part of standard mix	cement-17, sand- 50,fly ash-17 rice husk-50,
4	6	1/6 th part of standard mix With Fungi #21 CMSTITNEY, #31 CMLPITNEY	cement-17, sand- 50, fly ash-17 rice husk-50,
5	3	50% replacement of cement with Fly ash and 50% replacement of sand with rice husk (powedered form)	cement- 100, sand- 300,fly ash- 100, rice husk in powdered form-300
6	3	20%replacement of cement with fly ash and 50% replacement of sand with rice husk	cement-180, sand-300,fly ash-20 rice husk -300,
BY VOLUME CALCULATION			
7	3	with 50% replacement of sand and cement and fungi 44 CMSTNEY	cement-100, sand -300,fly ash-67, rice husk-139
8	3	Control sample with 50% replacement of sand and cement	cement-100, sand- 300,fly ash- 67, rice husk-139
9	6	50% Replacement of sand with Rice husk only	cement-200,sand-300,rice husk -417

10	3	15% replacement of cement with fly ash	cement-169.89, sand-600,fly ash-20.18
11	6	15% replacement of cement with fly ash #21 CMSTITNEY , #31 CMLPITNEY.No Growth of fungi	cement-169.89, sand-600,fly ash-20.18
12	6	combination of 15% replacement of cement with fly ash + 15% repl. Of sand with rice husk with fungi - #44 CMSTNEY	cement-169.89, sand-510 , fly ash-20.18,rice husk -41.91

3.4.1 Compressive Strength Testing Machine

The cubes thus obtained after curing were tested using universal testing machine. This machine consists of Loading Frame, Hydraulic Pumping system and electronic control machine. The rate of loading of the machine is 17 N/mm^2. The maximum load at which the specimen fails shall be the failure load.

3.5 IDENTIFICATION OF FUNGUS

The fungal isolates which were showing positive results for being the potential architect of biological composite material were examined under the microscope so as to characterize the isolate on the basis of their microscopic characters and morphology. The cultures were grown on PDA for 7 days and then viewed under microscope. Briefly describing, the glass slide was cleaned with alcohol and dried. A drop of water was put on glass slide, upon which the mycelial mass that was taken from the tip of the colony using a fine tipped needle was placed along and teased properly. It was then stained with lactophenol cotton blue (Hi Media). The slide was covered with 18 x 10 mm cover-slip avoiding the formation of air bubble and mounted with DPX. The slide was microscopically observed at 100X, 400X and 1000X using Nikon Stereozoom microscope and Nikon binocular microscope. The fungi were identified based upon their spore structure and other morphological characteristics.

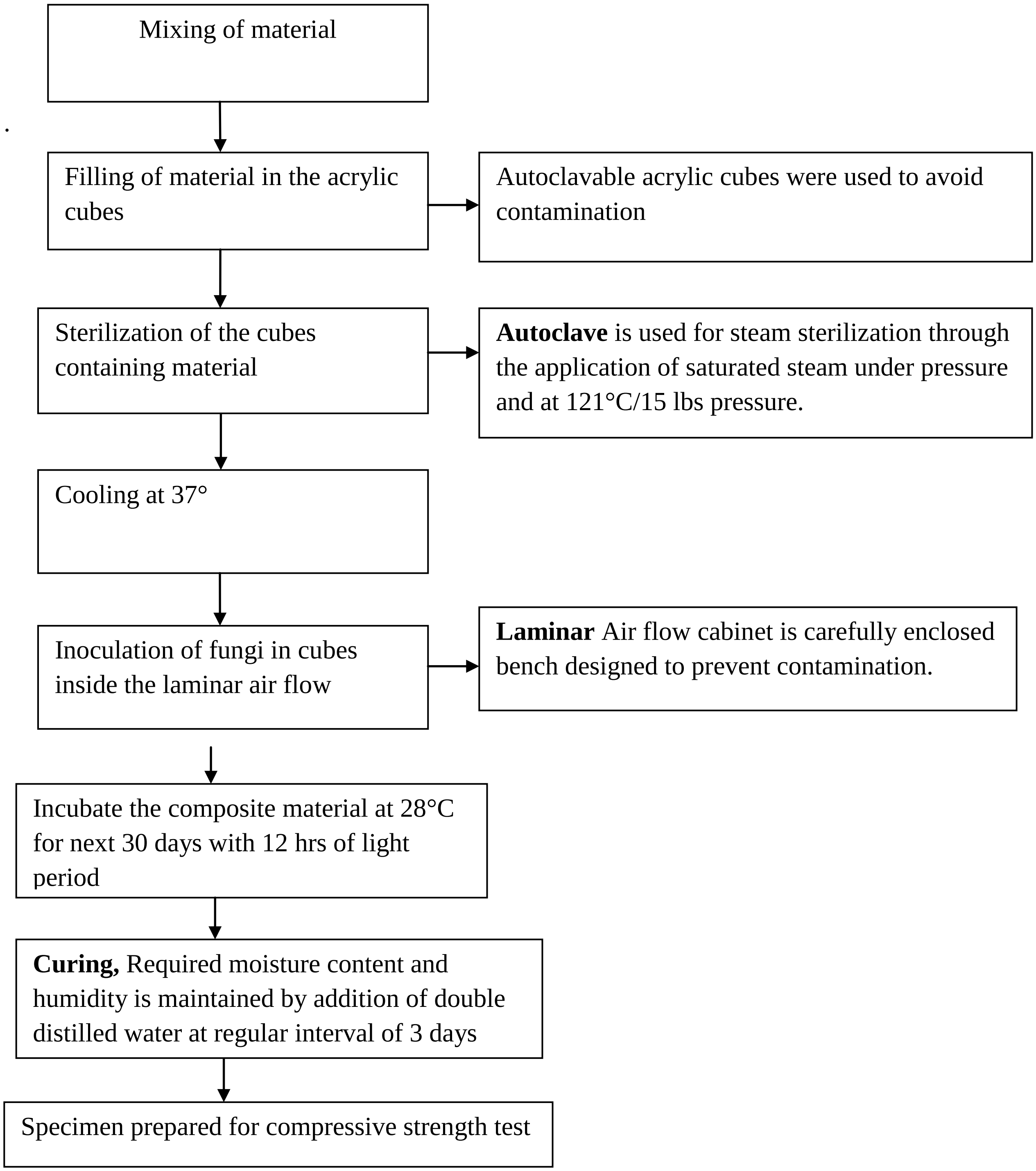

Fig 3.1 Flowchart of the Procedure for Preparation of Composite Bricks

3.6 SEM-EDX STUDY OF THE FUNGAL COMPOSITES

Small section of the 30 day old fungal composite material was kept over the carbon tapped stabs. Gold palladium coating of fungal samples was done using a sputter coater and images were recorded in high vacuum mode using Zeiss Evo40 scanning electron microscope between 307 X – 2.02 KX magnification at 15 kV EHT.

3.7 TESTING OF COMPOSITE BRICKS

3.7.1 Water Absorption- Bricks for external use must be capable of preventing rain water from passing through them to the inside of walls of reasonable thickness. A good brick should absorb water maximum 1/7th of the weight of the brick. A sensitive balance capable of weighing within 0.1 percent of the mass of the specimen and a ventilated oven were used. Take 5 bricks and dry it completely at a temperature of 105 to 115°C till it attains considerably constant mass. Cool the specimen at a room temperature and obtain its wt. (M_1). Submerge completely dry 5 bricks in ventilated oven at a temperature of 27±2°C for 24 hours. Remove the specimen and clean out any traces of water with a damp cloth. Weigh the specimen (M_2). The formula after 24 hour immersion in cold water is given by the formula

$$[M_{2}-M_{1}/M_{1}] \times 100$$

For higher class brick the water absorption after immersion in cold water for 24 hours shall not be more than 15%. Average absorption shall not be more than 20% by weight up to class 125 and 15% by weight for higher classes.

3.7.2 Compressive Strength – The specimen with flat faces horizontal and mortar filled face facing upward between two 3- plywood sheets each of 3 mm thickness placed and carefully centered between plates of the testing machine. Apply load axially at a uniform rate of 14 N/mm^2 per minute till failure occurs and note down the maximum load at failure. The maximum load at which the specimen fails shall be the failure load. Compressive strength is given by maximum load at failure N (Kg)/Average area of bed faces mm^2. The usual crushing strength of common hand molded well burnt bricks is about 5-10 N/mm^2. Pressed and hand molded bricks are much stronger**.**

Table 3.9 Compressive Strength of Various Classes as per IS: 1077-1976

Class Designation	Average compressive strength			
	Not less than Kg/cm^2/N/mm^2		less than Kg/cm^2/N/mm^2	
350	350	35	400	40
300	300	30	350	35
250	250	25	300	30
200	200	20	250	25
175	175	17.5	200	20
150	150	15	175	17.5
125	125	12.5	150	15
100	100	10	125	12.5
75	75	7.5	100	10
35	35	3.5	50	5

4.7.3 Efflorescence of Bricks: The apparatus required is a shallow bottom dish containing sufficient distilled water to completely saturate the specimen. The dish shall be made of glass, porcelain or stone work and size not less than 150mm in diameter and 30mm in depth. Take 3 bricks and place the end of the brick in the dish, the depth of immersion in water being 25mm. Place the whole arrangement in the warm well ventilated room until all the water in the dish is absorbed by the specimen and the extra water evaporated. When the water has been absorbed and bricks appear to be dry, placed a similar quantity of water in the dish and allow it to evaporate as before. Examine the bricks for efflorescence after the second evaporation and report the results. Efflorescence shall be reported under the category of nil, slight, moderate, heavy or serious as given below:

1. **Nil**- when there is no noticeable deposit of efflorescence
2. **Slight**- when not more than 10% of the exposed area of the brick is covered with a thin deposit of salts.
3. **Moderate**- when there is a heavier deposit than under slight and covering up to50% of the exposed area of the brick surface but un-accompanied by powdering
4. **Heavy**-when there is a heavy deposit of salts covering 50% or more of the exposed area but un-accompanied by powdering.
5. **Serious**-when there is a heavy deposit of salts accompanies by powdering.

   Efflorescence should not be more than slight for higher class brick.

CHAPTER-4

RESULTS AND DISCUSSION

4.1 PURE CULTURING OF THE ENDOPHYTIC FUNGI

25 endophytic fungi were successfully recovered from the stock cultures. The cultures grew over PDA medium showing varying morphology. Table 4.1 shows different endophytic fungi with their host plant and taxonomic identification which were further studied for the formation of biological composite materials. Fig 4.1 shows the endophytic fungi growing over PDA medium after 7 days.

