BEHAVIOUR OF LIME STABILIZED REINFORCED FLYASH UNDER UNIAXIAL LOADING

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Civil Engineering

By

SOUBHAGYA RANJAN MOHANTY

ANIL MEENA

Department of Civil Engineering

National Institute of Technology

Rourkela

2007

BEHAVIOUR OF LIME STABILIZED REINFORCED FLYASH UNDER UNIAXIAL LOADING

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Civil Engineering

By

SOUBHAGYA RANJAN MOHANTY
ANIL MEENA

Under the Guidance of

Dr. S.P. Singh

Department of Civil Engineering
National Institute of Technology
Rourkela

2007

National Institute of Technology
Rourkela

CERTIFICATE

This is to certify that the thesis entitled, "BEHAVIOUR OF LIME STABILIZED REINFORCED FLYASH UNDER UNIAXIAL LOADING" submitted by Sri Soubhagya Ranjan Mohanty and Anil Meena in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Civil Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date

Dr. S.P. Singh
Dept. of Civil Engineering
National Institute of Technology
Rourkela - 769008

National Institute of Technology

Rourkela

ACKNOWLEDGEMENT

We would like to articulate our deep gratitude to my project guide Dr. S.P. Singh for providing us an opportunity to work under his supervision and guidance. He has always been our motivation for carrying out the project.

We express our deep appreciation and sincere thanks to Dr. K.C. Patra, professor and Head of the Civil Engineering Department for providing all kinds of possible help and encouragement during our thesis work.

An assemblage of this nature could never have been attempted without reference to and inspiration from the works of others whose details are mentioned in reference section. I acknowledge my indebtedness to all of them.

Last but not the least to all of my friends who were patiently extended all sorts of help for accomplishing this undertaking.

Date

Soubhagya Ranjan Mohanty

Anil Meena

Dept. of Civil Engineering

National Institute of Technology

Rourkela - 769008

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

LIST OF PHOTOGRAPHS

CHAPTER 1

INTRODUCTION

INTRODUCTION

The use of reinforcement in improving the strength parameters of geomaterials has taken momentum due to the availability of variety of synthetic materials commercially at cheaper rates. The basic principles involved in earth reinforcement techniques are simple and have been used by mankind for centuries.

One of the essential characteristics of reinforced soil is that it is made with two types of elements, soil grains and reinforcements. The basic mechanism of reinforced earth involves the generation of frictional forces between the soil and reinforcement. By means of friction the soil transfers the forces developed in earth mass to the reinforcement thus developing tension. The earth develops pseudo cohesion in the direction in which reinforcement is placed and the cohesion is proportional to tension developed in reinforcement.

Flyash ,which is a coal combustion by-product, has the potential to become one of the major disposal problem or one of the major alternate construction material solution of the next decade.Flyash which can be used for soil improvements has gained tremendous impetus during the last two decades. Initial uses of flyash, stabilized with lime, as a highway sub grade dates back to the late 1950s and early 1960s (Davidson & Handy 1960;Snyder and Nelson 1962).In1970s the variety of flyash applications increased(Copp & Spencer 1970 Joshi etal 1975), and applications enveloping cement stabilized flyash were introduced.

However, the present scenario of the utilization of flyash in India is grim. About 8% of the produced flyash is being used commercaily.This shows that there exists a tremendous potential of utilization of flyash in geotechnical constructions in order to preserve the valuable top soil.

Geotechnical constructions like embankments, retaining structures,etc require huge amount of earth materials. Rapid industrialization and non availability of conventional earth material have forced the engineers and scientist to utilize the waste product of industries which either degrade the environmental pose problems for their disposal. In this connection utilization of by- products like flyash needs special attention.Flyash is a byproduct of a coal fired thermal power plants and contains particles of fine sand to silt sizes. For the design of cement stabilized reinforced flyash structures, a proper understanding of the interaction between reinforcement materials and stabilized flyash is necessary.

Some research work has been carried out to find the suitability of compacted flyash in geotechnical construction like embankments, retaining walls, structural fills,etc However, these structures are to be protected from getting wet in order to preserve the inherent strength of the compacted flyash,which is difficult task in field situations. Keeping this in view the flyash sample has been stabilized with cement and to modify the stress-strain behaviour of destabilized material, fiber reinforcement in the form of recron were used. The effect of cement as well as fiber reinforcement on the stress-strain behavior, strength parameters of compacted mixes has been evaluated through a series of unconfined compression tests with confining pressures varying from 0 to 3 N\mm^2 The test results show that the inclusion of fiber reinforcement are very efficient in increasing the failure load. The stabilized flyash has distinct advantages as there is a little loss of strength due to wetting. Hence, it can be used in large scale geo-technical construction like base and sub-base courses of roads, airport pavements, retaining walls, and embankments, structural land fills in conjunction with suitable reinforcements.

CHAPTER 2

LITERATURE REVIEW

LITERATURE REVIEW

INTRODUCTION

Flyash is a waste product of coal combination in thermal power plants. It posses problem for safe disposal and cause economic loss to the power plants. Thus utilization of flyash in large-scale geotechnical constructions as a replacement to conventional earth material needs special attention. The inherent strength of flyash can be improved either by stabilizing the material with cement, lime etc. and by reinforcing the same.

Reinforced earth is a composite material, which is a combination of soil and reinforcement, suitably placed to withstand the developed tensile stresses and also it improves the resistance of the soil in the direction of the greatest stress. The essential features of reinforced earth are the friction between the earth and reinforcement, by means of friction the soil transfer to the reinforcement the forces built in the earth mass. The reinforcement thus develops tension when the earth mass is subjected to shear stresses along the reinforcement.

REINFORCED EARTH

Early Practices:

Soil specially cohesion less material like gravel, sand and coarse silt cannot take even low stress in tension and fails instantaneously. The early man has known this phenomenon from intuition. Men used woven reeds in making sun dried bricks in ancient times even prior to Christian era. Fibrous materials like vines and papyrus are used in earth structures and mud walls in Egypt and Babylon. In the construction of the Great Wall of China where are used extensively, branches of trees were used as reinforcement in the construction of Agar-Quif ziggurat near Baghdad. Romans who developed a high degree of engineering skills in construction to meet the civic needs and military requirements built reed reinforced earth leaves along the river Tiber. Wharf walls in England also were constructed by Romans using wooden scantling as earth reinforcement. In the last century Col. Palsey introduced reinforced earth for military construction in British army. The Dutch used reinforced earth by faggoting for sea protective works.

Modern Development:

The modern approach to reinforced earth techniques was first introduced in France and USA. In 1925, the concept was first introduced by Monster. The structure built was retaining wall with reinforced earth, wood was used as reinforcement. In the early fifties, the French constructed retaining walls constructed of granular fill with membrane. This cladding membrane was anchored with flexible ties. The first major work on reinforced earth was introduced in large scale from 1964 onwards both in USA and Europe and this was followed by detailed experimental and theoretical investigation to study the mechanism of the reinforced earth in France. This programmed was introduced by Henry Vidal and François Schlosser and the scientific approach to the study of reinforced earth structures can be said to have opened up since then.

However steel was used as reinforcement in the form of stripes which when exposed to aggressive environment like humidity, access to oxygen and exposure to corrosive agents rusts rapidly. But with the introduction of such man made fibers like nylon, propylene and other forms of organic stable polymers which can withstand ultra-violet light rays and resistant to acid in industrial applications, the deficiency suffered by steel has greatly been overcome. With the introduction of such man made fibers which are found to be superior to natural fibers and steel it is now feasible to build reinforced earth structure even in soil and environment aggressive to steel reinforcement.

PRINCIPLES OF REINFORCED EARTH:

Soil mass is generally a discrete system consisting of soil grains and is unable to withstand tensile stresses and this is particularly true in the case of cohesion less soil like sand. Such soils cannot be stable on steep slopes and relatively large strains will be caused when external loads are imposed on them. Reinforced earth is a composite material, a combination of soil and reinforcement suitably placed to withstand the development of tensile stresses and also to improve the resistance of soil in the direction of greatest stress. The presence of reinforcement modifies the stress filed giving a restraint mostly in the form of friction or adhesion so that less strains are induced and tension is avoided. Inclusions like discrete shot fibers placed random or in different layers will also impart additional resistance by way of cohesion and friction, but these are not included in the Vidal's concept of reinforced earth.

EFFECT OF REINFORCEMENT ON SOIL:

Force transfer From Soil to Reinforcement:

Fig. 2.1 shows cohesion less soil mass reinforced by a flat strip. The force at the two ends of the strip is not same when there is transference of force by friction to the soil mass (Vidal, 1969). If the average cortical stress in the soil is σ_v in the region, the difference between the forces at the ends of a reinforcing element AB of length 'dl' is given by

$$dP= \sigma_v . 2w. dl. \tan \Phi_u \qquad (2.1)$$

where, 'w' is the width of the reinforcement and is Φ_u the angle of friction between the reinforcement and the soil.

Therefore if we consider a soil mass with spacing at a spacing of 'Δh' and 'Δv' as shown in the Fig. 2.2 the effect of this reinforcement on the soil mass will be to restraint by imposing an additional stress of

$$\Delta\sigma_3 = \Delta h\ (dp/\Delta v) \qquad (2.2)$$

In the horizontal direction on face AD over that prevailling on face BC.

This restraint on the soil mass increases the resistance of the soil to failure under applied stresses and the result interpreted in two related ways.

Equivalent Confining Stress Concept:

Fig 2.3 (a) shows the comparision of of failure stresses on two soils, one unreinforced and the other reinforced. The increase in the deviator stress is seen to be $\Delta\sigma_3$ times Kp, where Kp is the coefficient of passive earth pressure equal to $\tan^2 (45 + \Phi/2)$ and $\Delta\sigma_3$ is the equivalent confining stress on sand imposed by the reinforcement (Yang, 1972).

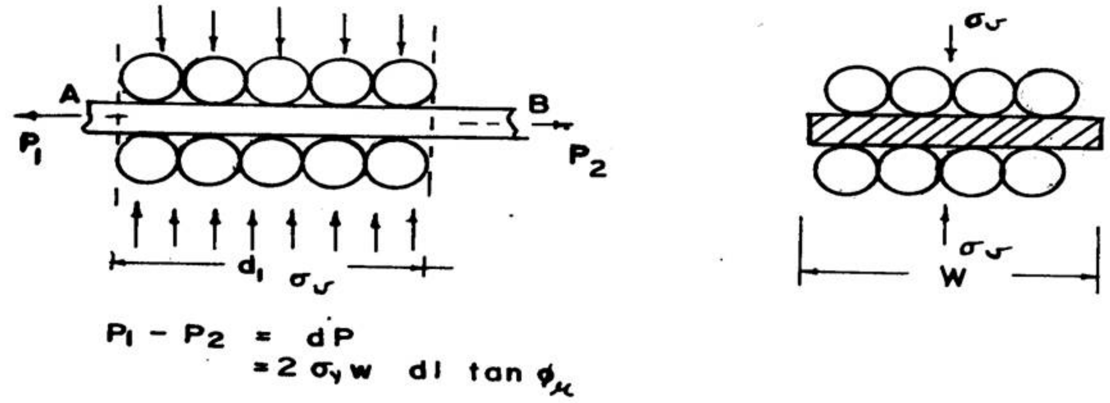


Fig. 2.1: STRESS TRANSFER BY SOIL REINFORCEMENT

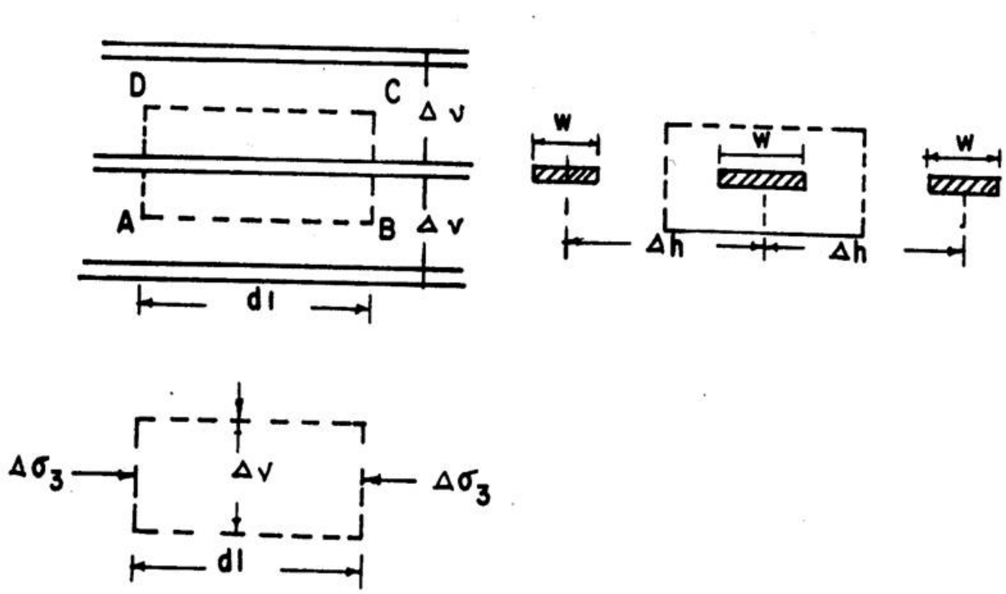


Fig 2.2: CONFINING STRESS ON SOIL BY REINFORCEMENT

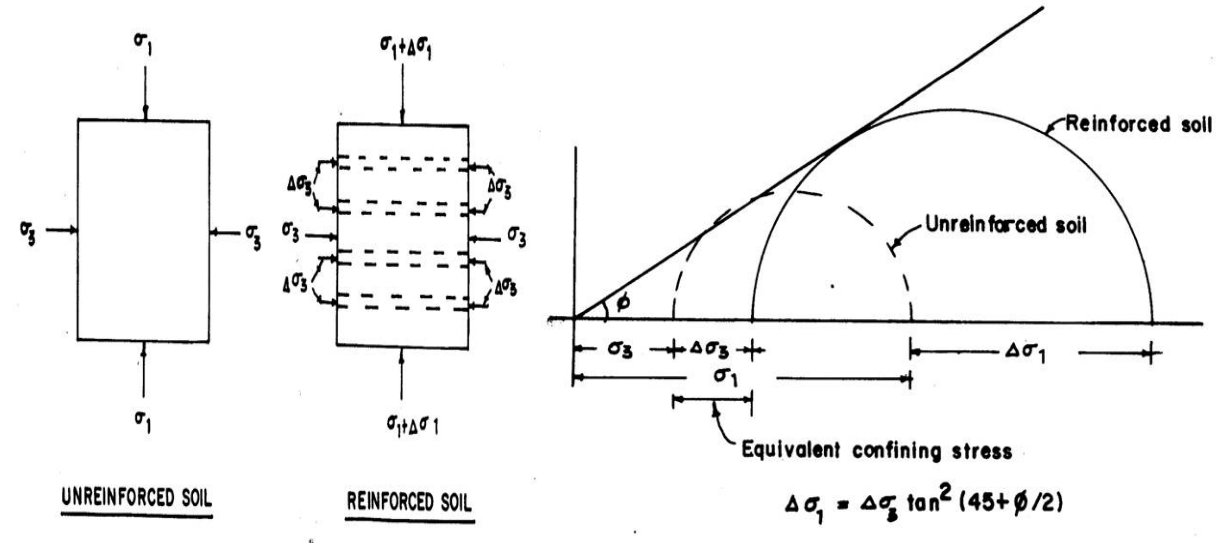


Fig 2.3 (a) : EQUIVALENT CONFINING STRESS CONCEPT

Pseudo – Cohesion Concept:

