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A Study on Lime Stabilized Fly-ash and its Characteristics on Different Curing Temperature

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***Abstract*—Coal-based thermal power plants are India's primary source of electricity generation, accounting for 59 percent of all electricity generated. The ash concentration of Indian coal is found to be high, ranging from 30% to 50%. The amount of Fly Ash produced is determined by the coal quality utilized and the thermal power plant's operating conditions. The yearly production of Fly Ash in India is currently over 115 million tons. Such a large quantity poses difficult issues in terms of land utilization, health risks, and environmental pollution. Both in terms of disposal and use, extreme caution must be exercised to protect human life, wildlife, and the environment. Fly ash is divided into two categories: Class C and Class F. The major goal of the research is to see if class F fly ash, which contains as little as 1.4 percent CaO and has been treated with lime, can be used as a construction material in various civil engineering sectors.**

Fly ash is waste product of power plant often hazardous in nature, easily flammable, corrosive, and reactive, and so have negative environmental consequences. Fly ash particles with comparable diameters ranging from 0.5 to 300 microns have the ability to become airborne and contaminate the environment due to their light weight. Fly Ash discharge in the sea, rivers, and ponds, if not adequately handled, can also harm aquatic life. Mosquitoes and bacteria love to breed in slurry disposal lagoons and settling tanks. It can also contaminate underground water resources by containing traces of harmful metals.

It is recommended to strengthen and improve various qualities of fly ash by stabilizing it with a suitable stabilizer such as lime in order to popularize its use as a dominant construction material. The goal of this study is to determine the effectiveness of adding lime as a stabilizing agent to waste products like fly ash, as well as its acceptability for use as a building material for structural fills and embankment materials.

The above-mentioned geo-engineering features of fly ash, as well as the treated fly ash with various proportions of lime, will be evaluated in this study. There were two parts to the total testing were used to investigate the physical, chemical, and engineering features of the fly ash samples in the first phase. Fly ash will be blended with 1 %, 3 %, 5 %t, and 7 % lime as a percentage of dry weight of Fly ash in the second part of the test programmed. The samples will be cured for 10, 17, 35, and 65 days at temperatures ranging from 15°C to 30°C, 50°C, and 90°C, with compaction energy ranging from 595 kJ/m3 to 2483 kJ/m3 to determine the effect of curing temperature on lime stabilized fly-ash strength.

***Index Terms*— Compaction energy, Flyash, Lime-treated compound material, Compression testing of lime-treated sample.**

I.INTRODUCTION

Fly ash is a waste material produced by thermal power stations when coal is burned. This fine residue from burned coal is conveyed in the flue gas, separated by electrostatic precipitators, and collected in a hopper field. Fly ash is the term for the collected residue, which is classified as an industrial waste that can be utilized in the construction business. One of the most common industrial wastes utilized as a construction material is fly ash. Fly ash can be disposed of in two ways dry or wet, in which it is mixed with water and deposited as a slurry into ash ponds. One of the most significant difficulties facing India's manufacturing industries is the disposal of residual garbage.

Coal is utilized as a primary fuel in thermal power plants and other sectors in many nations, including India. Each year, four countries, China, India, Poland, and the United States, create more than 270 million tons of fly ash, yet only about half of it is utilized. India's coal reserves are estimated to be at 200 billion tons, and its yearly production is around 250 million tons. In contrast to affluent countries, the ash content of coal utilized for electricity generation in India is around 30-40%. During 2010-11, ash production climbed to almost 131 million tons, and this trend is projected to continue.

Coal-based thermal power plants are India's primary source of electricity generation, accounting for roughly 57 percent of overall power generation. The ash concentration of Indian coal is found to be high, ranging from 30% to 50%. The amount of Fly Ash produced is determined by the coal quality utilized and the thermal power plant's operating conditions. The yearly production of Fly Ash in India is currently over 112 million tons, with ash ponds occupying 65000 acres of land, and is expected to reach 225 million tons. Such a large amount of material poses difficult issues in terms of land utilization, health risks, and environmental hazards. Extreme caution must be exercised both in disposal and in utilization.