Table No. 4.1. Endophytic Fungi with their Host Plant and Taxonomic Identification

S No	Culture Code	Host Plant	Common name	Taxomonic Identification
1.	#44 CMSTITNEY	*Cinnamomum malabaricum*	*Dal chini*	*Fusarium* sp
2.	#1 CCSTIDD	*Cinnamomum camphora*	Kapur	Mycelia sterile
3.	#2 CCSTITD	*Cinnamomum camphora*	Kapur	Mycelia sterile
4.	#1 CSSTOT	*Camellia sinensis*	*Tea*	*Schizophyllum* sp
5.	#4 CMBANEY	*Cinnamomum malabaricum*	*Dal chini*	*Lasiodiplodia* sp
6.	#96 CMSTITNEY	*Cinnamomum malabaricum*	Dal chini	Unidentified
7.	#21 TICSTITPLM	*Tinospora indica*	Giloy	Unidentified
8.	#2 CMLNEY	*Cinnamomum malabaricum*	*Dal chini*	*Fusarium* sp
9.	#2 PNLNEY	*Piper nigrum*	*Kaali mirch*	*Alternaria* sp
10.	#31 CMLPITNEY	*Cinnamomum malabaricum*	*Dal chini*	*Fusarium* sp
11.	#21 CMSTITNEY	*Cinnamomum malabaricum*	*Dal Chini*	*Fusarium* sp
12.	#55 CMSTITNEY	*Cinnamomum malabaricum*	*Dal chini*	*Artheminium* sp

13.	#1003 AMSTITNEY	*Aegle marmelos*	*Beal*	*Botyrospharea* sp
14.	#30 CZBAG	*Cinnamomum zeylanicum*	*Tez patta*	*Alternaria* sp
15.	#31 CZBAG	*Cinnamomum zeylanicum*	*Tez patta*	*Alternaria* sp
16.	#79 CMSTITNEY	*Cinnamomum malabaricum*	*Dal chini*	*Alternaria* sp

4.2 SCREENING FOR BIOLOGICAL COMPOSITE MATERIAL

25 endophytic fungi were screened in different proportions of mortar mix having cement, sand, fly ash and rice husk. Table no 4.1 gives the different type of fungus used. From all types of mixes the mix with 50% replacement of sand with rice husk was the best for the growth of the fungi. The possible reason is that the rice husk is an organic material and act as a nutrient for the fungi. The best growing fungi were #21CMSTITNEY, #31CMLPITNEY and #44 CMSTITNEY. Fig 4.1 represents the best growing endophytic fungi used for screening purpose. Figs. 4.2 to 4.4 show the mycelial mat formation for the three best growing fungi as mentioned above.

Fig 4.1 Endophytic Fungi Growing over PDA Medium after 7 Days

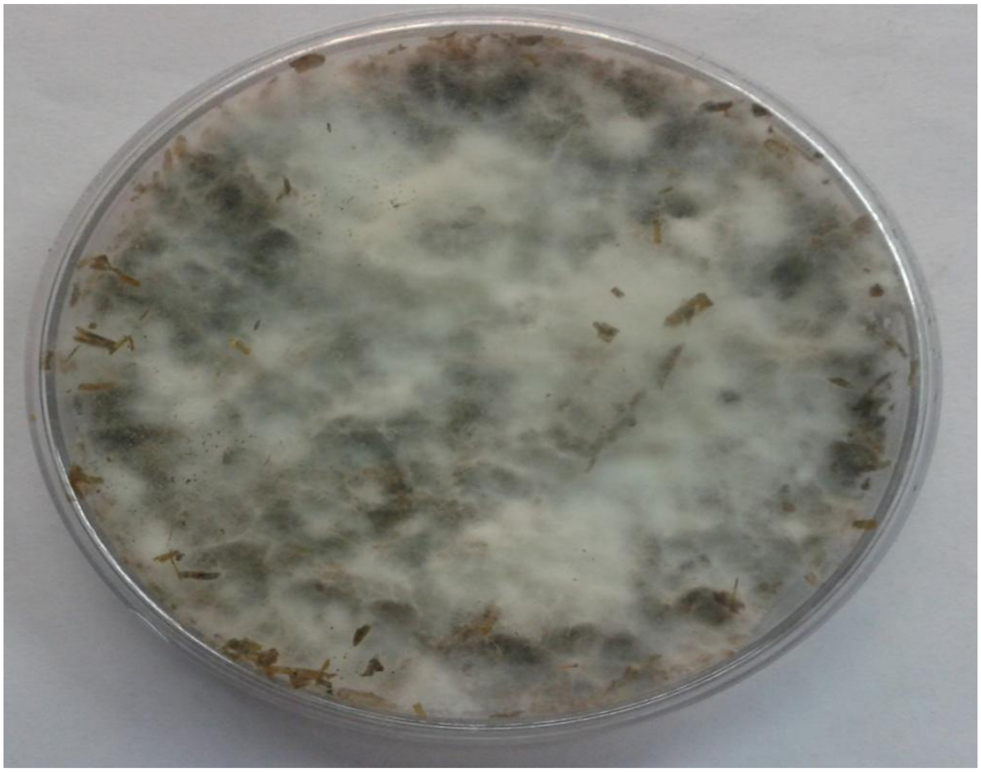

Fig 4.2   Mycelial Mat Formation over the Rice Husk Medium with #21 CMSTITNEY

Fig 4.3 Mycelial Mat Formation over the Rice Husk Medium with #31 CMLPITNEY

Fig 4.4 Mycelial Mat Formation over the Rice Husk Medium with #21 CMSTITPLM

4.3. ASSESSMENT OF BIOCOMPOSITE STRUCTURES

On the basis of screening procedure the two fast growing endophytic fungal isolates # 21 CMSTITNEY and #31 CMLPITNEY were chosen for further testing. These fungi were then grown over different replacement of mortar mix for next 30 days. The cubes with different replacements of cement with fly ash and sand with rice husk using these fungi were prepared under the controlled conditions. To compare the strength of the fungi controlled cubes were also casted. The results thus obtained were given in the Table 4.2. The comparison of the result is briefly shown with fungi and without fungi after 7, 14 and 28 days with different proportions by weight and by volume.

Fig 4.5 and 4.6 show that the growth of the fungus was very good in cubes but it has taken a lot of time to penetrate completely into the specially prepared acrylic sheet cubes with holes on all the faces to provide air and water. It easily penetrates through the material and covers the material fully. The filaments of the fungi were binding the cement mortar material with itself. The binding was very good. But the material did not have enough strength. This could be attributed to the use of rice husk, which has been used in the mix as a nutrient for the growth of the fungi.

Table 4.2 Testing Results of Cubes with different Mortar Concentrations and Replacements

S. No	Types of mix	Composition (Weight in gm)	Compressive strength in MPa (days)		
			7	14	28
1	Standard mix	Cement- 200 Sand - 600	21.98	30.49	40.99
By weight					
2	50% replacement of sand with rice husk and 50% replacement of cement with fly ash	Cement- 100 Fly ash- 100 Rice husk-150 Sand - 150	The cubes were unable to take the desired shape.		
3	20% replacement of cement with fly ash and 50% replacement of sand with rice husk	Cement- 160 Fly Ash- 40 Rice Husk- 300 Sand- 300	The cubes were unable to take the desired shape.		
By volume					
4	50% replacement of sand with rice husk and 50% replacement of cement with fly ash	Cement- 100 Fly ash- 67 Rice husk- 139 Sand- 300	Strength was checked after 28 days only.		0.233
5	Replacement of 50% sand with rice husk	Cement- 200 Sand- 300 Rice husk- 139 Fly ash- 100	Strength was checked after 28 days only.		0.534
6	15% replacement of sand with R.H, without fly ash	Cement- 200 Rice husk- 41.91 Sand- 510	0.129	0.143	0.309

7	15% replacement of cement with F.A, without rice husk	Cement- 169.89 Fly ash- 20.18 Sand- 600	18.17	20.10	26.32
8	15% of replacement of cement with F.A and 15% of Sand with R.H	Cement- 509.67 Fly ash- 20.18 Sand- 510 Rice husk- 41.91	0.164	0.178	0.195
With fungi (by weight)					
9	50% of replacement of cement with F.A , 50% of Sand with R.H and #21CMSTITNEY	Cement- 100 Fly ash- 100 Sand- 150 Rice husk- 150	The cubes were unable to take the desired shape.		
10	50% of replacement of cement with F.A , 50% of Sand with R.H and #31CMLPITNEY	Cement- 100 Fly ash- 100 Sand- 150 Rice husk- 150			
By volume					
11	50% of replacement of cement with F.A , 50% of Sand with R.H and #44 CMSTITNEY	Cement- 100 Fly ash- 67 Sand- 300 Rice husk- 139	Strength was checked after 28 days only.		0.217

Fig 4.7 (a) and Fig 4.7 (b) show the controlled mix cubes prepared for the compressive strength testing of mortar, but due to the presence of rice husk the binding was not good with the cement mortar material. The cubes with coarse rice husk of 50% replacement by weight were unable to take the shape. It is clearly shown in the fig 4.7 (b). The cubes with powdered form and with replacement of sand with rice husk did sustain some compressive load when tested after 7 and 28 days, but it was found to be very low. This was clear from the experiment that the strength was decreasing with the addition of rice husk. After the testing of cubes using Scanning Electron Microscopy and energy dispersive X- ray the surface images and chemical composition were determined respectively.