This concept (Schlosser and Long, 1974) proposes that the reinforcement induces an anisotropic or pseudo-cohesion to the soil which depends on the spacing and strength of the reinforcement. Fig. 2.3 (b) shows the approach. The increase in deviator stress at failure is

$\Delta\sigma_1 = 2c \tan (45 + \Phi/2)$……………………………………………………....(2.3)

where 'c' is the pseudo-cohesion induced in the soil and Φ is the angle of friction. Both the equivalent confining stress concept and the pseudo-cohesion concept are linked to the stress induced in the reinforcement. If α_f is the force in the reinforcement per unit width of the soil mass and Δv is the vertical spacing.

$\alpha_f /\Delta v$ is the eqivalent confining pressure $\Delta\sigma_3$

and $\Delta\sigma_1 = (\alpha_f /\Delta v) \tan^2 (45 + \Phi/2)$

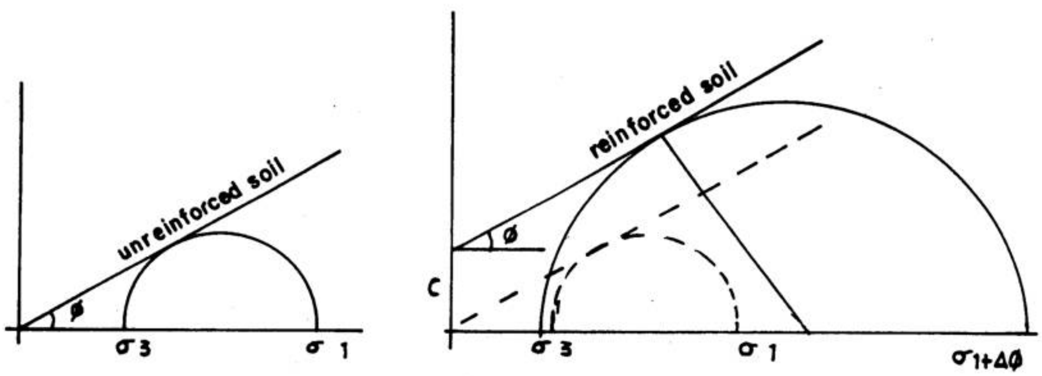
or $\Delta\sigma_1 = 2c \tan (45 + \Phi/2)$ which yields

$c= (\alpha_f /2\Delta v) \tan (45 + \Phi/2)$………………………………………………………...(2.4)

The value of α_f is equal to the tensile strength of the reinforcement, if the reinforcement fails by breakage or the maximum force transferred by the friction between the soil and reinforcement pulls off.

In the above concept outlined, it is necessary that the reinforcement layer must be close enough so that there is effective transfer of stress by friction or adhesion as the case may be and hence the granular soils of high relative density are particularly suitable for use in reinforced earth.

The concept outlined above can also hold good for cohesive soils to a very limited extent only since the adhesion of the clay to the reinforcement is small and its effect on reinforcement is small and its effect on restraint doesn't have a multiplying effect as in granular materials. Fig 2.4 shows the increase in strength at failure of an untrained clay sample with reinforcement.



$$\sigma_1 = \sigma_3 \tan(45+\phi/2)$$

$$(\sigma_1+\Delta\sigma_1) = \sigma_3 \tan^2(45+\phi/2)+2C\tan(45+\phi/2)$$

$$\Delta\sigma_1 = 2C\tan(45+\phi/2)$$

Fig 2.3 (b) PSEUDO – COHESION CONCEPT IN COHSIONLESS SOILS

REINFORCING MATERIALS:

General:

A number of materials have been reported to be successfully used as reinforcements such as steels, geofabrics, geogrids, aluminum, glass fiber, wood, rubber and concrete. In developed countries polypropylene based synthetic fibers and grids are now preferred due to their available with desired properties and durability. The durability of reinforcing materials is shown in Table 2.1. However, they are yet to be used widely in India as they are more costly. The reinforcement may take the form of strips, grids, sheet materials, rope and other combinations. The major requirements of the reinforcing materials are strength, durability, ease of handling, high adhesion or friction with soil and availability at low-cost.

The man made polymers are highly restraint to bacteria, alkalis and acid. Degradation characteristics of polymers are indicated in Table 2.2. Polyamides have a very good mechanical characteristics including excellent resistance to abrasion and absolute imperviousness to rotting. It can withstand high temperature without its performance being affected. However, their performance deteriorates on wetting.

Table 2.1: Durability of Reinforcing Materials

Reinforcing Materials	PH value		Maximum chloride ion content	Maximum total Sulphate (SO_3)	Maximum resistivity (ohm/cm)
	Min.	Max.			
Aluminum	**6**	**8**	**0.05**	**0.5**	**3000**
Copper	**5**	**9**	**0.05**	**0.5**	**2000**
Galvanized steel	**6**	**9**	**0.05**	**0.5**	**5000**
Stainless steel	**5**	**10**	**0.05**	**0.5**	**3000**
Geotextiles	-	-	-	-	-
Geogrid	-	-	-	-	-

Polyesters have very good resistance to abrasion and its behaviour in water is satisfactory. It has high modulus of elasticity and has only negligible creep. It can also withstand considerable temperature increase.

Polypropylene Is also rot-proof, water and most chemical reagents do not affect its performance. It has only fair resistance to abrasion and is affected by temperature increase. It has only a tendency to creep. However, a majority of geofabrics is manufactured from polypropylene.

For use as a reinforcing material, the geofabrics should possess a high modulus elasticity, low elongation and satisfactory puncture strength. For use as an asphalted overlay material, adsorption qualities may also be essential.

Table 2.2 Degradation Resistance of Various Synthetic Fibers

Resistance to Attack by	Type of Synthetics				
	Polyester	Polyamide	Polyethylene	Polypropylene	PVC
Fungus	**Poor**	**Good**	**Excellent**	**Good**	**Good**
Insects	**Fair**	**Fair**	**Excellent**	**Fair**	**Good**
Vermin	**Fair**	**Fair**	**Excellent**	**Fair**	**Good**
Mineral	**Good**	**Fair**	**Excellent**	**Excellent**	**Good**
Alkalis	**Fair**	**Good**	**Excellent**	**Excellent**	**Good**
Dry heat	**Good**	**Fair**	**Fair**	**Fair**	**Good**
Moist heat	**Fair**	**Good**	**Fair**	**Fair**	**Fair**
Oxidizing agent	**Good**	**Fair**	**Poor**	**Good**	**-**
Abrasion	**Excellent**	**Excellent**	**Good**	**Good**	**Excellent**
Ultraviolet light	**Excellent**	**Good**	**Fair**	**Good**	**Excellent**

Resistance to ultraviolet radiations and surface conformity should be considered for all jobs.

APPLICATIONS:

When designing civil engineering structures, the function to be performed have to be analyzed first, after that suitable materials and products can be selected. When geosynthetics are provided, the soil structure requires a strong, relatively stiff and preferably water permeable material. Table 2.3 gives functional applications of geosynthetics.

Table 2.3: Geosynthetics Applications Summary Table

Applications	Primary Function	Products
Subgrade stabilization	**Separation / Reinforcement / Filtration**	**Geotextiles / Geogrids**
Railroad track bed stabilization	**Drainage / Separation / Filtration**	**Geotextiles / Geogrids**

Sedimentation control silt Fence	**Sediment retention Filtration/Separation**	**Geotextile**
Asphalt overlay	**Stress relieving layer/ Waterproofing**	**Geogrid/ Geotextile**
Soil reinforcement/ Embankments/ Steep slope/ Vertical walls	**Reinforcement**	**Geotextile/ Geogrid**
Erosion control filter	**Filtration/ Separation**	**Geogrid/ Geotextile**
Remembrance Protection	**Protection/ cushion**	**Remembrance**
Subsurface Drainage	**Filtration/ Fluid transmission**	**Prefabricated Drainage Composites**
Surface erosion control	**Turf reinforcement**	**Erosion control mats**

MODES OF FAILURE IN REINFORCED EARTH STRUCTURES:

The following modes of failure have been observed in reinforced earth structures:

a) **Shear failure of the soil above the uppermost layer of reinforcement:** This mode of failure is possible if the depth to the topmost layer of reinforcement is sufficiently large so as to form an effective boundary into which the shear zones cannot penetrate.

b) Reinforcement pullout failures: The type of failure occurs for reinforcements placed at shallow depths below the footing and /or reinforcements which have insufficient anchorage.

c) Reinforcement tension failure: This type of failure occurs in the case of long and shallow reinforcements for which the frictional pullout resistance is more than the tensile strength.

FLYASH:

Flyash is produced as a result of combination of coal and is as very fine, light dust which is carried off in the stack gasses from a boiler unit and collected by mechanical and electrostatic methods. Among the industries thermal power plants are the major contributor of flyash. Besides this steel, copper and aluminum plants also contribute a substantial amount of flyash. Table 2.4 gives the detail of the industries producing flyash.

Table 2.4: List of Industries Generating Flyash:

Name of industry (1)	Name of the state situated (2)	Name of industry (1)
(A) Thermal power plants		
Kothagendem	Andhra Pradesh	Nellore
Ramagundam		Vijay Wada
Bongaigaon	Assam	Lakwa
Nanrup		Chandarpur
Barauni	Bihar	Bokaro
Chandradurg		Muzzafarpur
Patratu		
Indraprasta	Delhi	Rajghat
Badarpur		
Utraw	Gujrat	Gandhinagar
Sabarmati		Utkai
Wanakori		
Singrauli	U.P.	Mirjapur
Rihand		Panki
Paricha		Anapara
Obra		RPC
Hardoganj		Tanda
Ferozgandhi		
Korba M.P.		Satpura
Amarkantak		Vindhyachal
Gurunanak Dev		Ropar
Kota		
Raichur	Karnataka	
Ennore	Tamil Nadu	Tuticorin
Mettur		
Trombay	Maharastra	Nasik
Ballarshah		Paras
Chola		Bhusawal

Chandanpur		Koradi
Parli		Tata Elect. Co.
Talcher	Orissa	
Durgapur	West Bengal	Bundel
Santadir		Lolaghat
Farakka		DPL
C.E.S.C.		Titagarh
New Cossipore		Mulajore

Name of the Industry	Name of the State situated
(B) <u>Steel Industry</u>:	
Bhilai Steel	M.P.
Durgapur Steel	West Bengal
Rourkela Steel	Orissa
Bokaro Stel	Jharkhand
HSCO	W.B.
Salem Steel	Tamil Nadu
Vijay Nagar	Karnataka
Visakhapatanam Steel	A.P.
TISCO	Jharkhand
(C) Aluminum Industry:	
BALCO	M.P.
NALCO	Orissa
(D) Copper Industry:	
Chandamari Copper Project	Rajastan

Khetri Copper Project	Rajastan
Darbi Copper Project	Rajastan
Indian Copper Project	Bihar
Rakha Copper Project	Bihar
Malanjkhand Copper Project	M.P.

FACTORS AFFECTING PROPERTIES OF FLYASH :

Meyer (1976) and Despande (1982) represent that the chemical and physical composition of a flyash is a function of several variables.

(1) Coal source

(2) Degree of coal pulverization

(3) Deign of boiler unit

(4) Loading and firing condition

(5) Handling and storage methods.

Thus, it is not surprising that a high degree of variability can occur in flyash. Not only between power plants but a single power plants. A change in any of the above factors can result in detectable changes in the flyash produced. The chemical composition of some of the Indian flyash is given in Table 2.5.