Human life, wild life, and the environment must all be protected. When pulverised coal is burned to generate heat, the resulting residue contains 80% Fly Ash and 20% bottom ash.

Fly Ash: Overview

It is a very fine powdery particle that is recovered from the gases produced when coal is burned to generate energy in thermal power plants. Silica, alumina, and iron make up the majority of these micron-sized earth elements. When fly ash is combined with lime and water, it forms a cementitious compound with characteristics that are remarkably similar to Portland cement. Fly ash may be utilized as a great alternative for a portion of cement in concrete because of their similar qualities, which provides quality benefits. The concrete made with flyash is denser, resulting in a tighter, smoother surface with less bleeding. With expert textural uniformity and greater detail, fly ash concrete gives an amazing architectural benefit. Coal ash, Pulverized Flue ash, and Pozzolana are some of the other names for Fly Ash.

Impact of Fly Ash on Environment

A large volume of Fly Ash produced by coal-fired thermal power plants could pose a number of environmental issues. These waste products are often hazardous in nature, easily flammable, corrosive, and reactive, and so have negative environmental consequences. Fly ash particles with comparable diameters ranging from 0.5 to 300 microns have the ability to become airborne and contaminate the environment due to their light weight. Fly Ash discharge in the sea, rivers, and ponds, if not adequately handled, can also harm aquatic life. Slurry disposal lagoons/settling tanks can create mosquito and bacterium breeding grounds. With concentrations of harmful metals present in Fly Ash, it can also damage underground water resources. Large sums of money are spent simply to remove Fly Ash from thermal power plants and put it in ponds. It can be a valuable resource material if properly recognized and managed.

Lime: An Overview

Lime, or CaO or Ca(OH)2, is one of the oldest established construction materials. It is a by-product of burned lime stone (CaCO3) and is one of the oldest urbanized construction materials. It has been used by humans for for 2000 years. For the construction of roads, the Romans utilized soil-lime combinations. However, before 1945, its application in modern geotechnical engineering remained limited, owing to a lack of understanding of the issue Lime is now widely utilized to stabilize soils or waste materials in a variety of constructions, including highways, slope protection, embankments, railways, airports, foundation base, canal lining, and so on. This is mostly owing to the ease of building, as well as the technology's simplicity, and the fact that it is a very inexpensive construction material, which appeals to engineers. Several studies have been published that demonstrate the beneficial effects of lime in increasing the performance of waste materials.

Strength Characteristic of Flyash

It is recommended to strengthen and improve various qualities of fly ash by stabilizing it with a suitable method such as lime in order to popularize its use as a construction material. The goal of this study is to determine the effectiveness of adding lime as a stabilizing agent to waste products like fly ash, as well as its acceptability for use as a building material for structural fills and embankment materials. The fly ash used in this project was gathered from the NTPC sipat thermal power plant. Consistency qualities, compaction properties, strength parameters, and settling properties are the most significant properties to assess when evaluating the feasibility of any building material for various geotechnical engineering projects. The above-mentioned geo-engineering features of fly ash, as well as the treated fly ash with various proportions of lime, were evaluated in this project.

II.METHODOLOGY

It is a major challenge for thermal power plants to dispose a large amount of fly ash produced. It can be done by using flyash in construction such as highway, landfills, road base and so on. Construction work in the civil engineering field is cost-effective and efficient method to unitize the waste materials like flyash in very large scale. In order to convert garbage into a safe constructional material. It is necessary to improve the physical properties of lime-treated flyashin order to increase its use as a construction material. There are many different laboratory experiments needs be done to find out the best sample. In the laboratory lime stabilized samples are tested in the different parameters to find out the maximum strength and other physical properties. A series of compression tests were used to determine the effect of curing temperature on the strength of the lime-treated samples by the consideration of the curing period.