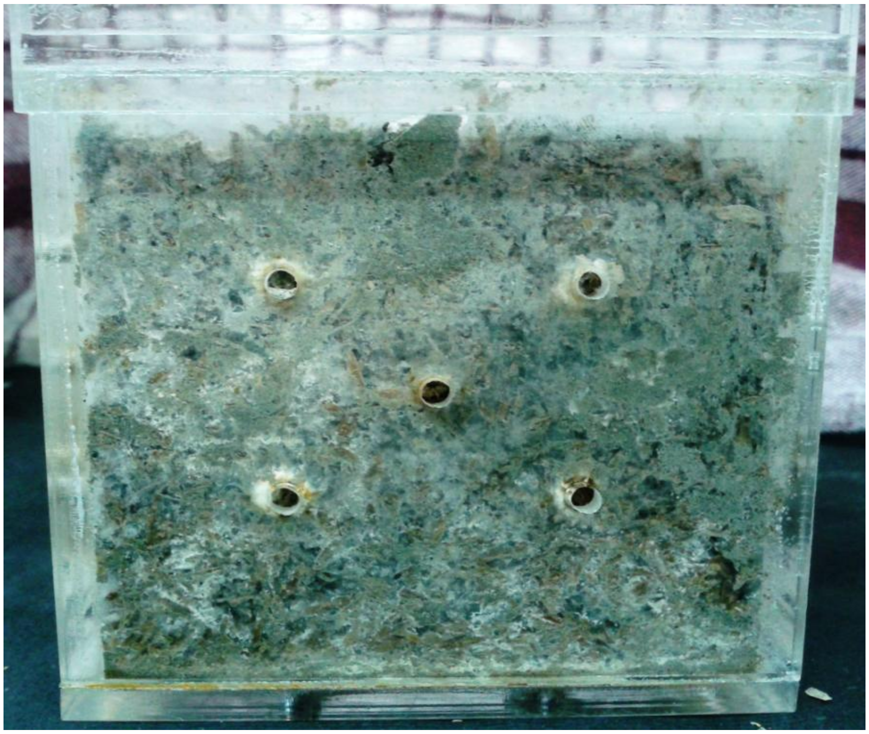

Fig 4.5 Cube with Fungus # 21 CMSTITNEY

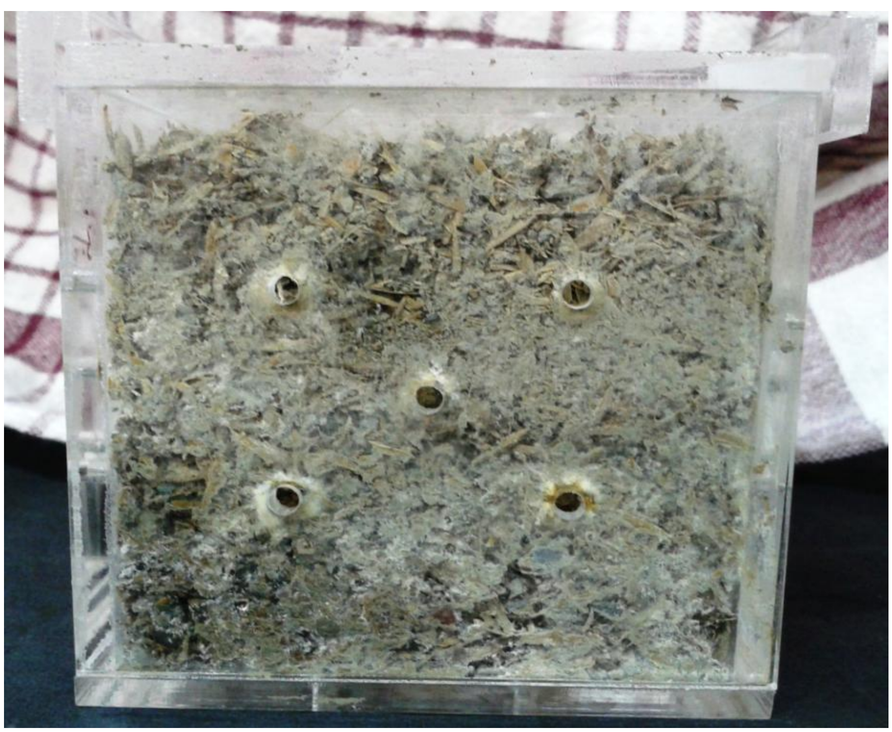

Fig. 4.6 Cube with Fungus #31 CMLPITNEY

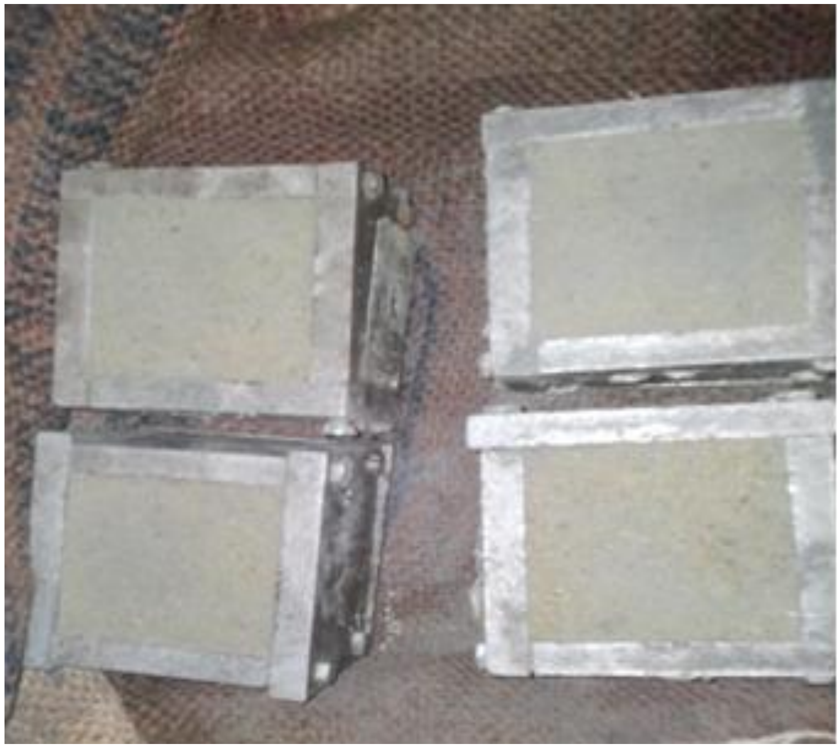

Fig. 4.7 (a) Controlled Mix Cubes in Moulds

Fig 4.7 (b) Disturbed Shape of the Controlled Sample

4.4 MICROSCOPIC VIEW OF THE FUNGAL SPECIES

The Fig 4.8 (a) and 4.8 (b) shows the fungal species #21 CMSTITNEY and their microscopic view and Fig 4.9 (a) and 4.9 (b) shows the fungal species of #31CMLPITNEY and their microscopic view, respectively. From the Fig. 4.8(a), which shows the fungal species #21 CMSTITNEY, it can be seen that the colour of the specimen from the front is pink and from the back is light whitish pink.

This indicates that the growth of the fungi is moderate and irregular. Appearance of the fungal species is cottony puffy.

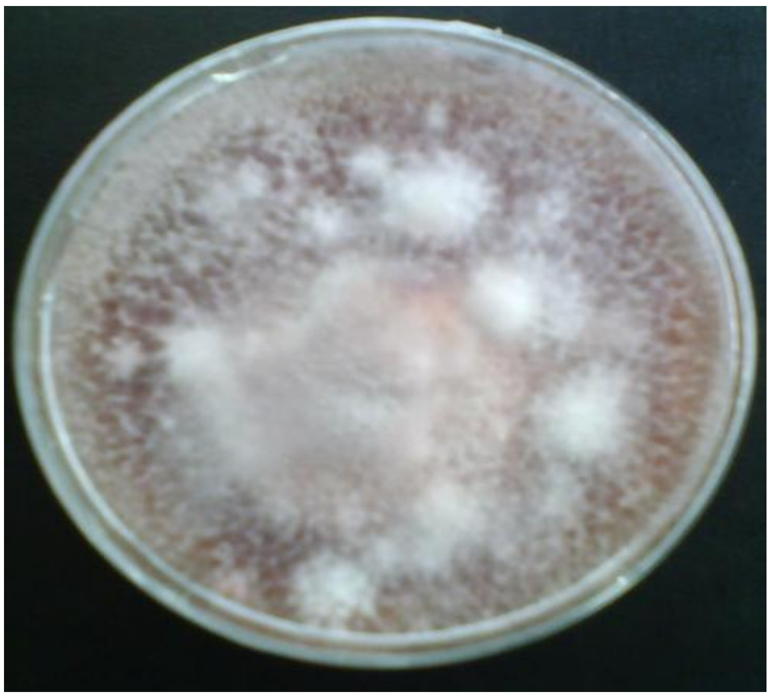

Fig 4.8 (a) The Fungal Species #21 CMSTITNEY

The microscopy character of the fungal species, as seen from Fig. 4.8(b) is Mycelium septate, hyaline. Macroconidia are produced from phialides on unbranched conidiophores. They are two or more celled, thick walled. It is smooth and cylindrical or sickled shaped. Macroconidia have a distinct basal foot cell and pointed distel ends. They are single celled, smooth, hyaline, ovoid to cylindrical, and arranged in balls. Hence the fungus was tentatively identified a *Fusarium sp.*

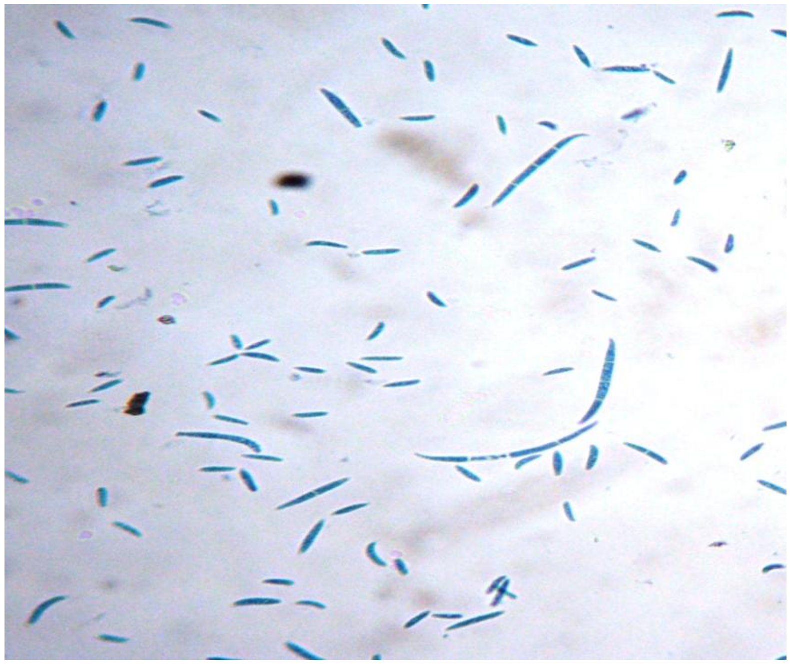

Fig 4.8 (b) Microscopic View of #21 CMSTITNEY

The Fig 4.9 (a) shows the fungal species of #31CMLPITNEY, and from this it can be seen that this fungus is pinkish white from the front and white from the back. The elevation is slightly elevated at centre. The growth of this fungus is moderate and regular and its appearance is Cotton Puffy.

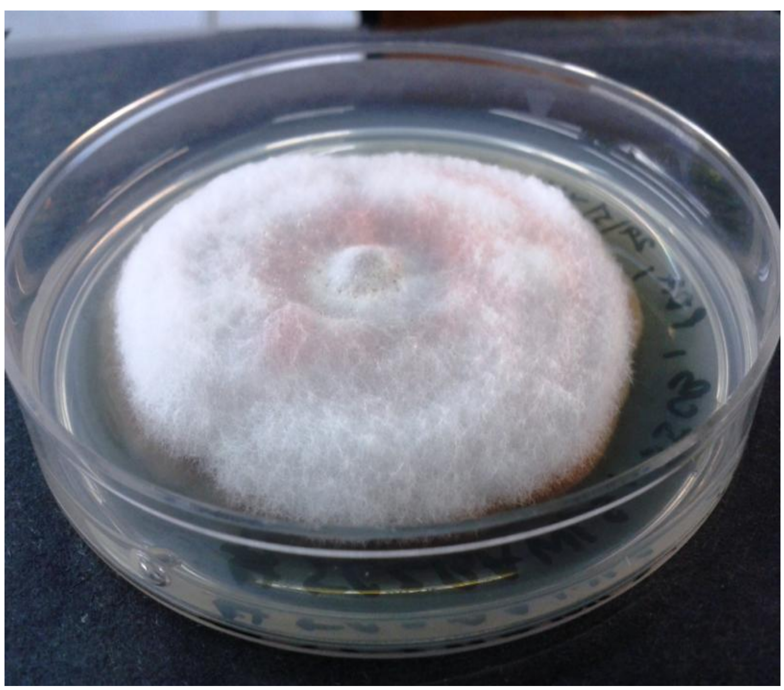

Fig 4.9 (a) The Fungal Species #31CMLPITNEY

Fig 4.9 (b) shows the microscopy view of the fungus 31 CMLPITNEY. The microscopy characters are Mycelium but is non septate, colored, coenocytic and branched. Spores are sickle shaped, 3-4 celled, single walled, moderate in size. Hence the fungus was tentatively identified as *Fusarium species*