Table 2.5: Chemical Composition of some of the Indian Flyash

Thermal Plant	SiO_3	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	LOI	TiO_2
Ukkai	52.44	28.12	6.18	3.48	5.44	-	3.88	-
Tuticorn	53.44	22.72	4.48	7.25	3.33	1.34-	1.5	-
Bokaro	56.5	25.3	4.1	1.3	1.6	-	18-26	0.5
Delhi	60.1	18.6	6.4	6.3	3.6	-	18-26	-
Hardua	60.78	23.63	6.48	15.59	1.54	-	18-26	-
Korba	58.3	24.64	4.4	5.4	3.9	-	18-26	1.0
Obra	56.15	28.87	8.13	2.29	1.45	1.37	18-26	-
Durgapur	50.65	19.65	18.8	2.2	1.49	-	18-26	-
Satpur	59.7	25.69	7.31	2.0	2.89	1.02	18-26	-
Talcher	47-57	18.31	18.69	0.67	0.28	Trace	1.26	-

Rourkela	45-51	20.25	7.95	2-3	1-1.5	-0	18-26	-
Nellore	60.18	18.44	16.28	2.08	1.28	0.58	1.05	-
Neyveli	45-59	23.33	0.6-4.0	5-16	1.5-5	2.50	1-2	0.5-1
Panki	53.44	22.72	6.56	3.22	4.48	-	4.21	-
Chandrapur	56.70	23.80	4.0	2.10	1.40	-7.4-	11.4	-
Kothagudam	66.74	23.20	6.58	2.71	0.77	0.05	0.30	-
Bandel	50-95	24.25	9.95	2.59	3.7	2.91	7.1	-
Panipat	60.64	15.70	2.36	0.80	0.25	-	18.86	-
Paras	55.30	27.81	5.09	3.44	3.08	1.20	3.85	-
Kanpur	49.20	22.00	7.50	2.84	0.98	0.24	15.81	-

ENVIRONMENTAL IMPACT OF FLYASH:

Flyash is very light in weight and can fly in air causing environmental pollution.

In addition to it, it directly or indirectly causes health hazards. Some of the environmental aspects associated with flyash are:

a) With the rapid depletion of natural sites, acquistion of fertile land would become necessary for disposal of ash, acquistion of fertile land would become necessary for disposal of ash, which may cause ecological imbalances and related environmental problems.
b) Environmental pollution due to ash handling and disposal sytem as a result of fugitive emmission at plant site enroute and dumps.
c) Contamination of the ground equifers of surface water bodies owing to seepage of water flowing over ash fills both dry and wet type.
d) Contamination of river/sea and agriculture field due to overflow of ash water in case of ash pond and fills, which is situated near these water bodies.

USE OF FLYASH:

Introduction:

Huge quantites of flyash is produced from coal-based power plants. Out of 100 million tonnes of flyash producedin India, at present about 5% of this flyash finds its commercial use and the rest are dumped in ash ponds.

In Land Fill:

DIGIOA (1972) says that with drainage, the flyash can be effectively and economically utilized as a fill material to construct stable embankment for land reclamation on which structure cn be safely founded. In structure fill, LEONARDS (1972) reported that untreated pulvirised coal ash with no cementing quantities was used successfully as a material for structural fill. Although, the ash was inherently variable, it could be compacted satisfactorily.if the moisture content was maintained below the optimum obtained from standard laboratory tests and if the percentage of fines (passing the No.200 sieve) was below 60%. CHAN (1988) quotes that flyash has low unit weight, thus is quite suitable for structural fills over soil with low preconsolidation pressures, such as alluvial clay and silts. Flyash can be easily handled with conventional equipment and compacted over a wide range of moisture contents.

The case studies have demonstrated that the physical behaviour of flyash is similar to that of silt and the structural fill produced with flyash will perform better than the same fill constructed with silt sized natural material, with respect to case of compaction and pack to the amount of the settlement of the fill and underlying soil. The corrosion of buried services in flyash and bottom ash should not be a concern. Laboratory and field testing on samples of the most commonly used metals for buried services have shown that the corrosion rates of the materials tested are low.

Manufacture of Portland Cement:

ARTHANOOR (1976) says that Neyveli flyash is suitable for making Portland Pozzolana cement has been well established and the cement manufacturers in this part of the country have lifted moe than 120000 tonnes of Neyveli flyash for this purpose. They are manufacturing pozzolana cement by inter grinding flyash (20-25%) with Portland cement clinkers and gypsum.

Lime – Flyash Soil Stabilizing in Pavement and Sub-base:

ARTHANOOR (1976) reports that two sub-grade layers of each 100 mm thickness were laid one over the other with 75% sand, 22.5% flyash , and 2.5% lime with water flyash ratio as 0.9. After completion of water curing and drying of surface the conventional bituminous wearing coat of 25mm thick was laid. The cost cost is less by 30% as compared to conventional subgrades.

GREENWELL (1976) observed flyash lime soil stabilization works, lime well probably better than the crushed stone or graded gravel. Flyash with suitable amount of lime forms a hard and impermeable mass, which provides a very good base and sub base course for highway pavements.

SIVAGURU (1984) reports that bituminous binder and surface course when laid over lime flyash aggregate (LFA) base course would function better compared to water bound macadam (WBM) base covered with bituminous surfacing over LFA base. The performance of the LFA pavement propely surfaced would be almost similar to superior WBM bases. Consolidation and bonding of WBM layer on lfa bases are difficult and if the WBM is properly consolidated over the semi rigid LFA base course and surfaced with superior wearing surface such as asphalted concrete, dense carpet etc., the structural performance of the composite pavement would be quite satisfactory.

In Soil Conditioning;

ARTHANOOR (1976) reports that flyash increases the yield of paddy and ragi by 0 to 25% by conditioning of the soil. Flyash soil conditioning appears more suitable for acidic soils and it improves the consistency of clayey soils and supplies some micro nutrients to the soil.

MCLEAN (1979) says that the lack of vegetation results in erosion of the soils, the re-exposing the pyretic material within the strip mine soils to air and water. Flyash applied to the fine soil at a rate of 112 kg to 336 kg/hectare which caused a beneicial change in te soils pH, grain size and moisture retention capacity. However, an accurate application and uniform mixing of the flyash with the soil are essential to obtain the desired changes in soil parameter.

Manufacture of Bricks:

ARTHANOOR (1976) says that flyash lime gypsum can be made in an indegenious process by wet mixing 92% flyash, 4.5% lime and 3.5% gypsum and casting the mix into brick moulds. After remoulding the moisture curing for 10 days followed by air curing for a fortnight, good quality bricks are obtained. These bricks possess compressive strength of about 50 to 60 kg/cm^2 and in addition to that they have less heat conductivity and hence offer comfort value than burnt clay bricks. They are cheaper by 20 percent.

SHAMUGASUNDARAM (1994) reports that flyash bricks are much cheaper than burnt clay bricks available in the market but are compared to the latter , with a minimum compressive strength of 35 kg/cm^2. Due to its lesser thermal conductivity, the flyash bricks also provides better comfort value to the occupants of the house.

KRISHNAMURTY(1994) reprted that good bricls can be maunfactured with black cotton soll, by adition of flyash and for this flyash should be added in sufficient quantity to reduce differential free small index below 10% otherwise good bricks cannot be manufactured. The compressive strength of bricks made with replacement of soils above 50% (soil flyash ratio of 1:1) is very good, ranging from 9.8 to 11.5N/mm^2.

Apart from these short range advantages, manufacturing and using flyash flyash bricks on a scale could also bring about certain long range ecological improvements by

a) Obviating denudation of the rich clayey top soil from the alluvial fertile lands from which clay is being scraped for making bricks.
b) Preventing denudation of forests caused by felling of trees required for burning as fuel in brick kilns.

Mechanical properties of flyash concrete such as stress-strain characteristics, modulus of elasticity and modulus of rupture are not different from those obtained from conventional mixes. The conventional concrete mix 1:2:4 can accommodate flyash of the order of 80% of cement in case of ordinary portland cement and 50 % of the cement in case of ordinary slag cement to be suitable for concrete grade M15.

REDDY et.al (1994) reported that addition of flyash to lean concrete makes the mix more cohesive and workable and the development of compessive strength of flyash concrete is more during the period from 28 to 120 days tan the corresponding values for 28 days. The percentage of saving in cost due to partial replacement of cement by flyash is more for rich mixes.

In Mortars:

GAHLOT (1972) mentions that by replacing cement by equal weights of flyash in mortars, the strength goes down but the work ability improves upto about 20%. replacement.

The reduction in strength of equal replacement basis is caused because the ementing material produced by pozzolanaic action of flyash is not as effective as ordinary portland cement.

By considering flyash to be an additional ingredient of mortar it can be used upto 60 to 80 % by weight of cement in 1:3 (cement : sand) mortar without affecting the properties of mortar.

The cost of production of flyash cement mortar with 80% additional flyash is about 16.6% less as compared to that plain cement concrete. When strrength requirement is decreased , higher proportions of flyash may be used. The proportions of flyash of order of 100% of cement are found to be economical for design strength of 10 N/mm^2 and $5N/mm^2$.

LIME AS A STABILIZING AGENT:

Lime is one of the most wiely used and successful soil stabilizers. Generally recommended soil – lime mixtures are lime modified soil and plastic-lime. Lime reacts with the siliceous matter of the soil to form a bond. Organic matter interferes with the reactions which weakens the treated soil. Best results are obtained when lime is worked with well graded soil having les than 50% of its particle finer than 75 micron and a Plasticity index os less than 20%.

Factors affecting Soil-Lime:

There are a number of factors which affects the strength and durability of soil lime.

Nature of Soil:

The higher the specific surface of soil, the greater is the lime required for stabilization. Clayey sols containing expanding materials cause problems in pulverizing, mixing and compacting thus becoming difficult to stabilize.

Amount of Lime:

The more the lime added to the soil, the stronger the resulting soil-lime.

Mixing:

In general the more intimate the soil-lime mixture, the stronger and more durable the resulting soil-lime. Continued mixing gives better results but mixing past an optimum can result in segregation of components, reducing the strength of the mixture.

Compaction Conditions:

As with stabilized soil, the properties of soil-lime depend to a large degree on the moulding water content and the compacted density. The moulding water plays two roles in soil-lime (i) influences the compaction characteristics, as with natural soil and (ii) furnishes water for lime ractions.

Curing Conditions:

The manner in which soil lime is cured influences the resulting product. As with concrete, the strength of soil lime increaseswith age. Like concrete soil-lime must be kept moist during initial stages of curing.

Temperature during cure has a marked effect, higher the temperature the more rapid the cure, while soil lime will harden at all temperatures above freezing, warm weather cured soil-cement appears to be stronger.

Admixtures:

For many years engineers have added lime or calcium chloride to soil lime mixtures to accelerate the setting and to improve the properties of the final product. It has been observed the dramatic improvement of strength of soil- ement can be achieved by adding certain chemicals like NaOH, Na_2CO_3, $Na_2 SO_4$, Na_2SiO_3, $CaCl_2$.

Chemical composition of Lime:

The principal reactive compounds present are

- CaO
- MgO
- $Ca(OH)_2$
- $Ca(OH)_2 + MgO$
- $Ca(OH)_2 + Mg(OH)_2$

Lime Clay Reactions:

1) COLLOIDAL REACTIONS:

The colloidal reactions involve the following:

- Ion exchange
- Depression of double layer of water
- Increase of pH value

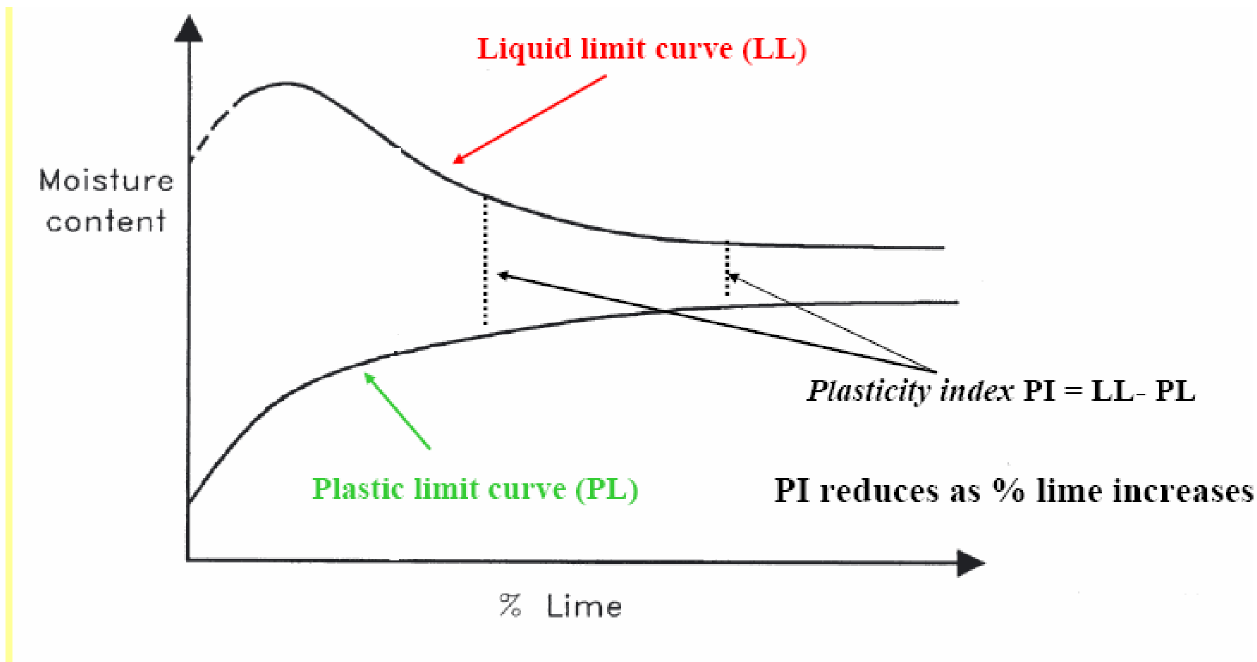


Fig 2.4: Variation of Plastic Limit and liquid limit with % of Lime

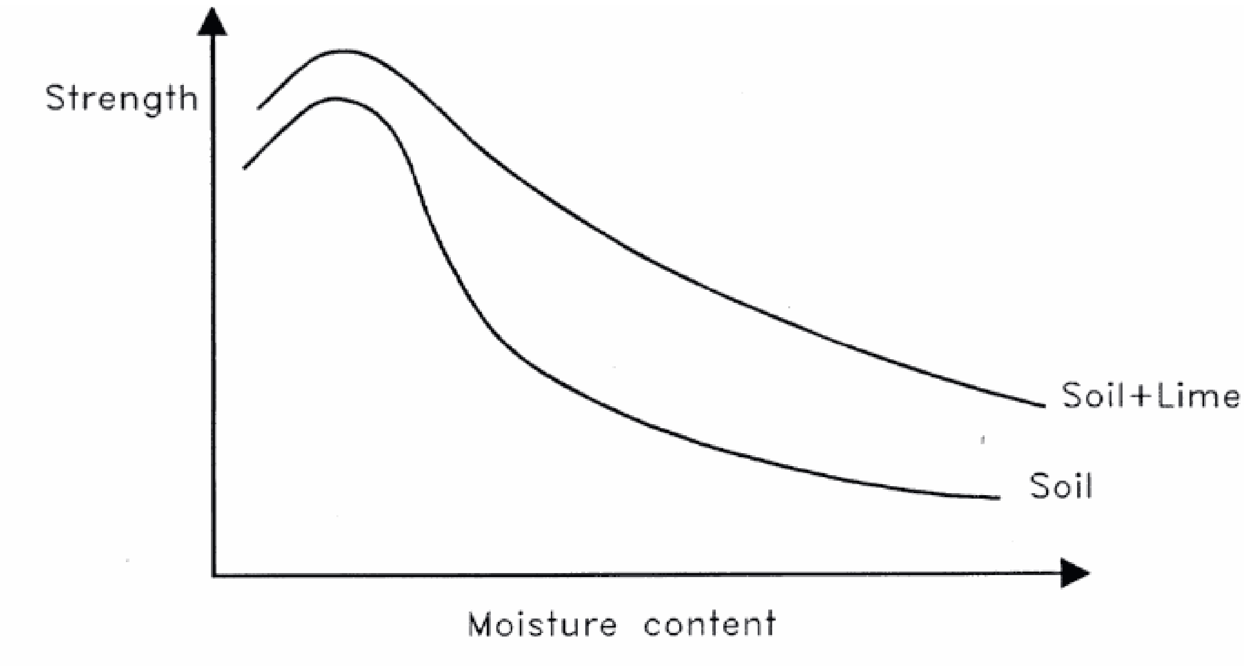


Fig 2.5: Relation between moisture content and strength

2) PUZOLLANIC REACTIONS:

Puzzolana is acompound which reacts with lime to form silicates and aluminates and clay is a natural puzollana. When lime is added , the calcium ions reacts with the silica and alumina present in clay to form such type of compounds which causes a cementing action. But this process is very slow.

Lime reduces the plasticity index of highly plastic soils making them more friable and easy to be handled and pulverised. The plasticity index of soils of low plasticty generally increases. There is generally an increase in the optimum water content and a decrease in the maximum compacted density, but the strength and durability increases. There is generaly an increase in in OMC and a decrease in the maximum compacted density, but the strength and durability increases.

The amount of lime required may be used on the unconfined compressive strength or the CBR test criteria. Normally 2 to 8% lime may be required for coarse grained soils and 5 to 10 % for plastic soils.

CHAPTER – 3

EXPERIMENTAL WORK

EXPERIMENTAL WORK

INTRODUCTION

Safe and economic disposal of flyash is the main concern of coal based thermal power plants. Large scale utilitzation of flyash in geotechenical constructions will reduce the problems faced by the thermal power plants for its disposal. In this connection assessment of the behaviour of structures constructed using flyash is required for satbility and safe functioning of structures. Even through adequate substitute for full scale field tests are not available,tests at laboratory scale have the adavatage of allwoing a close control of many of the variable encountered in practice. The trends and behaviour pattern observed in the laboratory tests can be used in understanding the performance of the structures in the field and may be used in formulating mathematical relatioship to predict the behaviour of field strucures. In the present work the behaviour of randomly reinforced cement stabilized flyash has been evaluated thriugh a series unconfined compression test. Details of material used, sample preparation and testing procedure adopted has been outlined in this chapter.

MATERIALS USED:

FLYASH:

Source of flyash:

Flyash used for the test was collected in gunny bags from the ash pond of Rourkela Steel Plant. These were throughly mixed in order to bring homogeneity in the sample. These samples were air dried and then dried in ovens at a temperature 105^0 to 110^0 C after 24 hours of oven drying, these were kept in a tight containers for subsequent use.

Chemical composition of flyash:

The chemical composition of flyash as obtained from the research laboratory of Rourkela Steel Plant is given in Table 3.1

Table 3.1: Chemical Composition of RSP flyash

Constituents	% by weight
Silica (SiO_3)	**45 – 51**
Alumina (Al_2O_3)	**20 – 25**
Iron Oxide (Fe_2O_3)	**7 – 9.5**
Calcium (Ca)	**2 – 3**
Carbon	**18 – 26**
MgO	**1 – 1.5**

RECRON FIBRES:

Concrete Lends itself to a variety of innovative designs as a result of its many desirable properties. Not only can it be cast in diverse shapes but it also possesses high compressive strength, stiffness, low thermal and electrical conductivity and low combustibility and toxicity. Two characteristics however have limited its use; it is brittle and weak in tension and develops cracks during curing & due to Thermal expansion/ contraction over a period of time This describes the general properties and application of RECRON 3s fibre reinforced concrete used in construction. The thinner and stronger elements spread across entire section, when used in low dosage arrests cracking.

Role of RECRON:

- Controls Cracking:

RECRON 3s prevents the shrinkage cracks developed during curing making the structure/plaster/component inherently stronger. Further when the loads imposed on concrete approach that for failure, cracks will propagate, sometimes rapidly. Addition of RECRON 3s in concrete and plaster prevents/arrests cracking caused by volume change (expansion & contraction).

- Reduces water permeabillity:

A cement structure free from such micro cracks prevents water or moisture from entering and migrating throughout the concrete. This in turn helps prevent the corrosion of steel used for primary reinforcement in the structure. This in turn improves longevity of the structure.

- <u>Reduces Rebound In Concrete - Brings Direct Saving &Gain</u>**:**

RECRON 3s fibers reduce rebound "splattering" of concrete and shotcrete. The raw material wastage reduces & results in direct saving in terms of raw material. More importantly it saves a great deal of labour employed for the job, which could be completed earlier.

- <u>Increases Flexibility:</u>

The modulus of elasticity of RECRON 3s is high with respect to the modulus of elasticity of the concrete or mortar binder. The RECRON 3s fibers help increase flexural strength.

- <u>Safe And Easy To Use:</u>

RECRON 3s fibers are environmental friendly and non hazardous. They easily disperse and separate in the mix.

<u>Specifications:</u>

Denier	1.5d
Cut length	4.5 mm,6mm, 12mm…. 24mm
Tensile Strength	~ 6000 kg/cm2
Melting point	> 250ºC
Dispersion	Excellent
Acid resistance	Excellent
Alkali resistance	Good

<u>Primary Applications</u>:

- Plain concrete & Wall plastering
- Footings, foundations, walls and tanks
- Pipes, burial vaults, pre-stressed beams etc.
- For improving the properties of soil by increasing its strength..
- Roads & pavements
- Bridges and dams

<u>DETERMINATION OF INDEX PROPERTIES:</u>

Specific Gravity;

The specific gravity of flyash was determined as per IS:2720 (Part III section 1) 1980 and was found to be **2.48**.

Determination of Grain Size Distribution:

For determination of grain size distribution, the flyash of **1 kg** was washed thoroughly through an IS test sieve having opening size of 75 microns.

Size of sieve (ɥ)	Wt of retained particles
600	**0**
450	**0.1 mg**
300	**0.4 mg**
150	**7.2 mg**
75	**66.2 mg**
In pan	**7.5 mg**
TOTAL	81.4 mg

DETERMINATION OF ENGINEERING PROPERTIES:

Moisture Content vs Dry density relationship through Procter Compaction test:

The moisture content, dry density relationship were found by using light compaction test as per IS:4332 (part III). For this test flyash was mixed with waterand the mixture was compacted in procter mould in three equal layers aplying 25 number of blows to each layer by standard procter rammer of 2.6 kg with a free fall of 310mm. the moisture content of the compacted mixture was determined as per IS: 2720 (part VII) 1985. From the dry density and moisture content relationship, OMC and MDD are determined. Similar compaction tests were conducted on various mixes of flyash-lime in order to find out the effect limecontent on the OMC and MDD on the compacted mixture. Table 3.3 shows the variation of OMC and MDD with the variation in number of blows. Table 3.4 shows the variation of OMC and MDD in flyash-lime mixture with 25 blows with the varying percentages of lime.

Table 3.3: variation of OMC and MDD with the variation in number of blows

No. of blows	**5**	**15**	**25**	**35**	**45**
MDD (gm/cc)	**0.9677**	**1.0284**	**1.0625**	**1.0655**	**1.0756**
OMC	**55.36**	**47.8**	**45.88**	**45.77**	**45.49**

Table 3.4: the variation of OMC and MDD in flyash-lime mixture at 25 blows with the varying percentages of lime

Lime %	OMC (%)	MDD(gm/cc)
0	**44.4**	**1.072**
3	**44**	**1.078**
6	**43.6**	**1.086**
9	**42**	**1.094**
12	**39.8**	**1.104**

Unconfined Compressive Strength:

Sample preparation I (FLYASH + RECRON FIBRES)

- The specimens for UCS test are prepared by mixing required weight of flyash and recron fibers with 45.88% water to give proper consistency to the mixture for easy moulding.
- The wet mixture is then compacted in a constant volume mould with static compactive force.
- After giving required compactive force the samples were ejected out from the mould.
- The size of specimens were **75mm** dia. & **150mm** in height. In this series of tests the percentage of fibers was varied from 0.05% to 0.4%

Sample preparation II (FLYASH + LIME + RECRON FIBRES)

- The specimens for UCS test are prepared by mixing required weight of flyash, lime and recron fibers with required quantity of water which depends upon the percentage of lime to give proper consistency to the mixture for easy moulding.
- The wet mixture is then compacted in a constant volume mould with static compactive force.
- After giving required compactive force the samples were ejected out from the mould.
- The size of specimens were **50mm** dia. & **100mm** in height. In this series of tests the percentage of fibers was 0.3% and the percentage of lime varies from 0% to 12%.
- The samples were cured under controlled temperature at 40^0 C and relative humidity of 80% in humidity chamber. The samples were placed in the chamber and tested after 3, 7, 14, 28 days.

CHAPTER 4

TEST RESULTS

Stress – strain relationship:

FLYASH + RECRON FIBRES

Typical sets of stress – strain curves were obtained from triaxial tests conducted on compacted flyash – Recron with fibre contents of 0 to 0.5% . These stress-strain curves show three distinct portions. Initially the stress increases linearly with axial strain, thereafter, a mild ono-linear increasese of stress occurs up to a peak value and finally the deviator stress tend to decrease with further increases in axial strain. The failure stress as well as the failure stain of a particular mixture of flyash-cement-fiber is found to increases with increase in the confirming pressure. The initial stiffness of the stress-stain curve are also found to increase with the increase in confining pressure.