Determination of Compressive Strength

The Unconfined compressive strength test is the most popular tests used to investigate the strength characteristics of samples created in laboratory. Lime-treated fly ash specimens were compacted to respective energies ranging from 593 to 2483 kj/m^3(IS: 2700). The cylindrical test specimens, with 40 mm diameter and 80 mm tall, were tested until the sample failed. The samples were cured at temperature of 15°C, 30°C, 50°C, and 90°C for 10, 17, 35, and 65 days before testing to see how curing temperature and curing period affected the strength qualities of the samples.

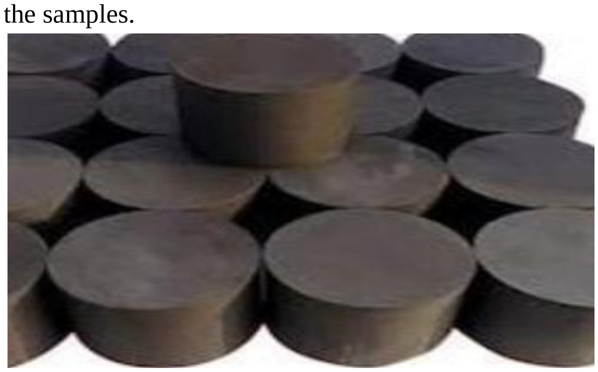


Fig. No. - 1Line-treated sample

Fig. No.- 2 UCS Testing machine

The laboratory experiments give the following data as the failure stress and related failure strain at different temperature15°C, 30°C, 50°C, and 90°C with respect to curing period (10, 17, 35 and 65 days) by the percentage of lime added to the specimen.

Table 1: Unconfined compressive strength of lime-fly ash samplewith compaction energy 595 kJ/m^3 and curing temperature at 15°C.

Lime content (%)	Immediate		10days		17 days		35 days		65 days	
	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)
	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %
1	187	2.85	195	3.1	217	3.1	243	2.7	287	3.35
3	270	2.8	322	2.8	346	2.4	435	2.2	456	1.88
5	322	2.85	461	2.8	465	2.6	545	2.1	686	2.3
7	346	3.2	502	2.48	617	2.7	1085	2.4	1656	2.4

Table 2: Unconfined compressive strength of lime-fly ash samplewith compaction energy 2483kJ/m^{3}and curing temperature at 15°C.

Lime content (%)	Immediate		10days		17 days		35 days		65 days	
	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)
	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %
1	378	3.8	387	3.3	405.4	3.8	521.4	3.1	555.3	3.35
3	576	3.8	666	2.95	710.8	3.1	850.8	2.45	899.7	2.87
5	635	4.1	676	3.1	980.7	3.95	1111	2.58	1191	2.4
7	611	3.8	929	2.8	1161	3.9	1890	3.1	2088	2.2

Table 3: Unconfined compressive strength of lime-fly ash samplewith compaction energy 595 kJ/m^{3}ant its curing temperature at 30°C.

Lime content (%)	Immediate		10days		17 days		35 days		65 days	
	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)
	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %
1	211	2.85	221	2.6	246	2.8	285	3.2	325	3.1
3	311	2.65	366	2.35	391	2.2	466	2.35	476	2.85
5	336	2.85	486	2.2	546	2.2	560	2.85	685	3.1
7	345	3.05	810	2.15	1105	2.3	1160	2.55	1681	3.15

Table 4: Unconfined compressive strength of lime-fly ash samplewith compaction energy 2483 kJ/m^3 andcuring temperature at 30°C.

Lime content (%)	Immediate		10days		17 days		35 days		65 days	
	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)
	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %
1	411	3.45	436	3.2	435	3.9	589	3.85	595	3.2
3	580	3.56	711	2.85	795	3.4	857	3.45	886	2.8
5	685	3.8	895	2.85	995	2.8	1198	3.85	1286	2.8
7	700	3.9	###	3.45	1598	2.2	1956	3.2	2246	3.15

Table 5: Unconfined compressive strength of lime-fly ash samplewith compaction energy 595 kJ/m^{3}and curing temperature at 50°C.