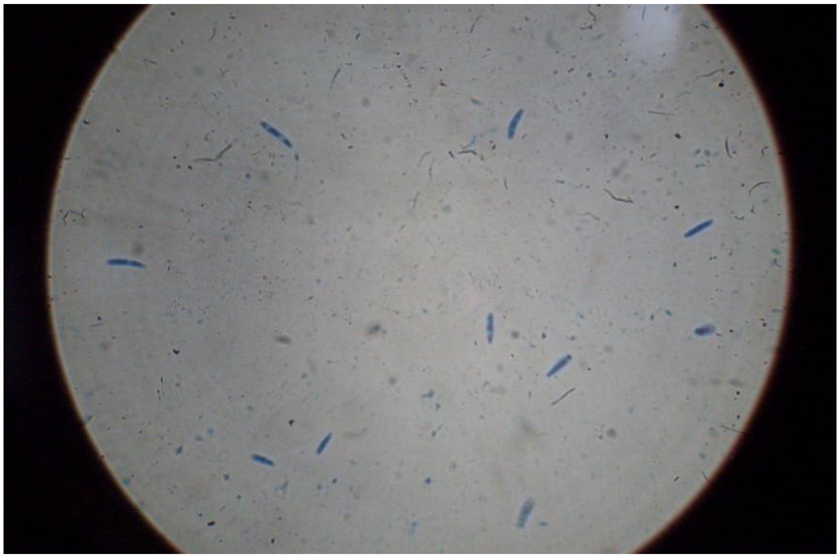

Fig 4.9 (b) Microscopic view of #31CMLPITNEY

4.5 SCANNING ELECTRON MICROGRAPHS (SEM) OF FUNGI

To obtain high magnification images of cement mortar surface or to analyze material, not identifiable by optical microscopy, SEM is a good technique which takes care of these limitations very well. The ultra structure of the best growing isolates #21 CMSTITNEY and #31 CMLPITNEY was analyzed through SEM analysis. Fig. 4.10(a) shows the SEM Analysis of Cement Mortar at point 11 with Fungus #21 CMPLNTEY (20 µm) and Fig. 4.10(b) shows the SEM Analysis of Cement Mortar at point 12 with Fungus #21 CMPLNTEY (20 µm). It can be observed from these SEM's that #21 CMSTITNEY forms dense mycelial lawn over the medium as seen from fig 4.10 (a). The fungus clearly seems to be entrapping the mortar mix thereby showing the tendency of enhancing its compressive strength shown in fig 4.10 (b). The images are taken at two different points.

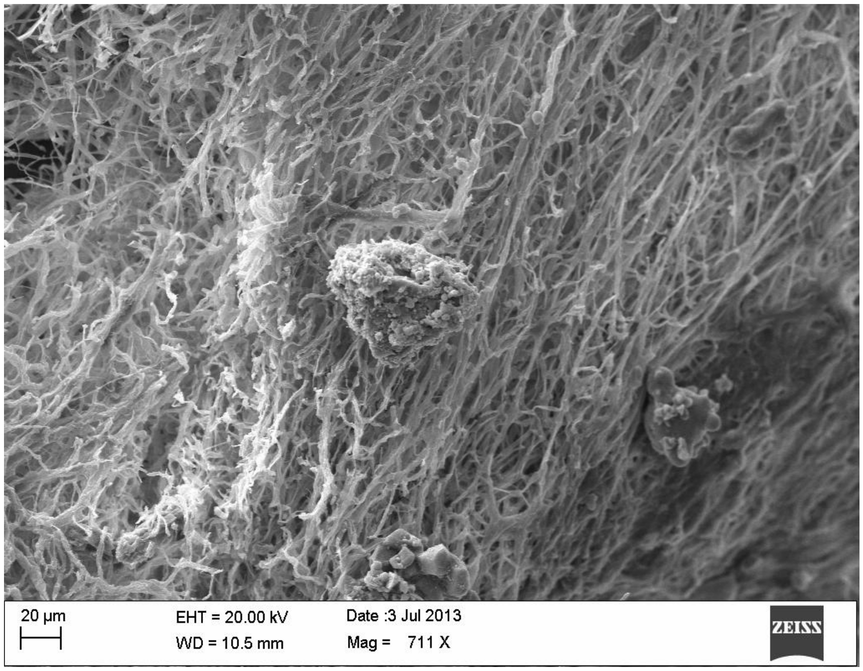

Fig. 4.10 (a) SEM Analysis of Cement Mortar at point 11 with Fungus #21 CMPLNTEY (20 µm)

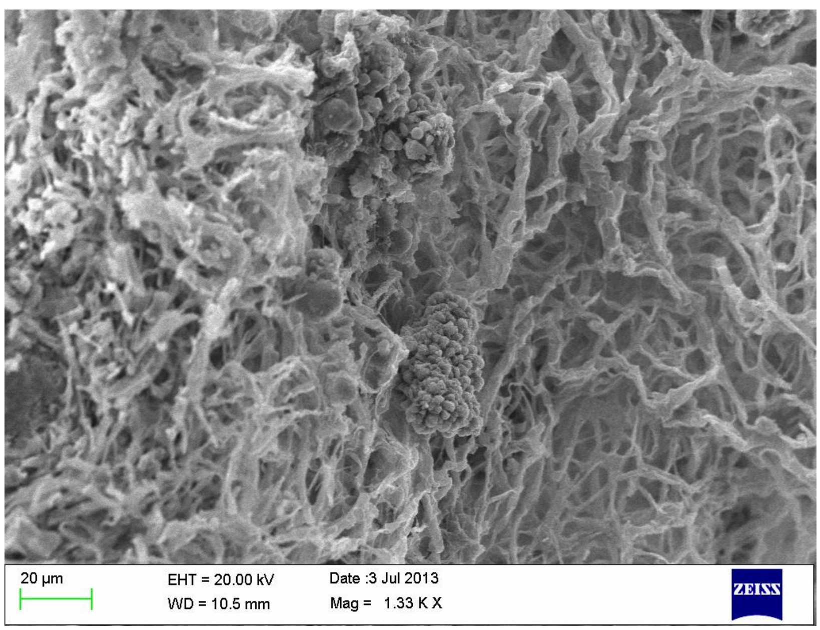

Fig 4.10(b) SEM Analysis of Cement Mortar at point 12 with Fungus #21 CMPLNTEY (20 µm)

The fig 4.11 (a) and 4.11 (b) show the close view of the cement mortar with fungi #21 CMSTITNEY at the magnification of 2 µm. The spherical particle shown in fig 4.11 (a) are of 3.279 µm and 3.475 µm. Fig 4.11 (b) shows that the fungi has totally covered the cement mortar.

It is the best image which clearly shows that the fungi has entrapped the whole cement material, but it is at a particular point i.e at point 12, not all over the material indicating that the growth of this fingi is not uniform across the matrix.

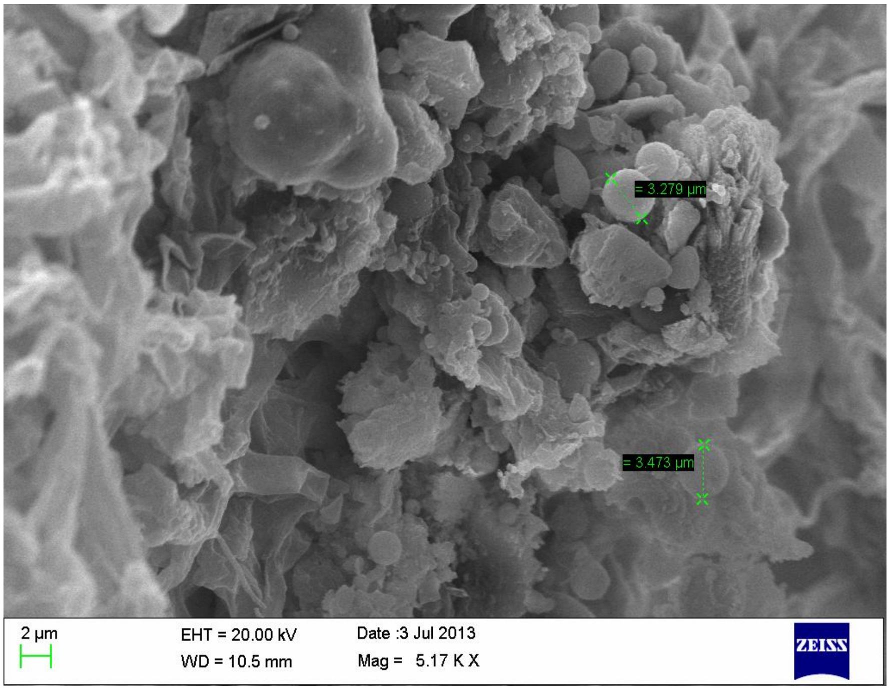

Fig 4.11(a) Close View of the Cement Mortar at point 11 with Fungus #21 CMSTITNEY (2µm)

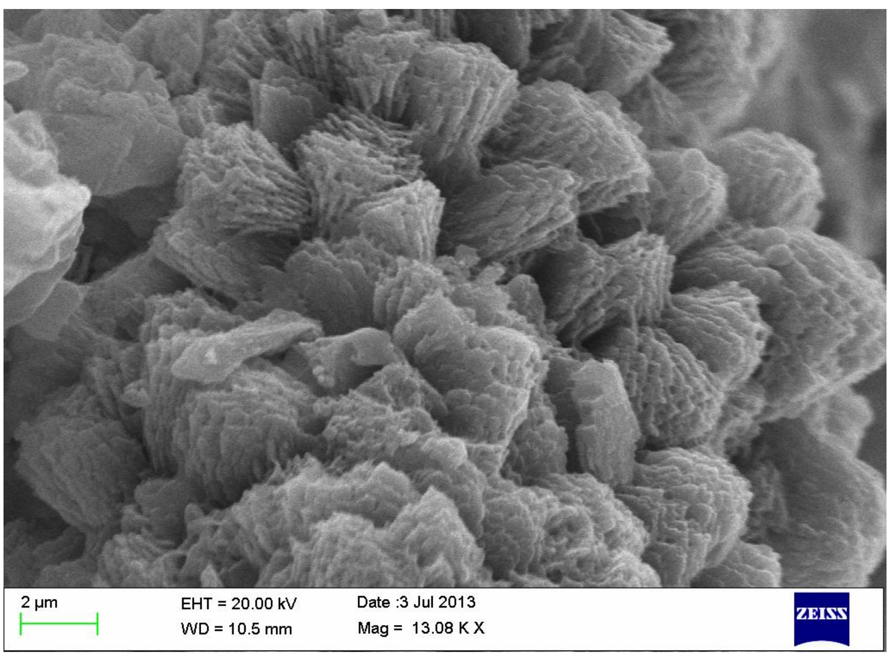

Fig 4.11 (b) Close View of the Cement Mortar at point 12 with Fungus #21 CMSTITNEY (2 µm)

However, the strength achieved is very low indicating that such formations can only be used as controlled low strength composites. This low strength is primarily attributed to the induction of rice husk in the mortar mix. Thus, there is a need to find another organic nutrient for the growth of fungi in the mix.

The fig no. 4.12 (a) and 4.12 (b) shows the SEM photographs of #31 CMLPITNEY at a point 15 and 16 respectively. The magnification of the images is 10 µm. Fig 4.12 (a) and 4.12 (b) show the binding of fungal mycelim to the mortar mix but this binding is significantly less as compared to the binding of 21 CMSTITNEY fungus. The width of the filament has checked at two points in Fig 4.12 (a). It is 1.121 µm at one point and 1.642 µm at another point.