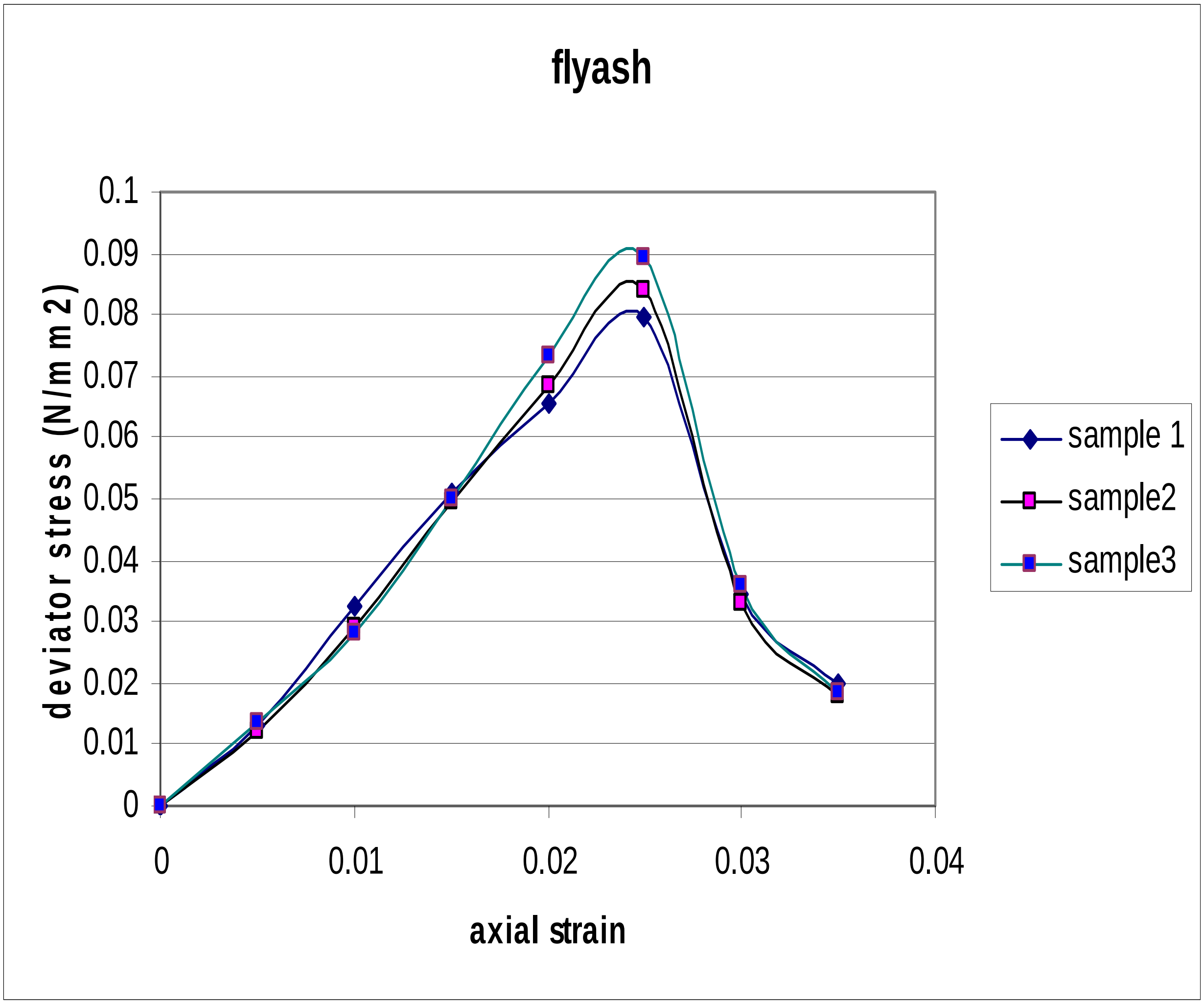


Fig 4.1: stress – strain relationship of flyash

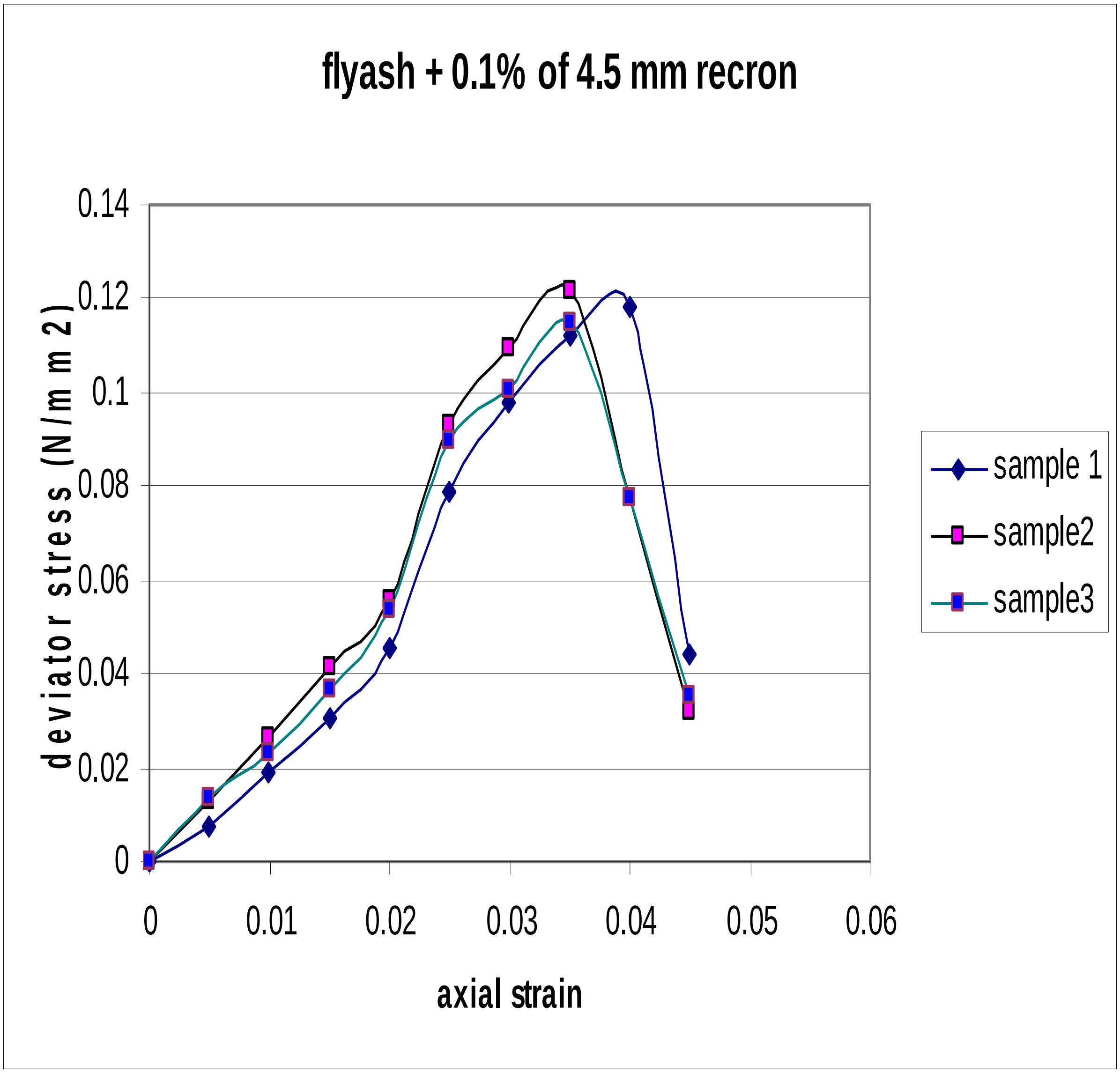


Fig 4.2: stress – strain relationship of reinforced flyash (0.1% 4.5 mm recron)

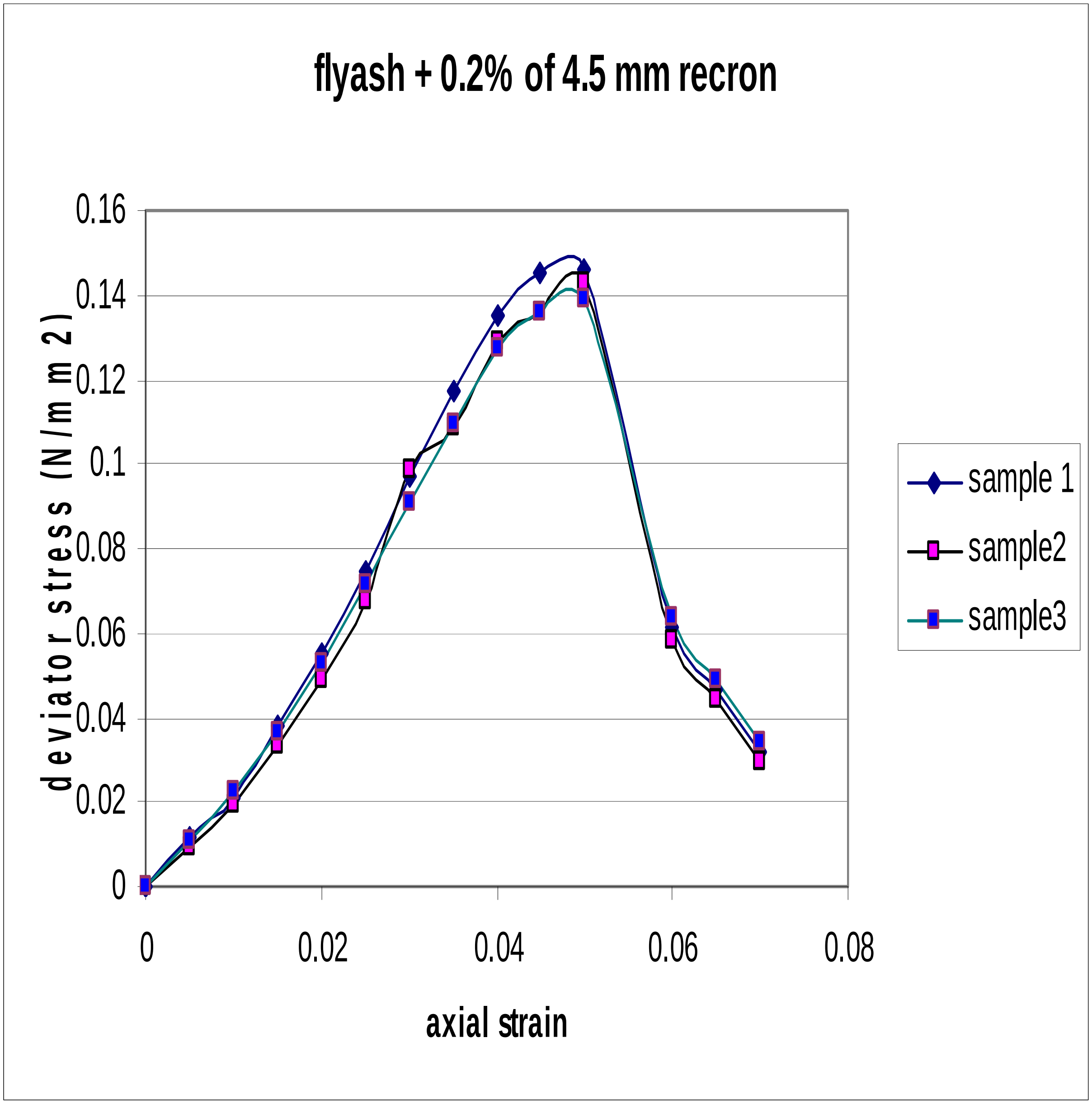


Fig 4.3: stress – strain relationship of reinforced flyash (0.2% 4.5 mm recron)

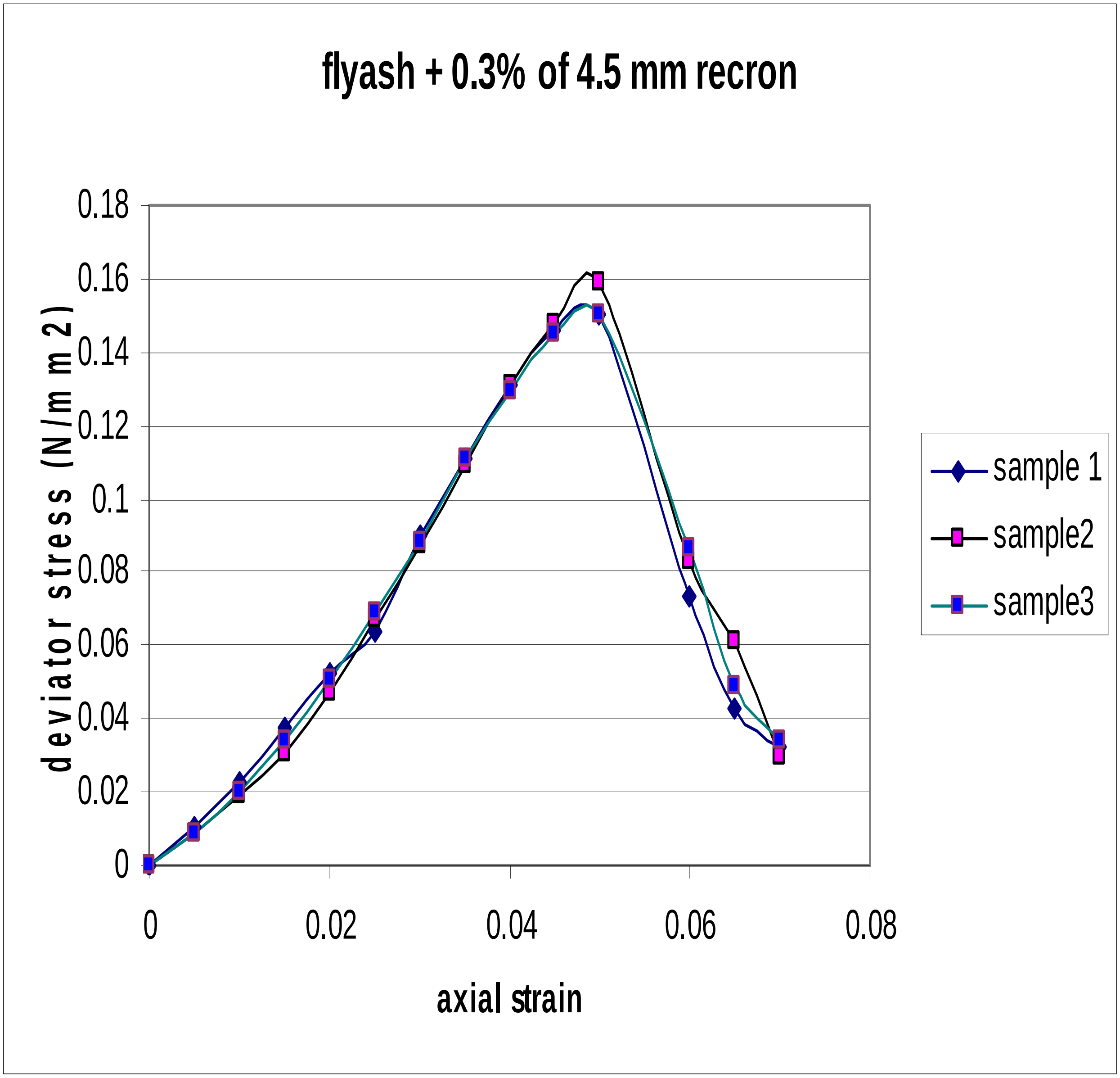


Fig 4.4: stress – strain relationship of reinforced flyash (0.3% 4.5 mm recron)