Lime content (%)	Immediate		10days		17 days		35 days		65 days	
	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)
	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %
1	205	2.85	215	2.65	235	2.8	310	2.8	326	3.2
3	315	2.85	381	2.45	386	2.1	483	2.45	512	2.85
5	346	2.85	487	2.1	511	2.4	615	3.2	695	3.2
7	350	3.15	951	2.15	1103	2.2	1184	2.8	1793	2.65

Table 6: Unconfined compressive strength of lime-fly ash sample with compaction energy 2483 kJ/m^3 and curing temperature at 50°C.

Lime content (%)	Immediate		10days		17 days		35 days		65 days	
	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)
	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %
1	413	3.85	426	3.1	425	3.9	570	3.85	589	3.45
3	590	3.85	715	2.85	798	3.6	857	3.85	896	3.2
5	655	3.85	865	2.85	1018	3.1	1259	4.2	1945	3.35
7	702	4.25	1099	2.9	2645	2.9	3103	2.4	3346	2.65

Table 7: Unconfined compressive strength of lime-fly ash samplewith compaction energy 595 kJ/m^3 energy and curing temperatureat 90°C.

Lime content (%)	Immediate		10days		17 days		35 days		65 days	
	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)
	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %
1	213	2.85	261	2.85	355	2.9	365	3.1	365	3.35
3	315	2.85	370	2.85	396	2.1	476	2.45	470	2.65
5	355	2.85	645	1.85	684	2.1	710	1.85	745	2.1
7	346	3.15	2113	2.65	2159	2	2246	2	2345	2.65

Table 8: Unconfined compressive strength of lime-fly ash sample with compaction energy 2483 kJ/m^3 and curing temperature at 90°C.

Lime content (%)	Immediate		10days		17 days		35 days		65 days	
	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)	(σ)	(ε)
	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %	in kPa	in %
1	414	3.8	645	2.85	546	3.1	611	3.1	645	2.85
3	565	3.8	710	2.85	846	3.5	896	3.35	925	2.55
5	683	3.8	1202	1.85	1425	3.2	1543	3.2	1946	3.55
7	702	3.65	3846	1.65	4412	2	4695	2.9	5013	2.15

III RESULTS

In this era, we need more power to run our industries, machines, vehicles and other needful equipment. These machines are powered by the power plants. Power produced by coal burning that consists of extremely fine particles that rise with the flue gases. This material solidifies while suspended in the exhaust or before reaching to chimney and is caught by electrostatics precipitators or other particle filtration equipment. Fly ash is made up of inorganic particles that has been together during coal combustion. Traditional laboratory experiments are performed on compacted fly ash mixed with different percentage of lime to calculate the unconfined compressive strength of the samples. In this portion the test findings are given and discussed.

Table 9: Unconfined compressive strength of lime-fly ash samplewith compaction energy 595 kJ/m^3 and curing temperature at 15°C.

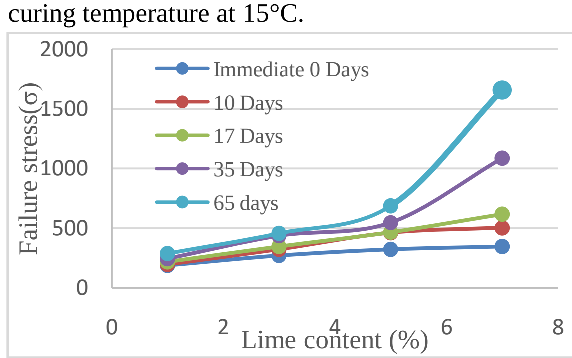


Table 10: Unconfined compressive strength of lime-fly ash samplewith compaction energy 2483kJ/m^{3}and curing temperature at 15°C.