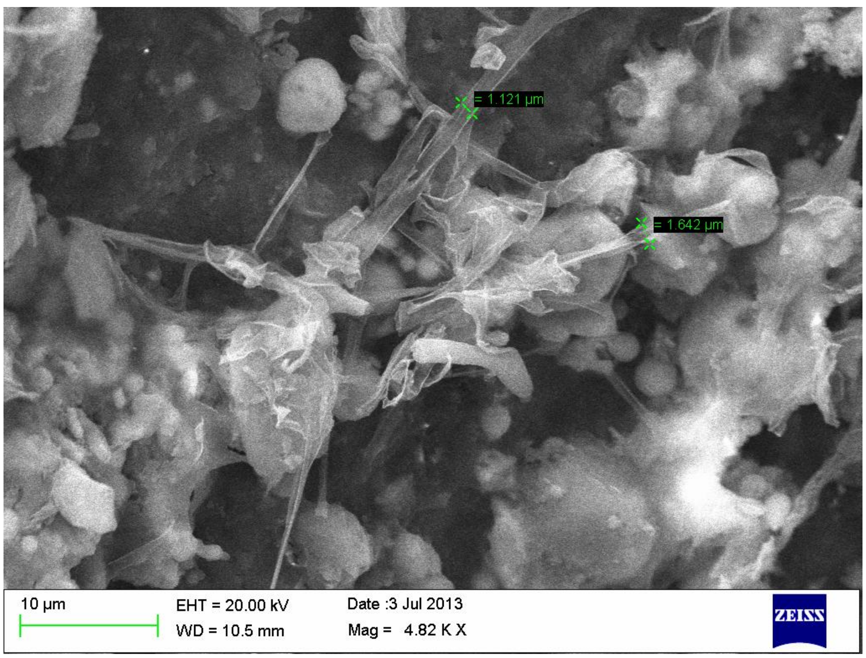

Fig. 4.12 (a) SEM Analysis of Cement Mortar at point 15 with Fungus #31 CMPLNTEY (10 µm)

SEM pictures 4.13 (a) and 4.13 (b) are the close view of the # 31 CMLPITNEY at a magnification of 2 µm. The figures show the ultrastructure of the fungus and the mortar mix. The fig 4.13 (a) shows that there is no growth of fungi at point 15 due to less rice husk there at a particular point and the growth shown in the Fig 4.13 (b) at point 16 is somewhat good. The filaments are seen trying to cover the mortar mix.

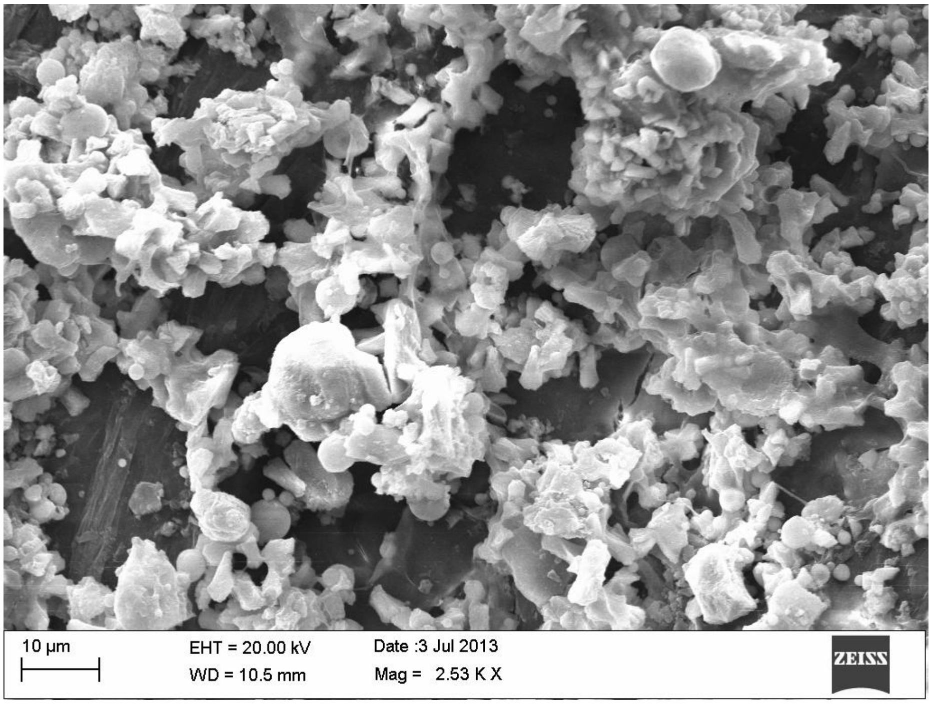

Fig. 4.12 (b) SEM Analysis of cement mortar at point 16 with Fungus #31 CMLPITNEY (10 µm)

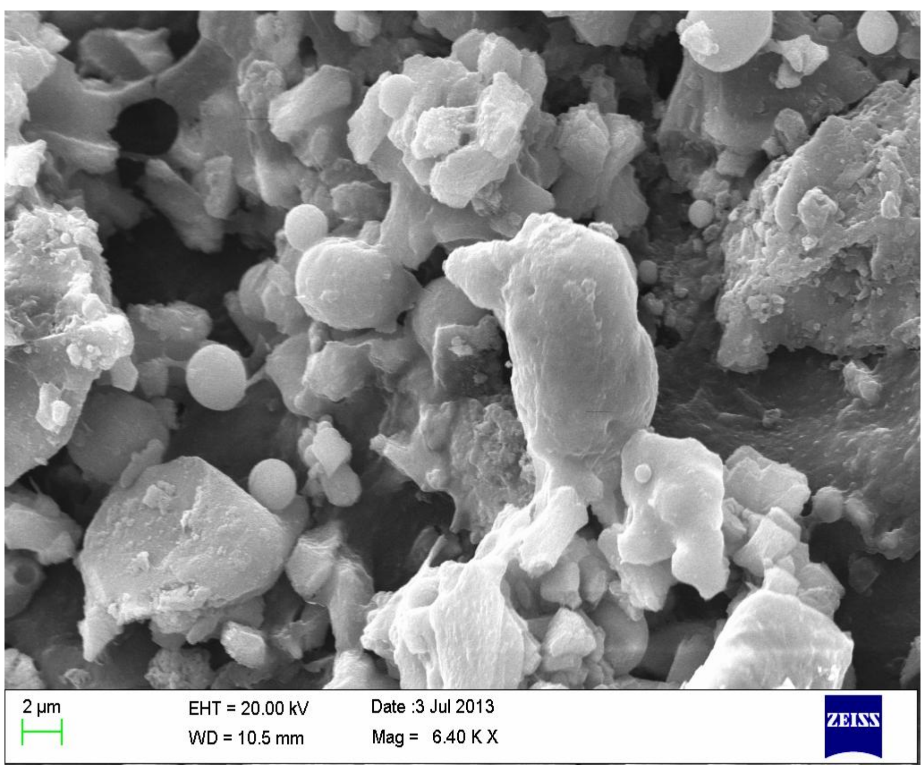

Fig 4.13 (a) Close View of Cement Mortar at point 15 with Fungus #31 CMPLNTEY (2µm)

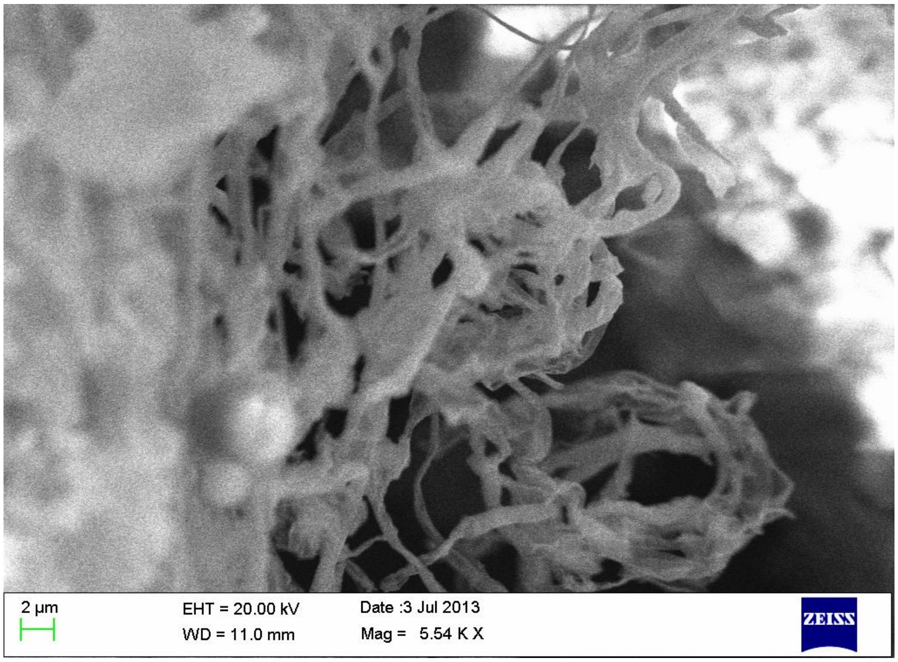

Fig 4.13 (b) SEM Analysis of cement mortar at point 16 with Fungus #31 CMPLNTEY (2µm)

4.6 SEM MICROGRAPH OF CONTROL SAMPLE OF CEMENT MORTAR

SEM micrographs of control sample are shown in Figs 4.14 and 4.15. The magnification is 10 µm and 1 µm, respectively. Fig 4.16 is the close view of the cement mortar.

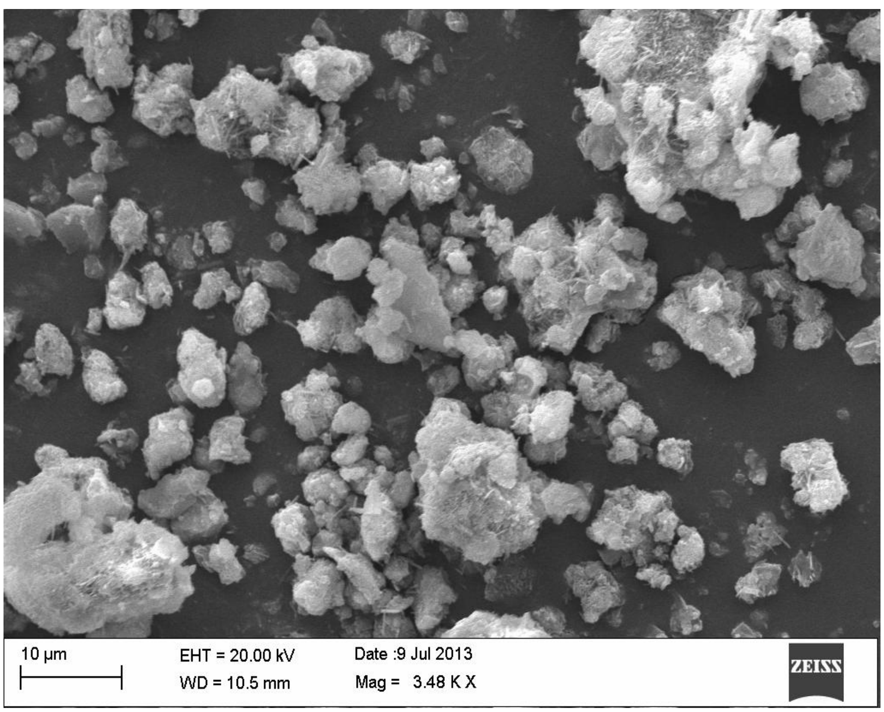

Fig 4.14 SEM analysis of control sample at point 1 of cement sand mortar (10µm)