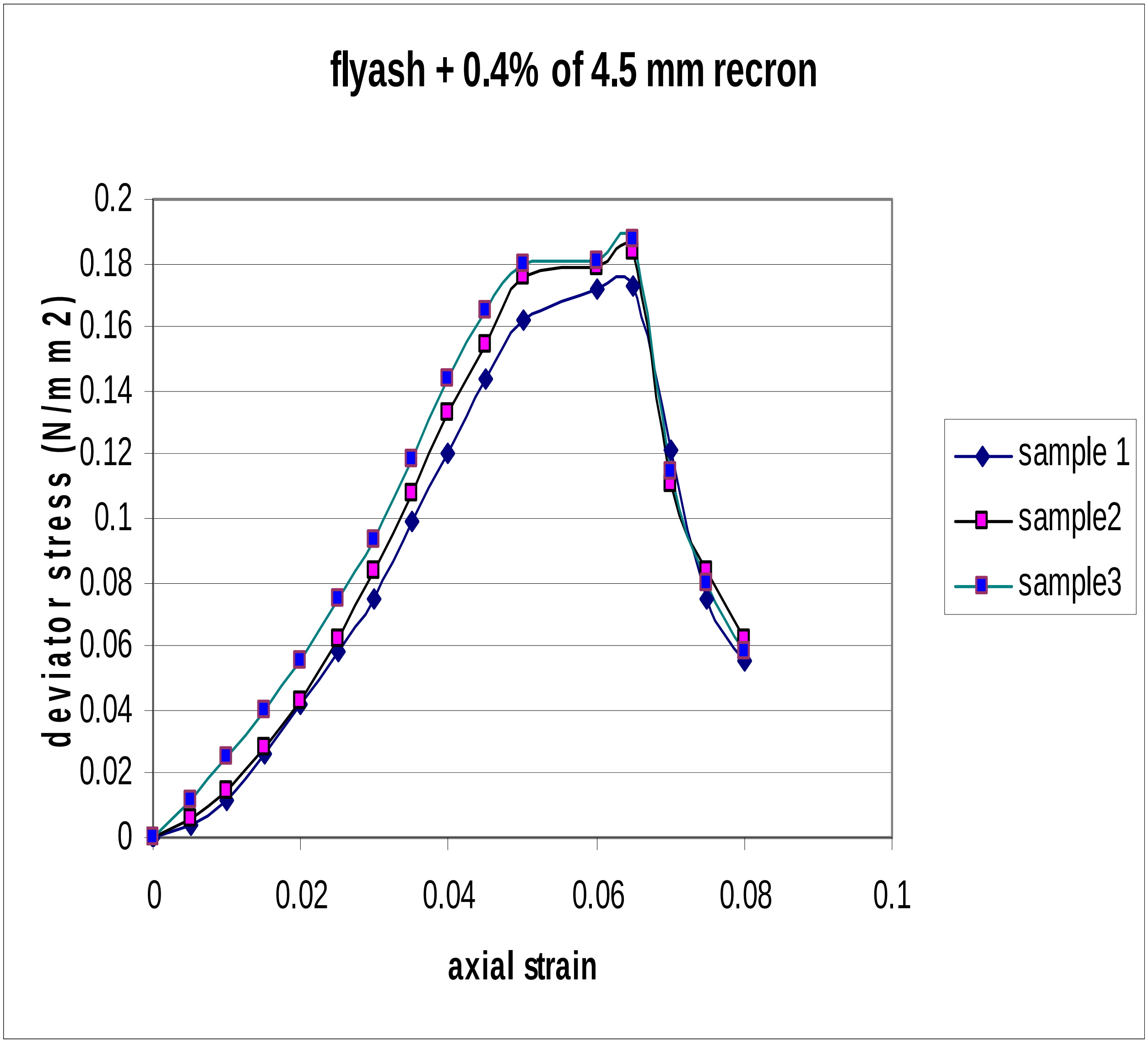


Fig 4.5: stress – strain relationship of reinforced flyash (0.4% 4.5 mm recron)

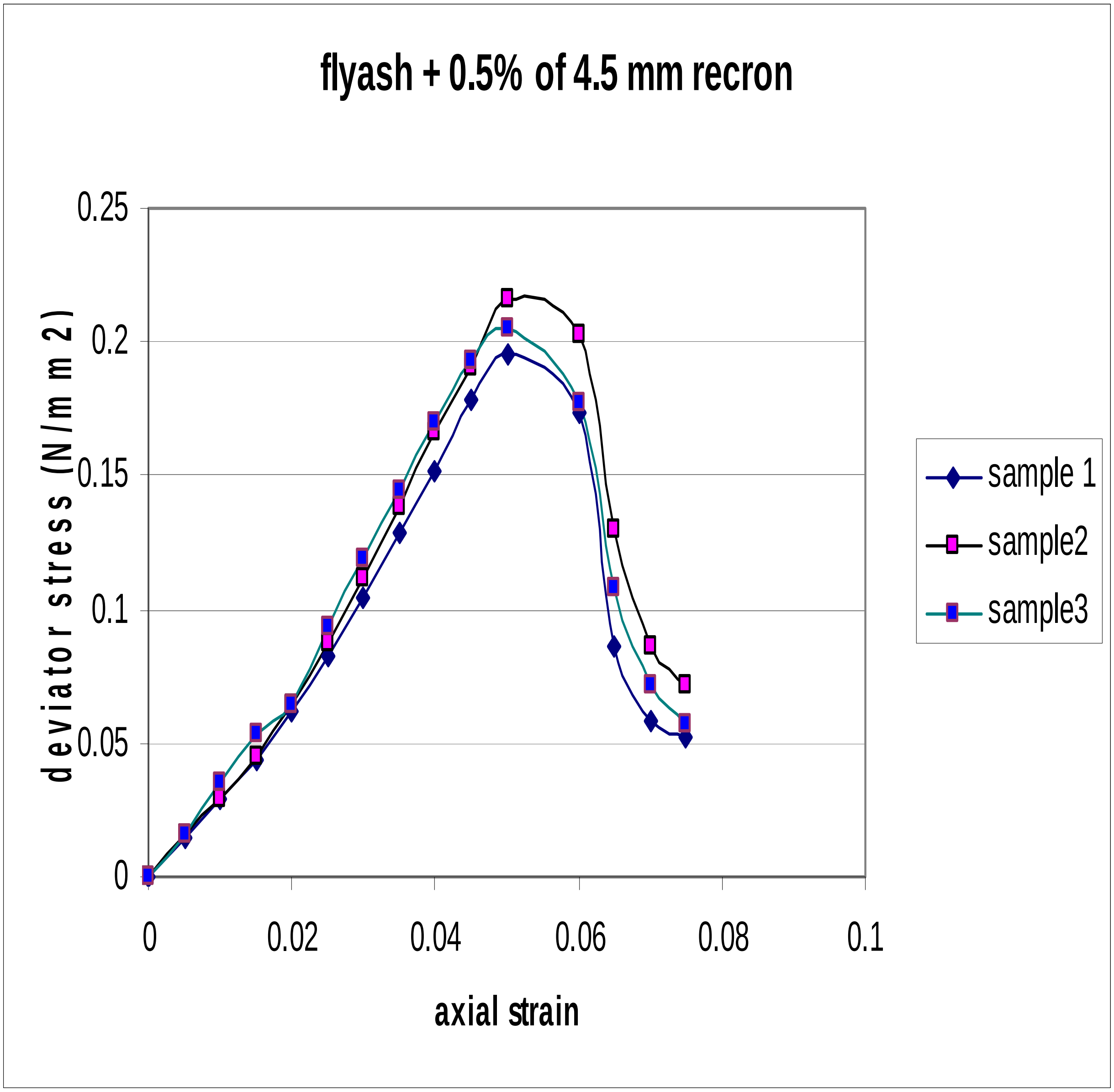


Fig 4.6: stress – strain relationship of reinforced flyash (0.5% 4.5 mm recron)

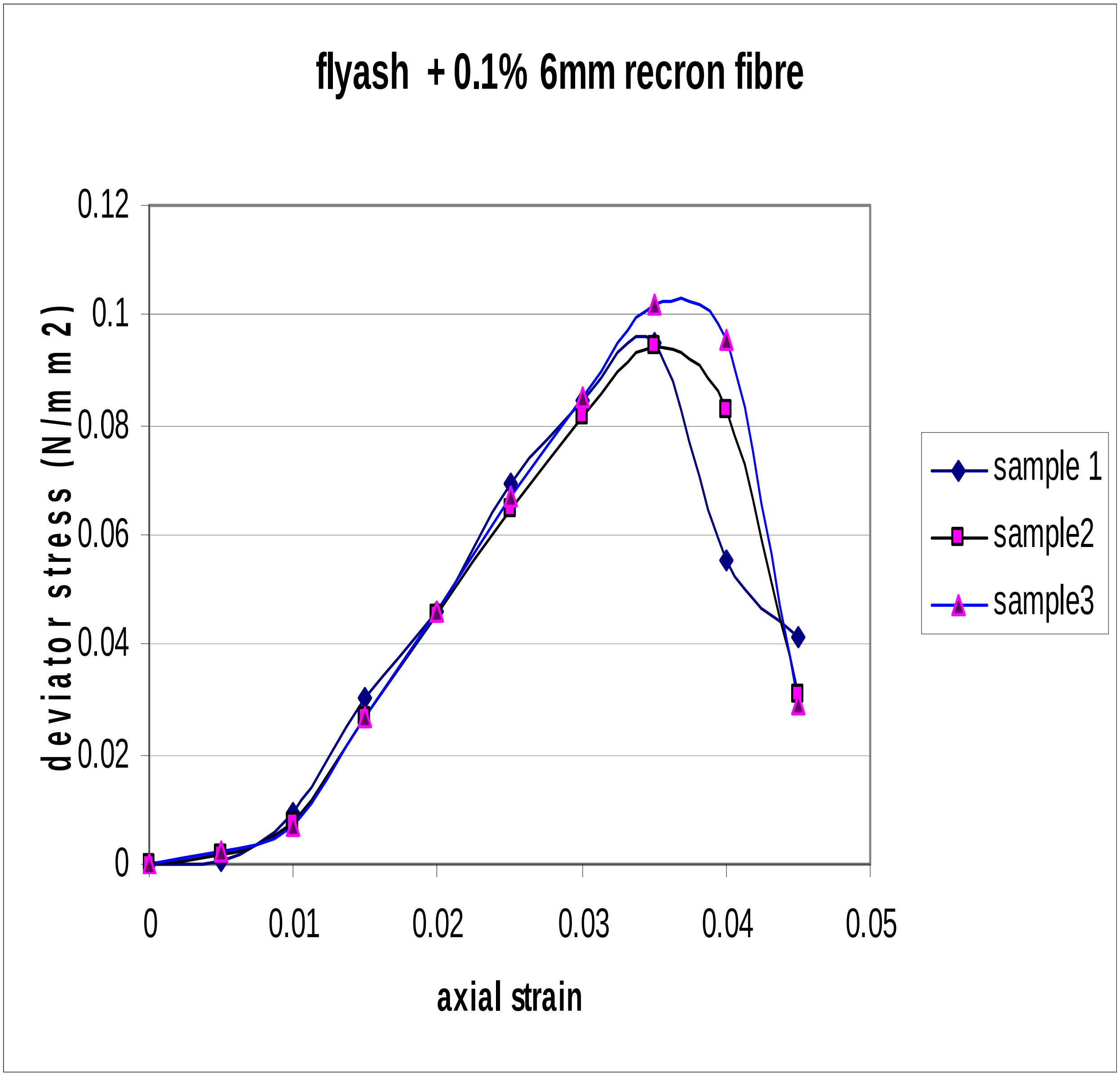


Fig 4.7: stress – strain relationship of reinforced flyash (0.1% 6 mm recron)

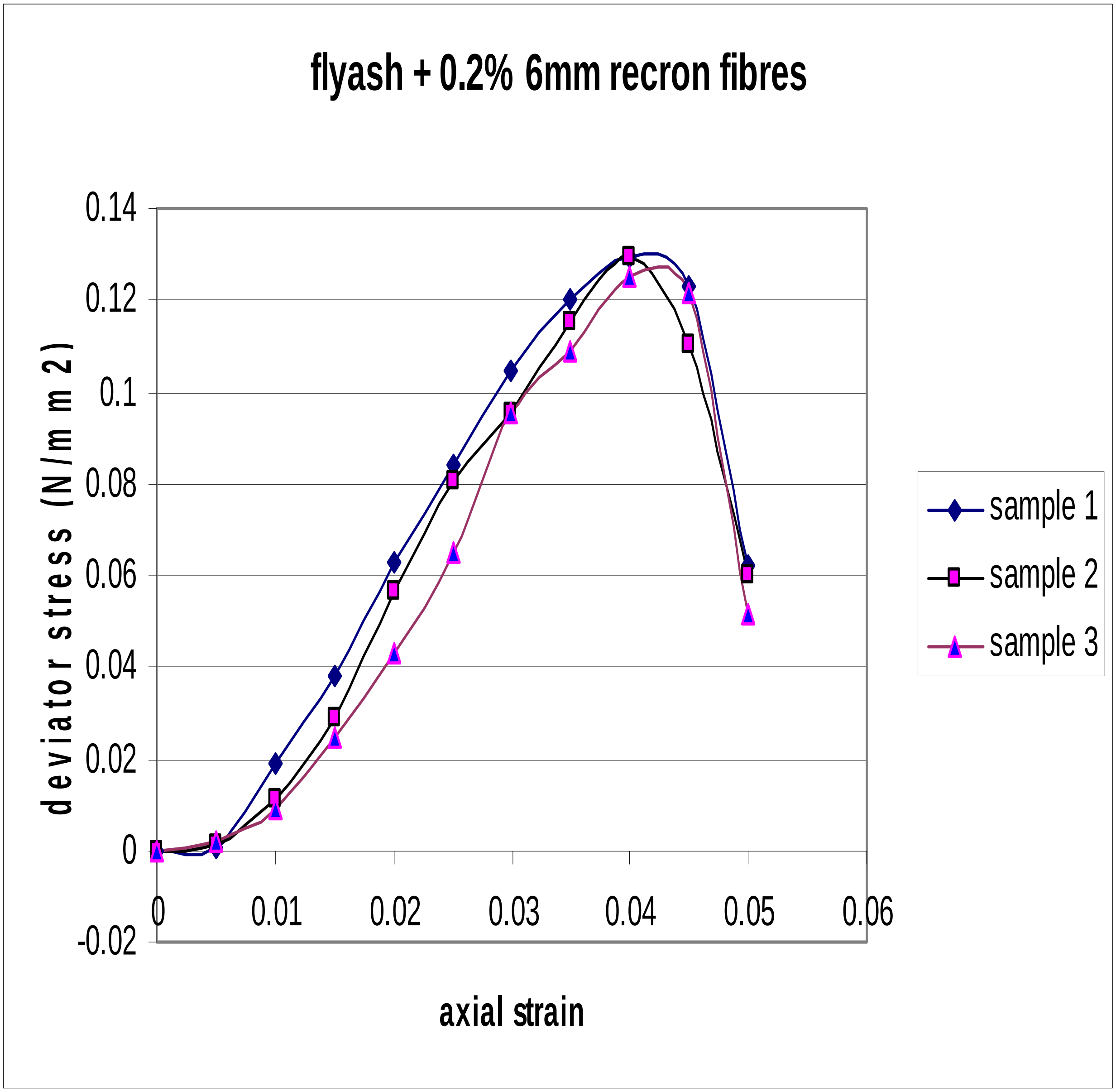


Fig 4.8: stress – strain relationship of reinforced flyash (0.2% 6 mm recron)