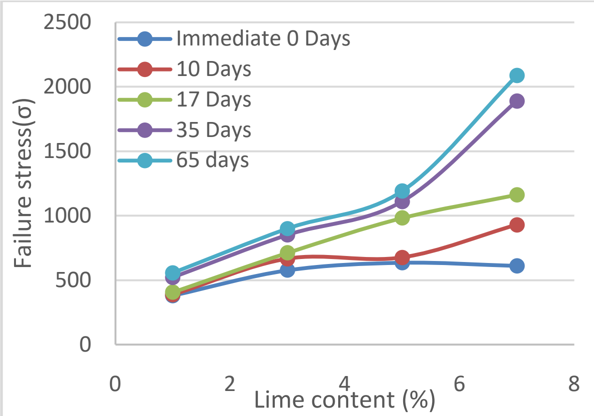


Table 11: Unconfined compressive strength of lime-fly ash samplewith compaction energy 595 kJ/m^{3}ant its curing temperature at 30°C.

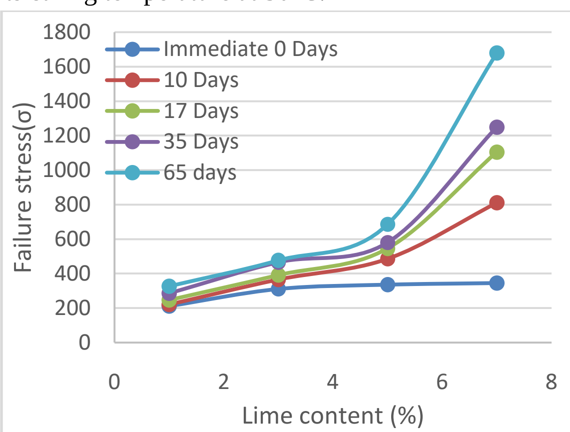


Table 12: Unconfined compressive strength of lime-fly ash samplewith compaction energy 2483 kJ/m^3 andcuring temperature at 30°C.

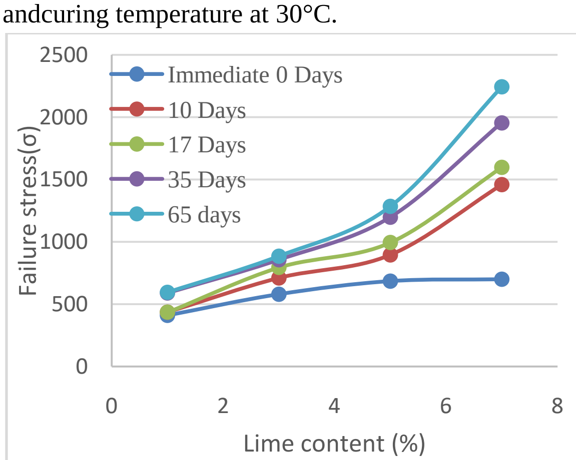


Table 13: Unconfined compressive strength of lime-fly ash samplewith compaction energy 595 kJ/m^{3}and curing temperature at 50°C.

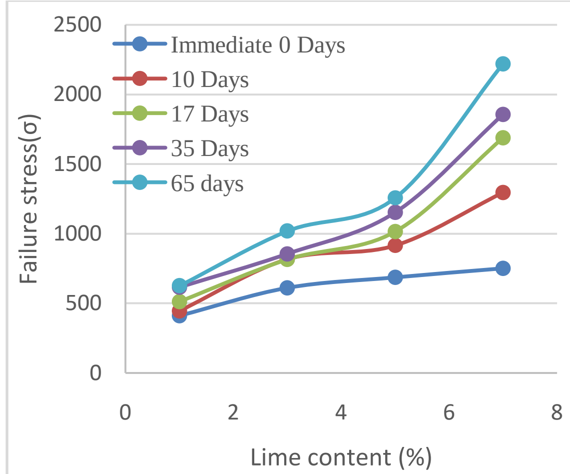


Table 14: Unconfined compressive strength of lime-fly ash sample with compaction energy 2483 kJ/m^3 and curing temperature at 50°C.