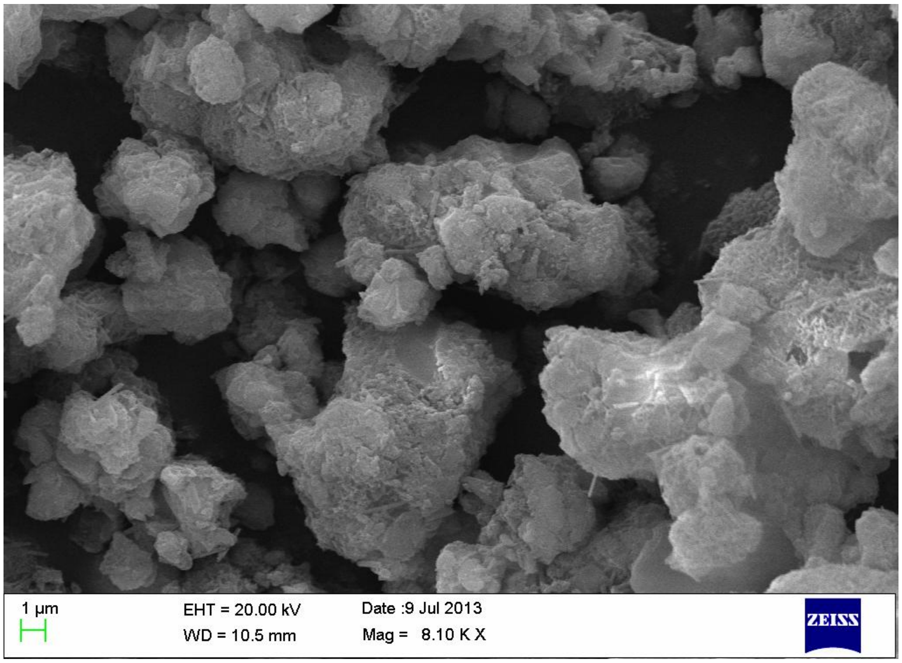

Fig 4.15 SEM Analysis of Control sample at point 2 of cement sand mortar (1 µm)

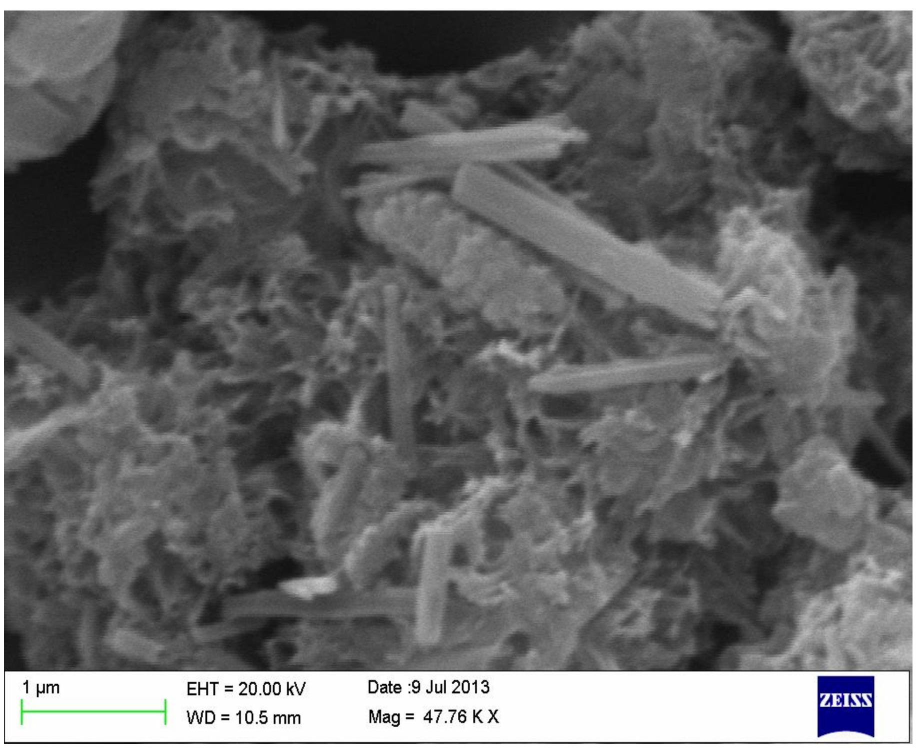

Fig 4.16 Close view of control sample of cement sand mortar (1µm)

4.7 SCANNING ELECTRON MICROSCOPY-ENERGY DISPERSIVE X-RAYS (SEM-EDX) OF FUNGI

The SEM-EDX analysis reveals the chemical composition of the mortar mix when incubated with the fungus for 30 days. EDX shows the composition of the cement mortar i.e. elements present in the cement mortar with different percentages. The EDX of cement mortar with #31 CMLPITNEY is shown below in Fig. 4.17. In the figure two spectrums, 15 and 16 were observed. The analysis of point no. 15 was done to find out the presence of different elements. Figure 4.18 shows the EDX analysis at point 15 with Fungi #31 CMLPITNEY and the results of the elements composition is given in the Table 4.3. The peaks show the variation in percentages of elements. The highest peak shows the higher percentage of the element present in the mortar mix. As the peaks goes down the percentage of the element present in the mix get reduced.

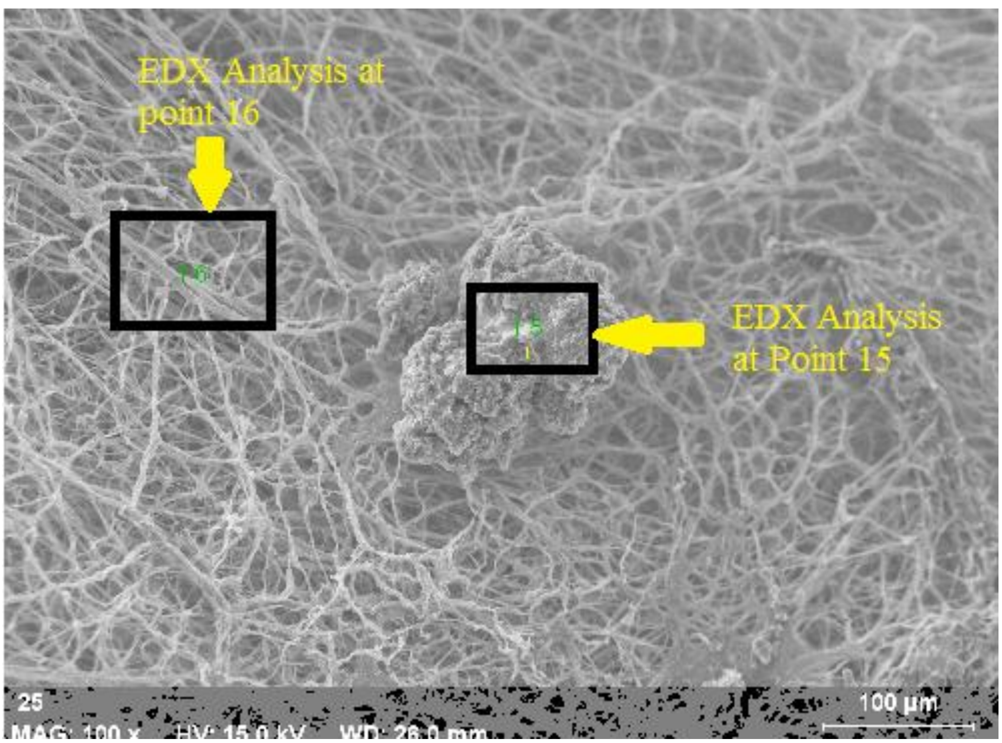

Fig 4.17 SEM analysis of #31 CMPLNTEY

Fig 4.18 shows the EDX result of fungi #31 CMLPITNEY at point 15 and Fig. 4.19 shows the results at point 16. Carbon content is the major component as is clear from the results at point 15 with a percentage of nearly 90. There is very little amount of silicon, calcium, potassium and iron. However, at point no.16 carbon content is only 19.3% and calcium content is more as compared to that present at point no 15. Also there is a significant presence of oxygen at this point. The low strength of the mortar mix, as can be seen from the composition shown in tables 4.3 and 4.4, may be attributed to less amount of silica.

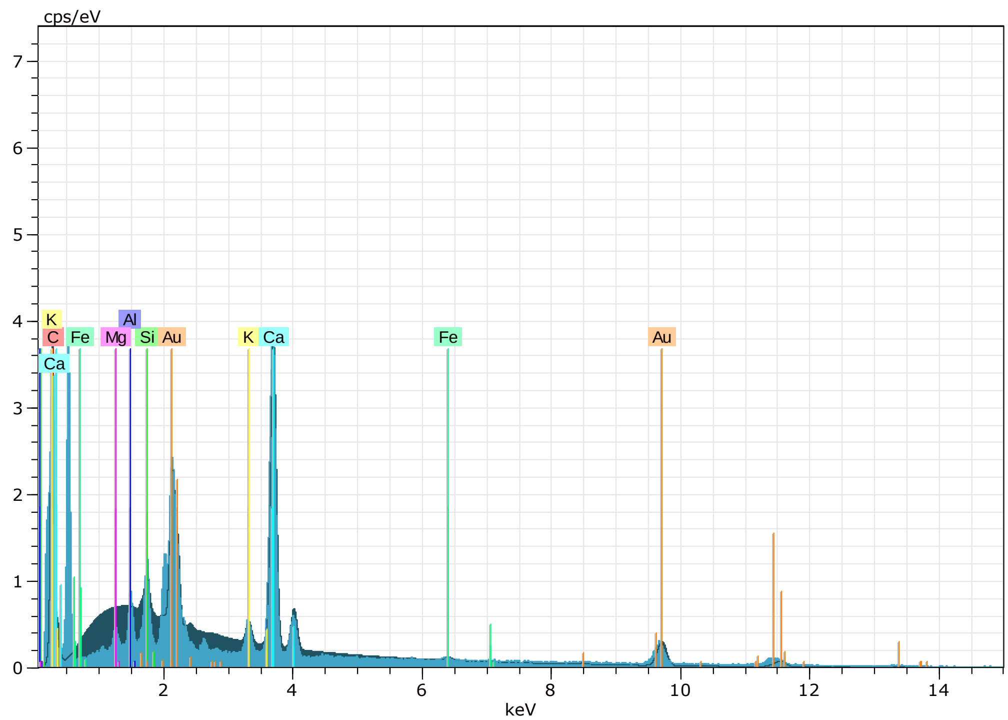

Fig 4.18 EDX analysis at point 15 with Fungi #31 CMLPITNEY

Table 4.3 EDX Result of #31 CMLPITNEY (Spectrum: 15)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Carbon	K-series	90.68	90.68	97.85	0.3
Silicon	K-series	0.25	0.25	0.11	0.0
Aluminium	K-series	0.00	0.00	0.00	0.0
Calcium	K-series	5.15	5.15	1.66	0.2
Magnesium	K-series	0.00	0.00	0.00	0.0
Potassium	K-series	0.28	0.28	0.09	0.0
Iron	K-series	0.23	0.23	0.05	0.0
Total:		100.00	100.00	100.00	