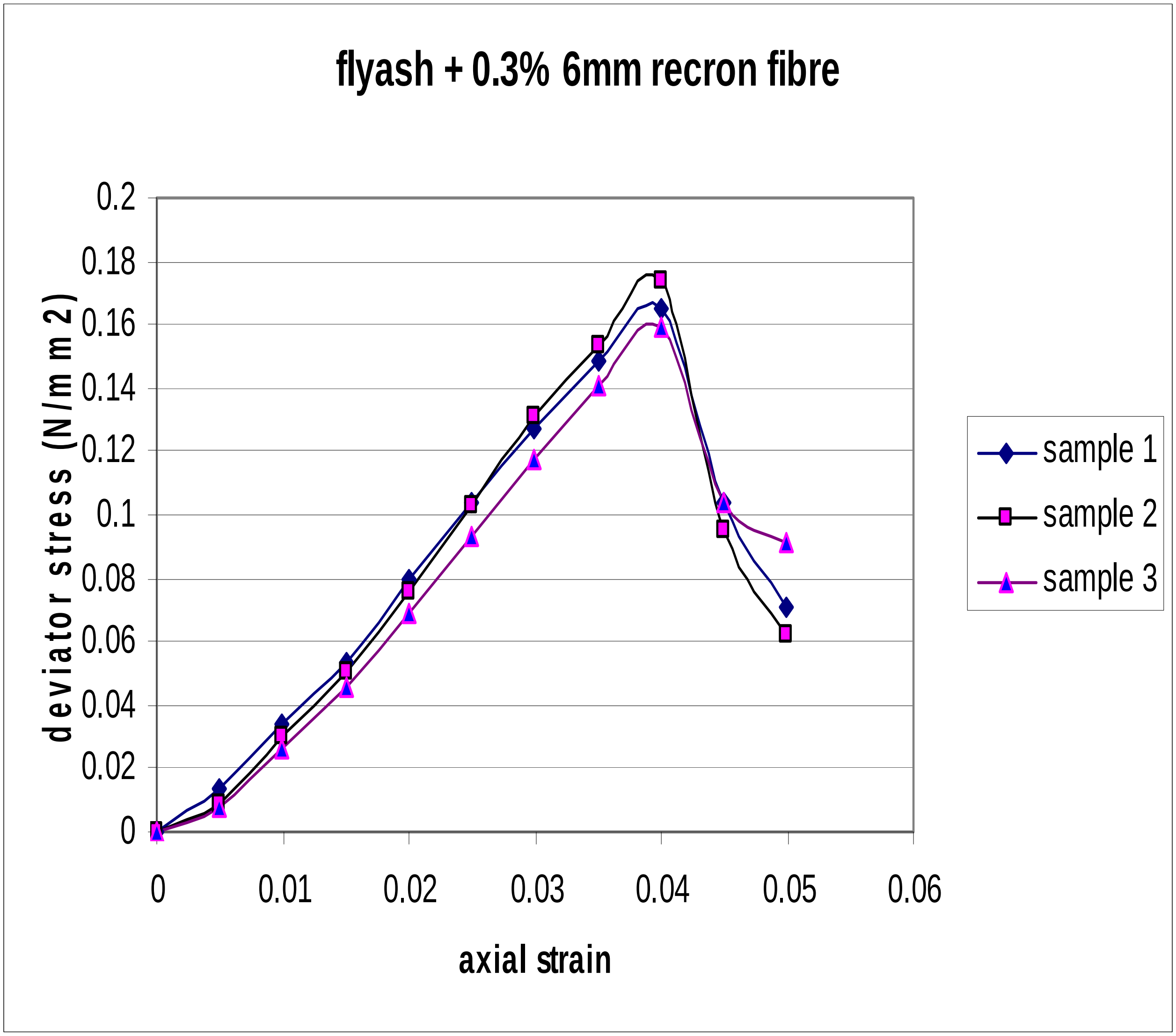


Fig 4.9: stress – strain relationship of reinforced flyash (0.3% 6 mm recron)

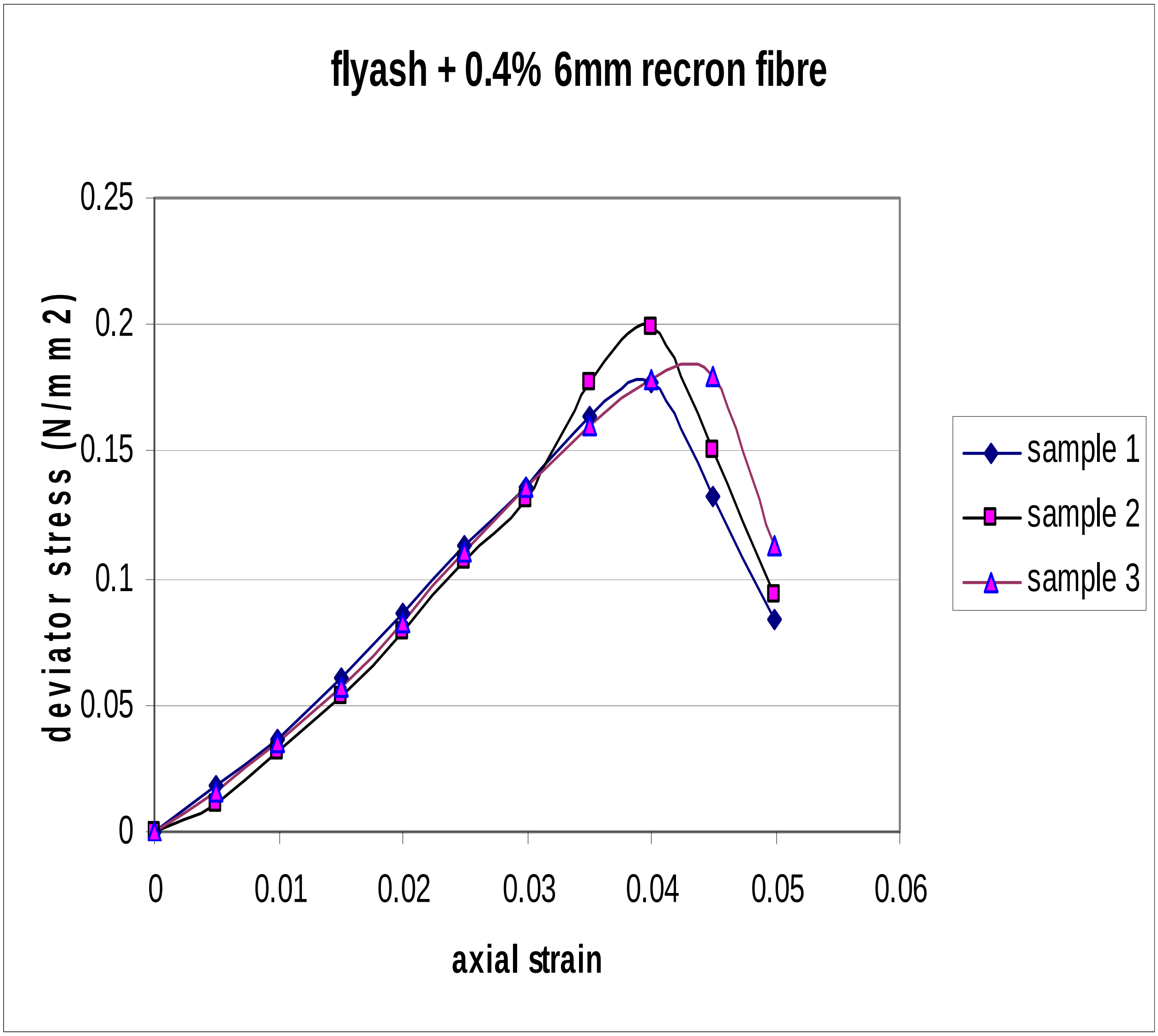


Fig 4.10: stress – strain relationship of reinforced flyash (0.4% 6 mm recron)

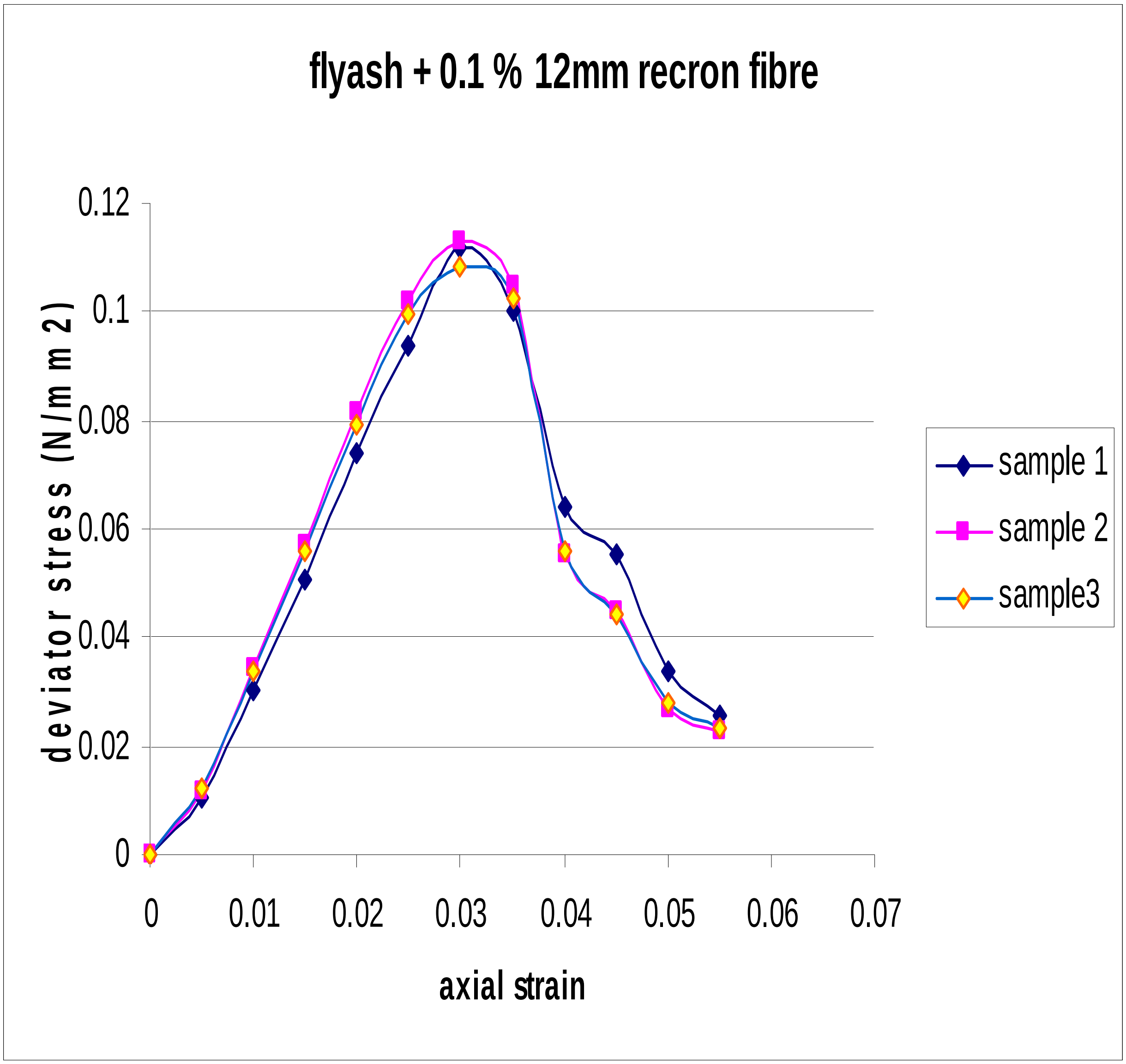


Fig 4.10: stress – strain relationship of reinforced flyash (0.1% 12 mm recron)

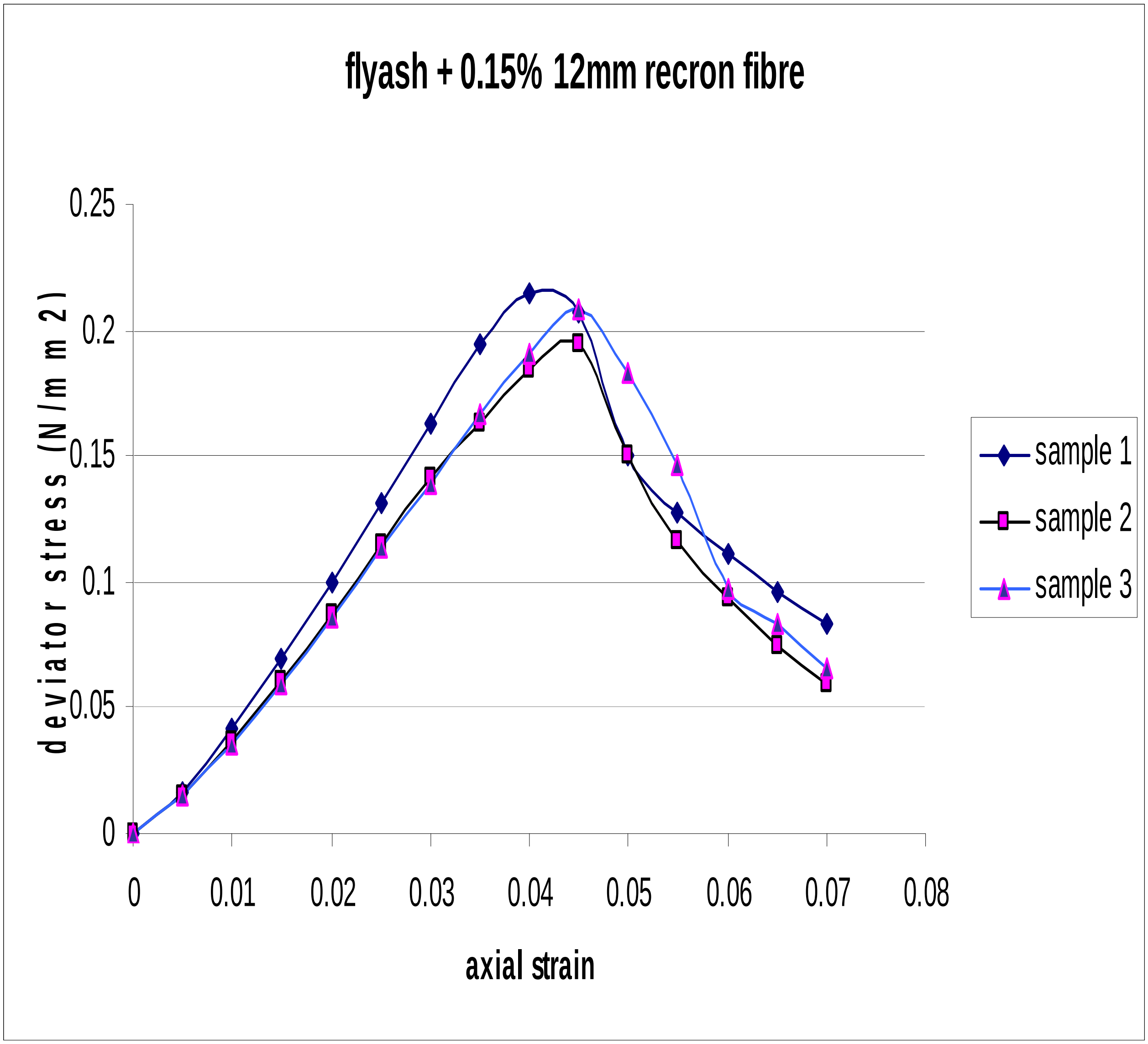


Fig 4.11: stress – strain relationship of reinforced flyash (0.15% 12 mm recron)