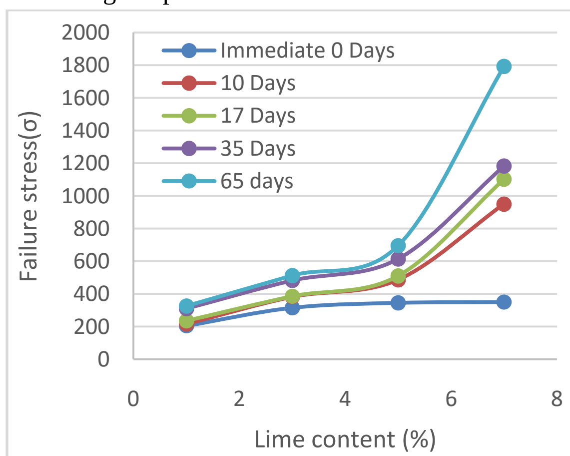


Table15: Unconfined compressive strength of lime-fly ash samplewith compaction energy 595 kJ/m^3 energy and curing temperatureat 90°C.

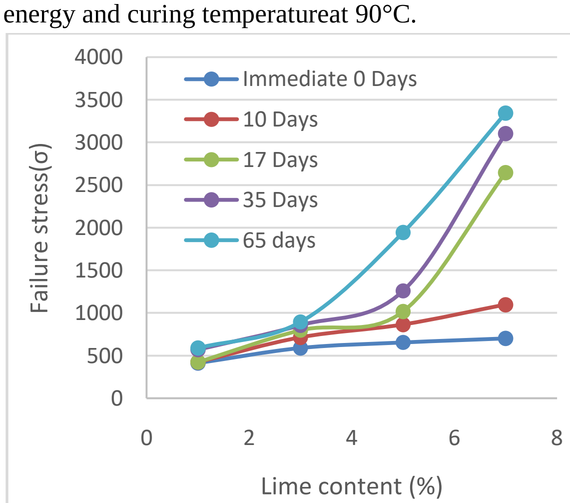
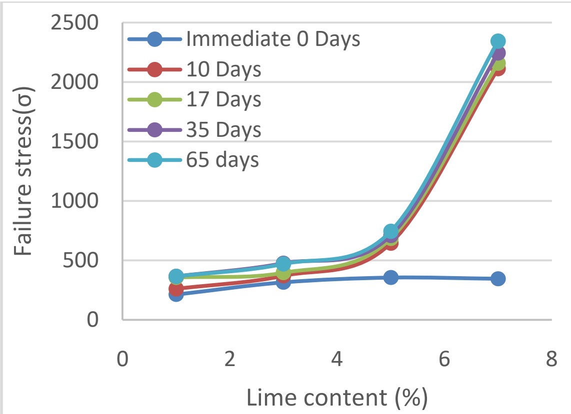


Table 16: Unconfined compressive strength of lime-fly ash sample with compaction energy 2483 kJ/m^3 and curing temperature at 90°C.



It is observed in the above graphs that the failure stresses of lime-treated samples compacted with higher compaction energies, are produced higher values as compare then the samples which are compacted with lower energies. With the increasing of curing period of lime-treated fly ash samples are performed good with the increasing of curing temperature.It is also observed that the strength improvement is negligible with the smaller percentage of lime 1% - 3%, even if it is cured for long period.

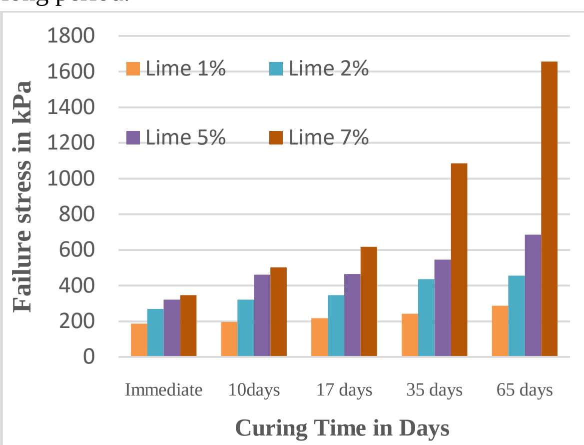


Fig. No.3: Curing period changes with unconfined compressive strength graphcreated at compaction energy 595kJ/m^3 and cured at 15°C.