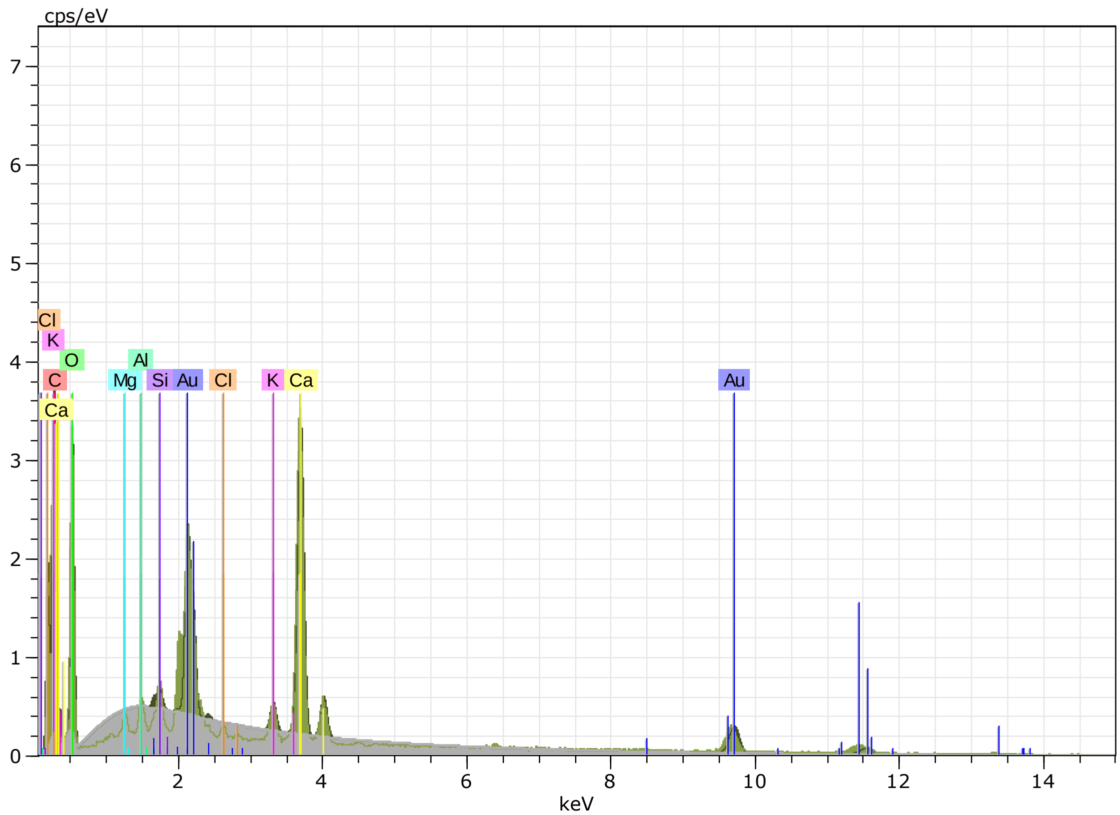

Fig 4.19 EDX analysis at point 16 with Fungi #31 CMLPITNEY

Table 4.4 EDX Result of #31 CMLPITNEY (Point: 16)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Carbon	K-series	19.31	19.31	26.58	6.3
Magnesium	K-series	0.00	0.00	0.00	0.0
Potassium	K-series	0.51	0.51	0.22	0.0
Calcium	K-series	6.88	6.88	2.84	0.2
Chlorine	K-series	0.00	0.00	0.00	0.0
Aluminium	K-series	0.01	0.01	0.00	0.0
Silicon	K-series	0.18	0.18	0.11	0.0
Oxygen	K-series	67.56	67.56	69.79	20.7
	Total:	100.00	100.00	100.00	

Fig. 4.20 shows the SEM picture of cement mortar with fungus #21 CMSTITNEY. Two points 11 and 12 were generated. Fig 4.21 shows the EDX result of fungi #21 CMSTITNEY at point 11 and Fig. 4.22 shows the results at point 12. The results are also tabulated in Tables 4.5 and 4.6. The results show that the highest peak of the element at point no. 11 was that of silica, with a percentage of nearly 13.25. Oxygen and calcium with 48.21% and 17.53%, respectively, are the other main elements. Elements like potassium, iron, copper and gold are present in less quantity. However, at point 12 is calcium content is significant with 16.98%, with a silicon content of 12.85%. The results clearly indicate that the presence of fungus # 21 CMSTITNEY in the mix is beneficial as it contains more calcium as compared to # 31 CMLPITNEY. Hence, the fungus # 21 CMSTITNEY can be more useful with a different nutrient in enhancing the strength of the mortar mix.

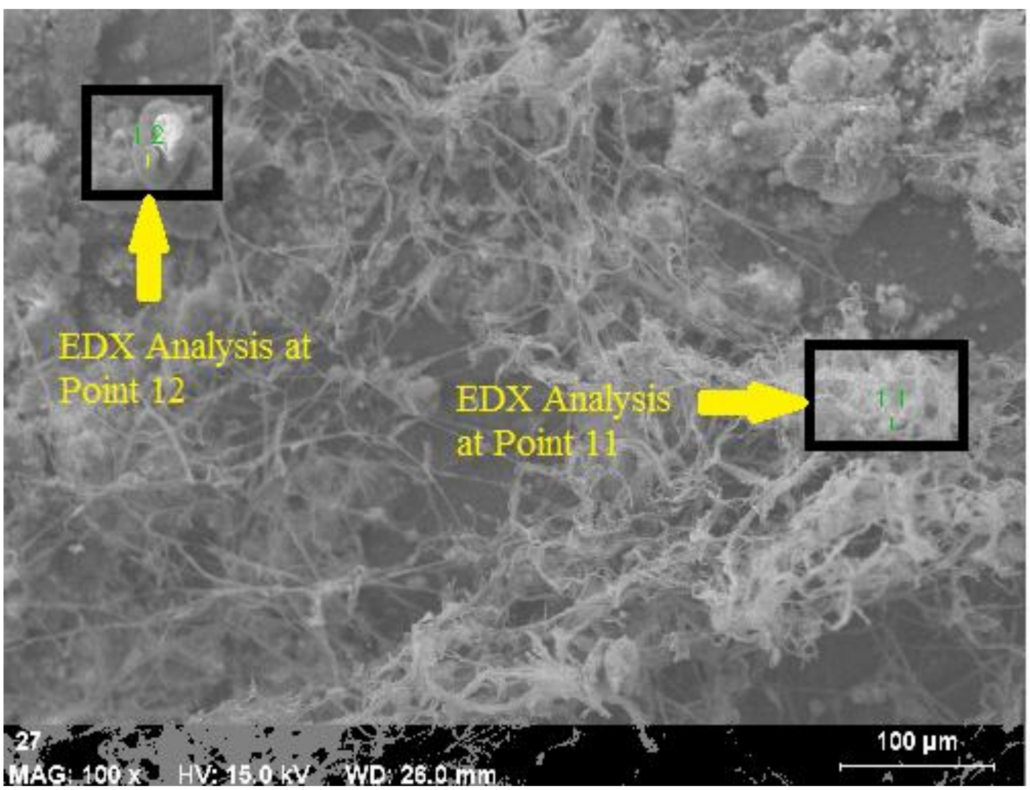

Fig 4.20 SEM Analysis of fungus # 21 CMSTITNEY

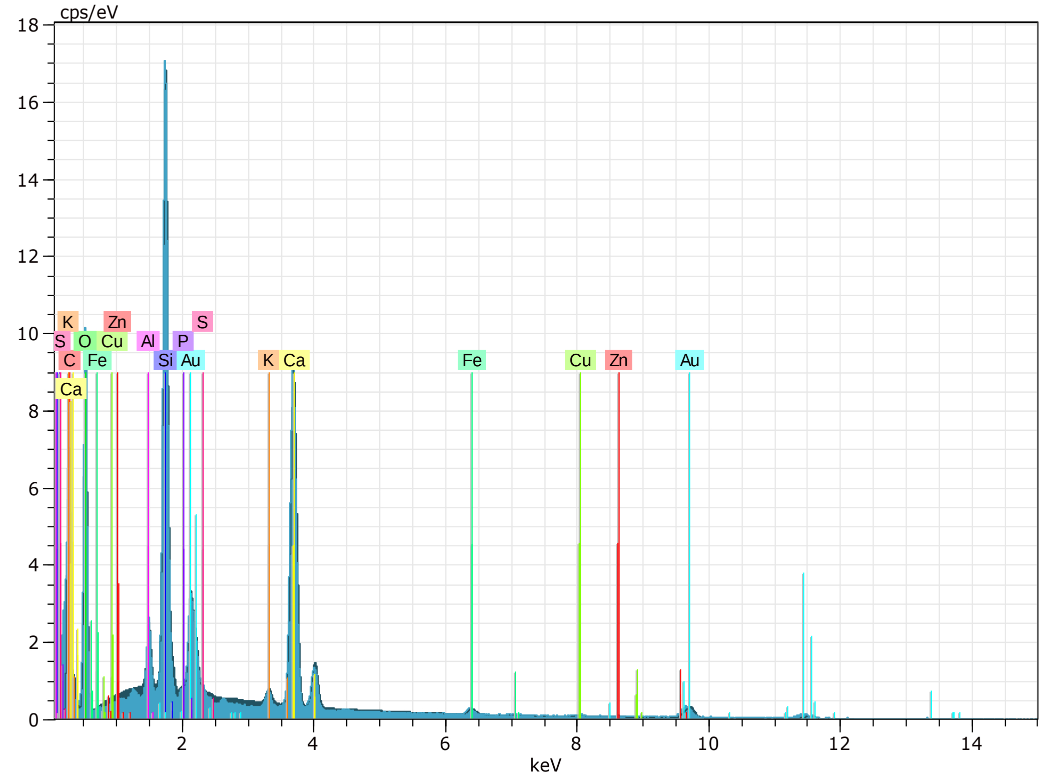

Fig. 4.21 EDX analysis at point 11 with Fungi #21 CMSTITNEY

Table 4.5 EDX Result of # 21 CMSTITNEY (Point : 11)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Carbon	K-series	6.00	7.74	13.61	0.7
Silicon	K-series	10.27	13.25	9.97	0.5
Gold	M-series	5.94	7.67	0.82	0.2
Aluminium	K-series	1.00	1.29	1.01	0.1
Calcium	K-series	13.58	17.53	9.24	0.4
Potassium	K-series	0.46	0.60	0.32	0.0
Iron	K-series	0.93	1.20	0.45	0.1
Phosphorus	K-series	0.10	0.12	0.08	0.0
Sulfur	K-series	0.15	0.20	0.13	0.0
Copper	K-series	0.86	1.11	0.37	0.1
Zinc	K-series	0.83	1.07	0.35	0.1
Oxygen	K-series	37.34	48.21	63.64	4.1
	Total:	77.46	100.00	100.0	

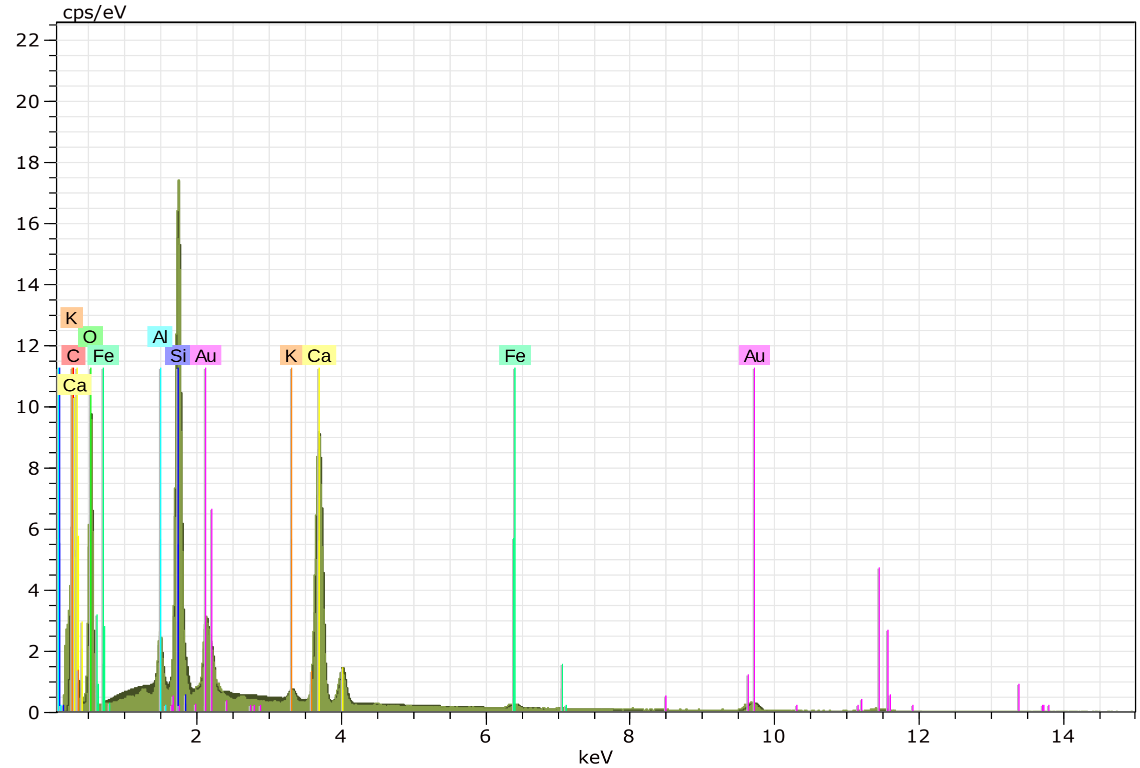

Fig 4.22 EDX analysis at point 12 with Fungi #21 CMSTITNEY

Table 4.6 EDX Result of # 21 CMSTITNEY (Point: 12)

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Carbon	K-series	6.70	9.03	15.13	0.8
Silicon	K-series	9.53	12.85	9.21	0.4
Aluminium	K-series	0.87	1.18	0.88	0.1
Gold	M-series	4.97	6.71	0.69	0.2
Calcium	K-series	12.51	16.88	8.47	0.4
Potassium	K-series	0.39	0.53	0.27	0.0
Iron	K-series	0.83	1.11	0.40	0.0
Magnesium	K-series	0.00	0.00	0.00	0.0
Chlorine	K-series	0.00	0.00	0.00	0.0
Sulfur	K-series	0.09	0.12	0.07	0.0
Oxygen	K-series	38.24	51.59	64.88	4.2
Total:		74.12	100.00	100.00	

4.8 SCANNING ELECTRON MICROSCOPY-ENERGY DISPERSIVE X-RAYS (SEM-EDX) OF CONTROL SAMPLE

Fig. 4.23 shows the SEM picture of cement mortar (control sample) without fungi induction. The results of SEM EDX are shown in Fig. 4.24 and are also tabulated in Tables 4.7. The results show that oxygen and calcium are the main constituents of the mix with a 62% and 26%, respectively.

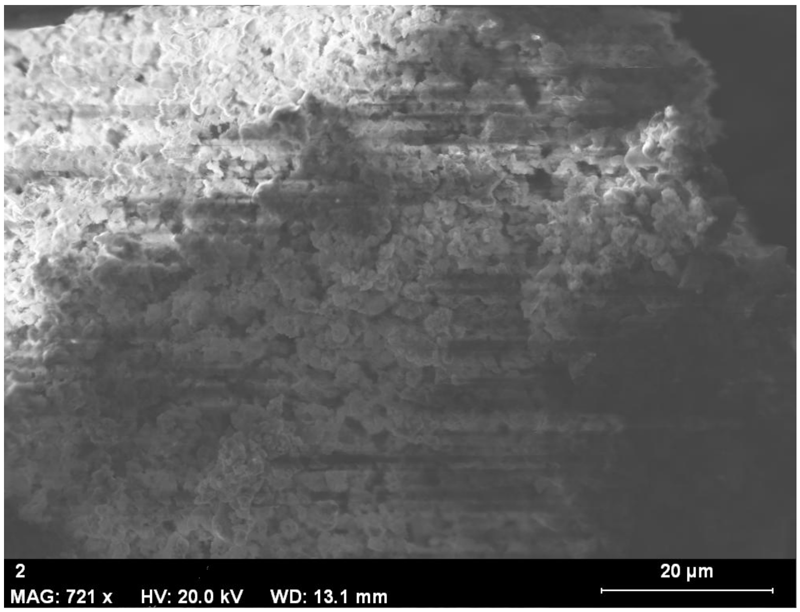

Fig 4.23 EDX of Control Sample of Cement Mortar

Table 4.7 EDX Result of Control Sample

Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]	Error [%]
Calcium	K-Series	18.91	25.98	13.45	0.
Silicon	K-series	3.32	4.57	3.38	0.2
Gold	M-series	2.31	3.17	0.33	0.1
Potassium	K-series	0.58	0.80	0.43	0.0
Iron	K-series	1.57	2.16	0.80	0.1
Magnesium	K-series	0.01	0.02	0.02	0.0
Aluminium	K-series	0.68	0.94	0.72	0.1
Sodium	K-series	0.00	0.00	0.00	0.0
Oxygen	K-series	45.38	62.36	80.87	4.8
	Total:	72.77	100.00	100.00	

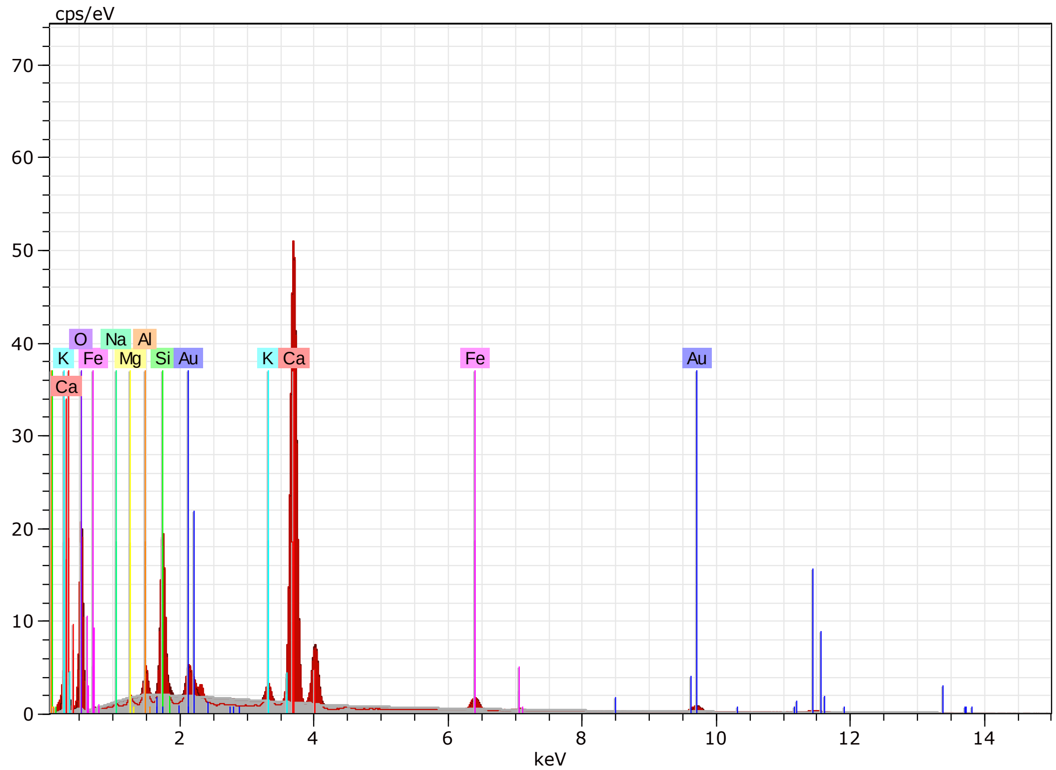

Fig 4.24 EDX of Control Sample of Cement Mortar

4.9 COMPARISON OF ELEMENT COMPOSITION OF CONTROL MIX OF CEMENT MORTAR AND MIX OF CEMENT MORTAR WITH FUNGI

The comparison of SEM-EDX of the control mix (without fungi) with the mixes induced with fungi, shows that the calcium %age in fungus # 21CMSTITNEY mix decreased by 35% as compared control mix, and with fungus # 31 CMPLTINEY mix it reduced by 80.17%. Silica is also a component which takes part in strengthening the mix. In this study it has seen that Silica increases 2.81 times as compared to control mix in case of #21 CMSTITNEY but in # 31 CMLPITNEY it reduced by 94.52%. Thus, it can be concluded that in order to use fungi as a binding material in the mix other mineral and chemical admixtures need to be added so that the workability and strength of the mortar mix can also increase.

CHAPTER 5
SALIENT OBSERVATIONS & CONCLUSIONS

5.1 GENERAL

This chapter highlights the salient observations of the research work carried out and also presents the major conclusions derived from the study.

5.2 SALIENT OBSERVATIONS

5.2.1 Effect of Rice Husk on the Fungi

1. Rice Husk, used as a nutrient, has made the growth of Fungi possible at higher percentages of replacement. From all types of mixes studied, it is observed that the mix with 50% replacement of sand with rice husk and 50% replacement of cement with Fly Ash was the best for the growth of the Fungi.
2. The growth of Fungi started within 7-10 days of incubation period with the Fungi #30 CZBAG, #21 CMSTITNEY, #31CMLPITNEY, #79 CMSTITNEY, # 31 CZBAG and #44 CMSTITNEY.
3. The best grown fungi with mortar mix are # 21 CMSTITNEY, # 31 CMLPITNEY and #44 CMSTITNEY.
4. The Fungi have made a Mycelial mat on the mortar mix. This shows that the growth of the fungi was very good with the rice husk in mortar mix.

5.2.2 Effect of Rice Husk on the mortar mix

1. Rice Husk was added in the cement mortar mix in the coarse form first, which lead to an increase in its volume. Subsequently rice husk was used in the powdered form.
2. Water absorption of the rice husk was considerably more. So during the use of rice husk it is very important to find out water absorption rate of rice husk on the Mortar Mix
3. The replacement of higher percentage of rice husk with sand reduced the compressive strength of the mortar mix.

4. Rice husk cannot be used to increase the compressive strength of the mortar mix. Even the cubes prepared were unable to take the shape. It reduced the compressive strength of the mortar mix .

5.3 SALIENT CONCLUSIONS

The major conclusions which can be drawn from the studies are enumerated below:

1. Rice Husk, used as a nutrient for fungi, is good for the growth inside the cement mortar matrix, at high percentage replacement levels of 50% only.
2. The presence of rice husk in the mix reduces the compressive strength of the mortar. Thus, it is imperative to look for another nutrient to be used for fungus growth.
3. The presence of fungus # 21 CMSTITNEY in the mix contains more calcium as compared to # 31 CMLPITNEY. Hence, the fungus # 21 CMSTITNEY can be more useful with a different nutrient in enhancing the strength of the mortar mix.
4. The mortar mixes containing high volumes of rice husk and fungi can be used as fill material where a later stage excavation has to be carried out. In other words the mixes infused with fungi and rice husk can be used as a controlled low strength material.

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