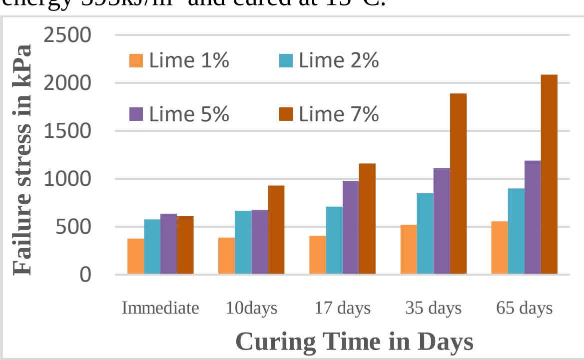


Fig. No. - 4 Curing period changes with unconfined compressive strength graph created at compaction energy 2483kJ/m^3 and cured at 15°C.

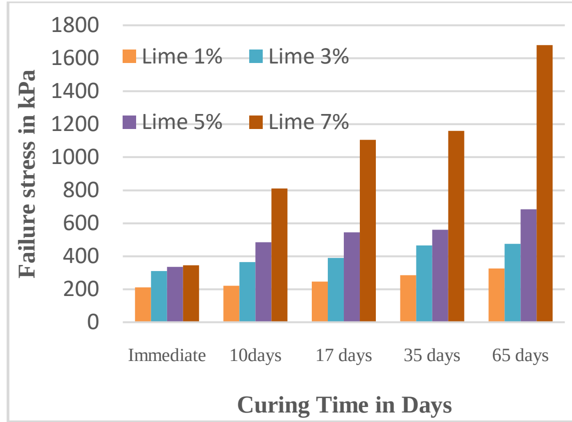


Fig. No. – 5 Curing period changes with unconfined compressive strength graph createdwith compaction energy 595kJ/m^3 and cured at 30°C.

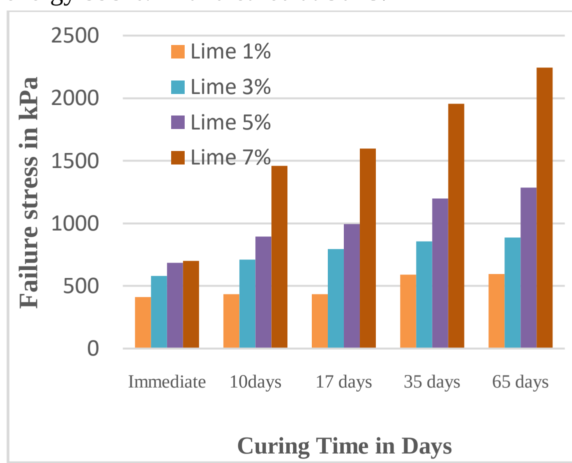


Fig. Np. -6: Curing period changes with unconfined compressive strength graph created at compaction energy 2483kJ/m^3 and cured at 30°C.

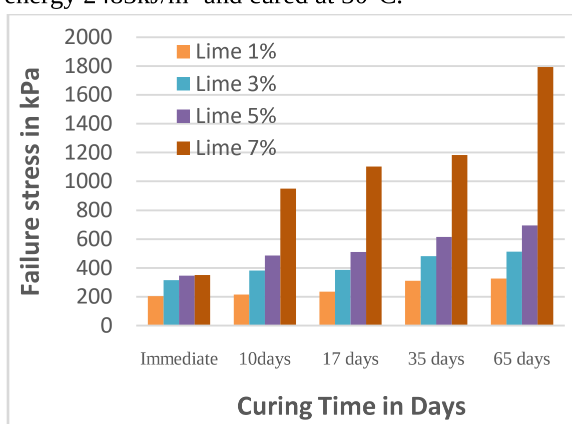


Fig. Np. 7: Curing period changes with unconfined compressive strength graph created at compaction energy 595kJ/m3 and cured at 50°C.

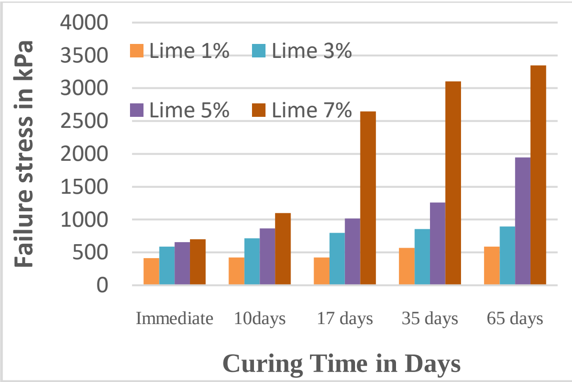


Fig. No. 8: Curing period changes with unconfined compressive strength graph created at compaction energy 2483kJ/m^3 and cured at 50°C.

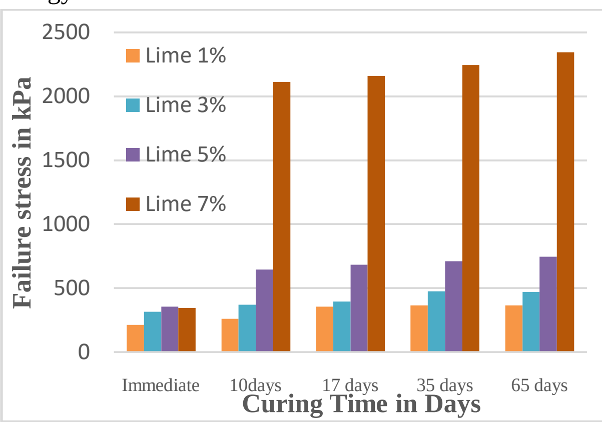


Fig. No. 9: Curing period changes with unconfined compressive strength graph created at compaction energy 595kJ/m3 and cured at 90°C.

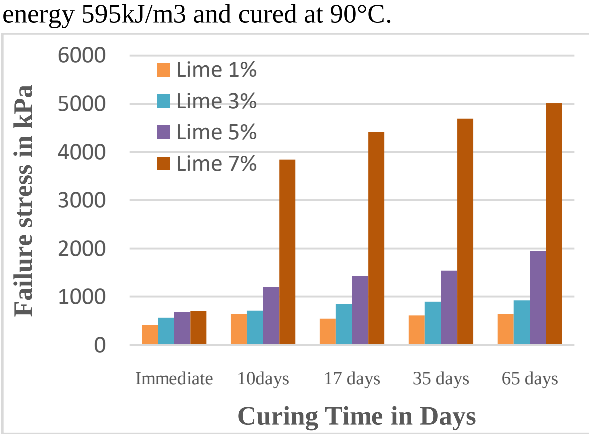


Fig. No. 10: Curing period change with unconfined compressive strength graph created at compaction energy 2483kJ/m^3 and cured at 90°C.

The above graphs are representing the failure stresses are increases with the compaction energy and the curing temperature plays a major role with respect to the longer curing period.

VII. CONCLUSION

The experimental study on the lime-treated flyash to determine the strength of the different samples. Strength of samples is depended on the percentage of lime content, curing temperature and curing period are observed. The main results are based on the experimental study. The flyashis available in the powdered form with fine sand to silt size.

The compaction energy is increased from 595 kJ/m^3 to 2483 kJ/m^3 and the OMC reduced from 39 to 34%. Is shows that the compaction energy impacts a negative effect on the sample.

Lime-treated samples have higher failure stresses if it is compacted with higher compaction energies similarly for lower compaction energies produced lower failure stresses.

Lime content from 0 to 1%, the value of UCS changes from 186.67tp286.76 kPa, shows that the increased value of strength of the sample is very small. It is also observed that the strength of the sample is not improved even when cured for a long period (65 days).

The value of UCS and CBR of samples treated with lime improved when the curing duration is increased. It is also observed that the strength improvement is depends on the percentage of lime added with the flyash and curing period. Strength of the samples are increased and it is proportional to the curing temperature.

Lime content low percentages takes low curing duration. Results shows that higher curing temperatures and longer curing period improved the strength of the samples. It is suggested that the higher percentages of lime required higher curing period.

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