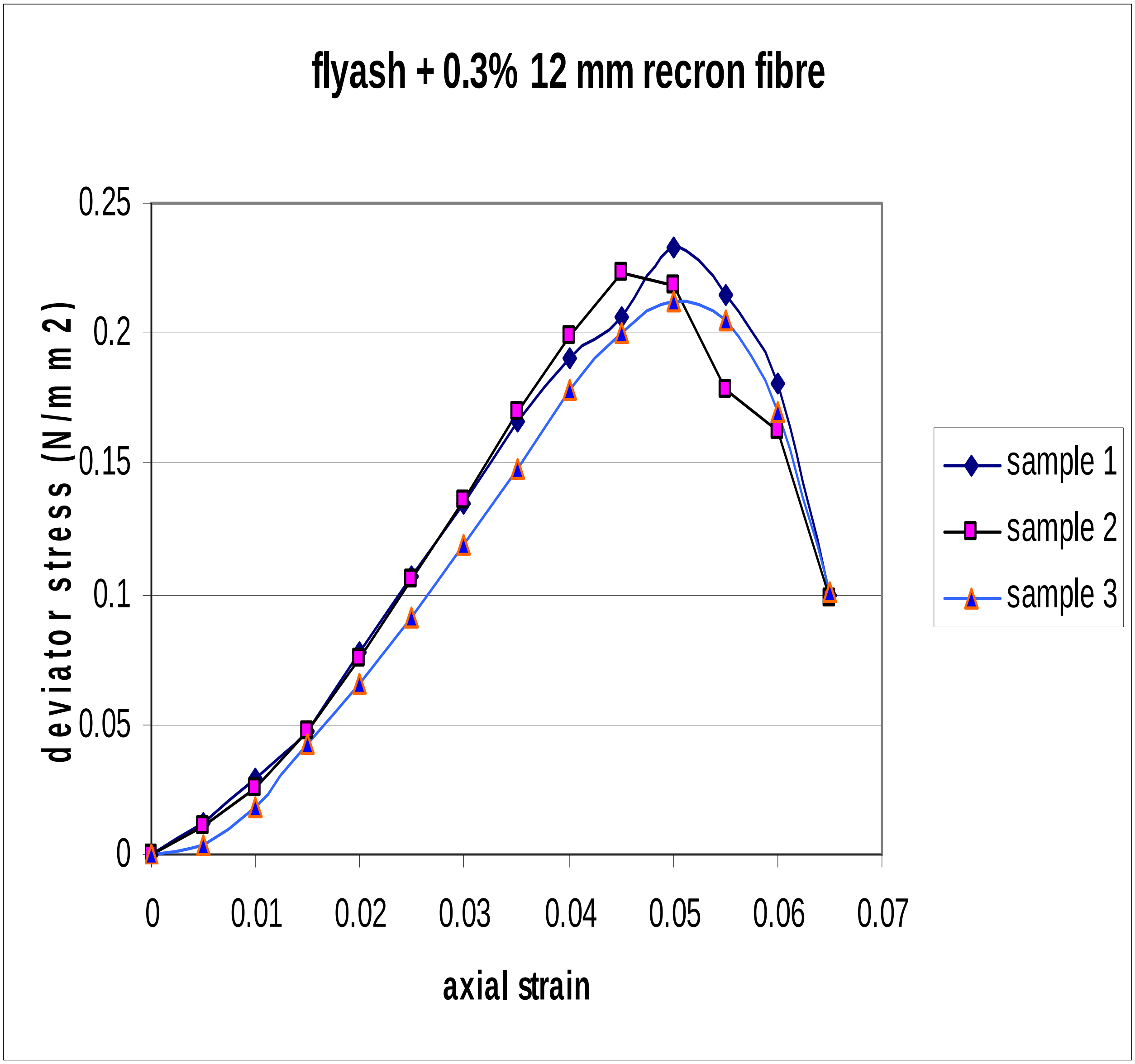


Fig 4.12: stress – strain relationship of reinforced flyash (0.3% 12 mm recron)

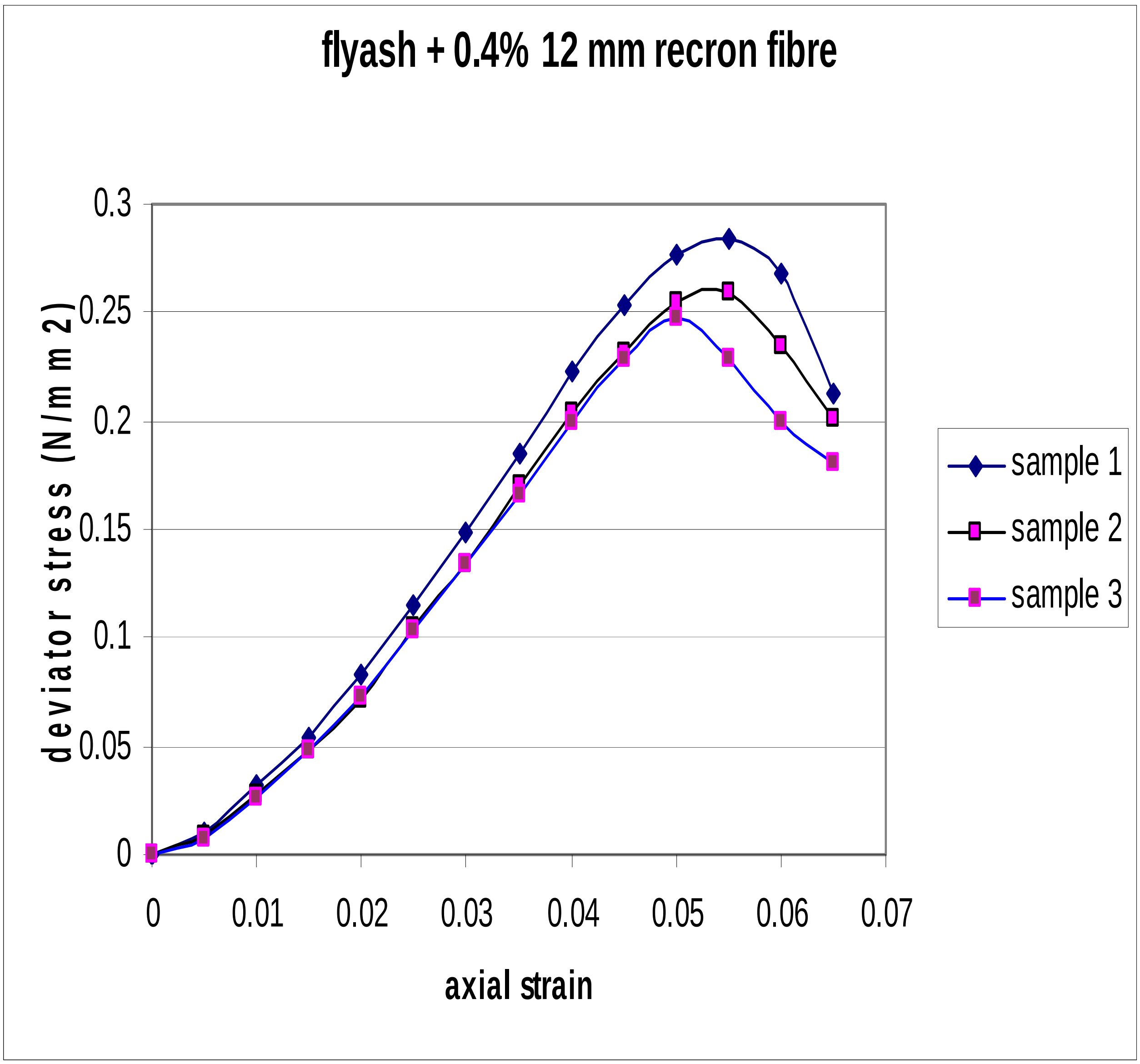


Fig 4.13: stress – strain relationship of reinforced flyash (0.4% 12 mm recron)

FLYASH + LIME + RECRON FIBRES

Typical sets of stress – strain curves were obtained from triaxial tests conducted on compacted flyash – lime – Recron with fibre contents of 0.3% and percentage of lime varying from 0, 3, 6, 9, 12%. The samples were cured in humidity chambers for varying days like 3, 7, 14and 28 days before testing. These stress-strain curves show three distinct portions. Initially the stress increases linearly with axial strain, thereafter, a mild ono-linear increasese of stress occurs up to a peak value and finally the deviator stress tend to decrease with further increases in axial strain. The failure streee as well as the failure stain of a particular mixture of flyash-cement-fiber is found to increases with increase in the confirming pressure. The initial stiffness of the stress-stain curve are also found to increase with the increase in confining pressure

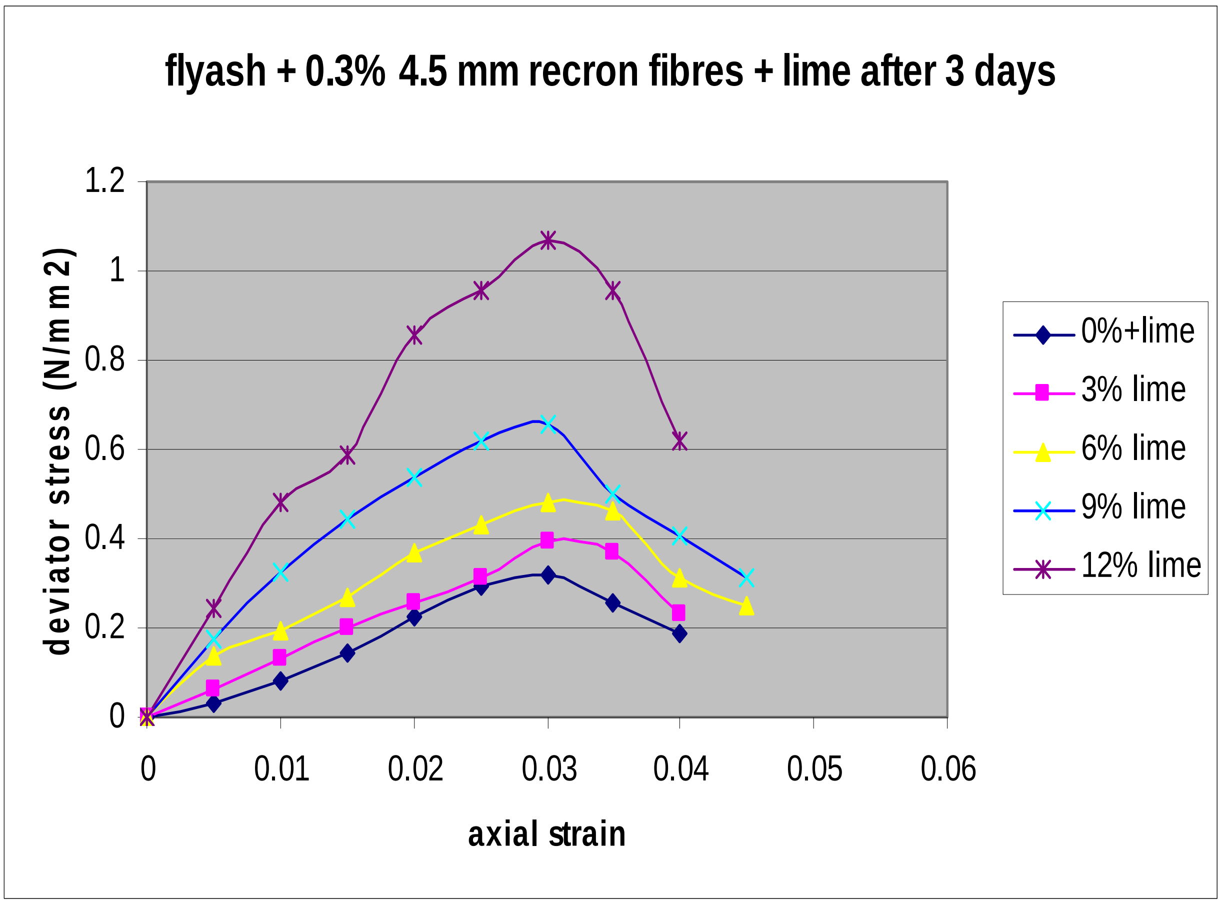


Fig 4.14: stress – strain relationship of lime stabilized reinforced flyash

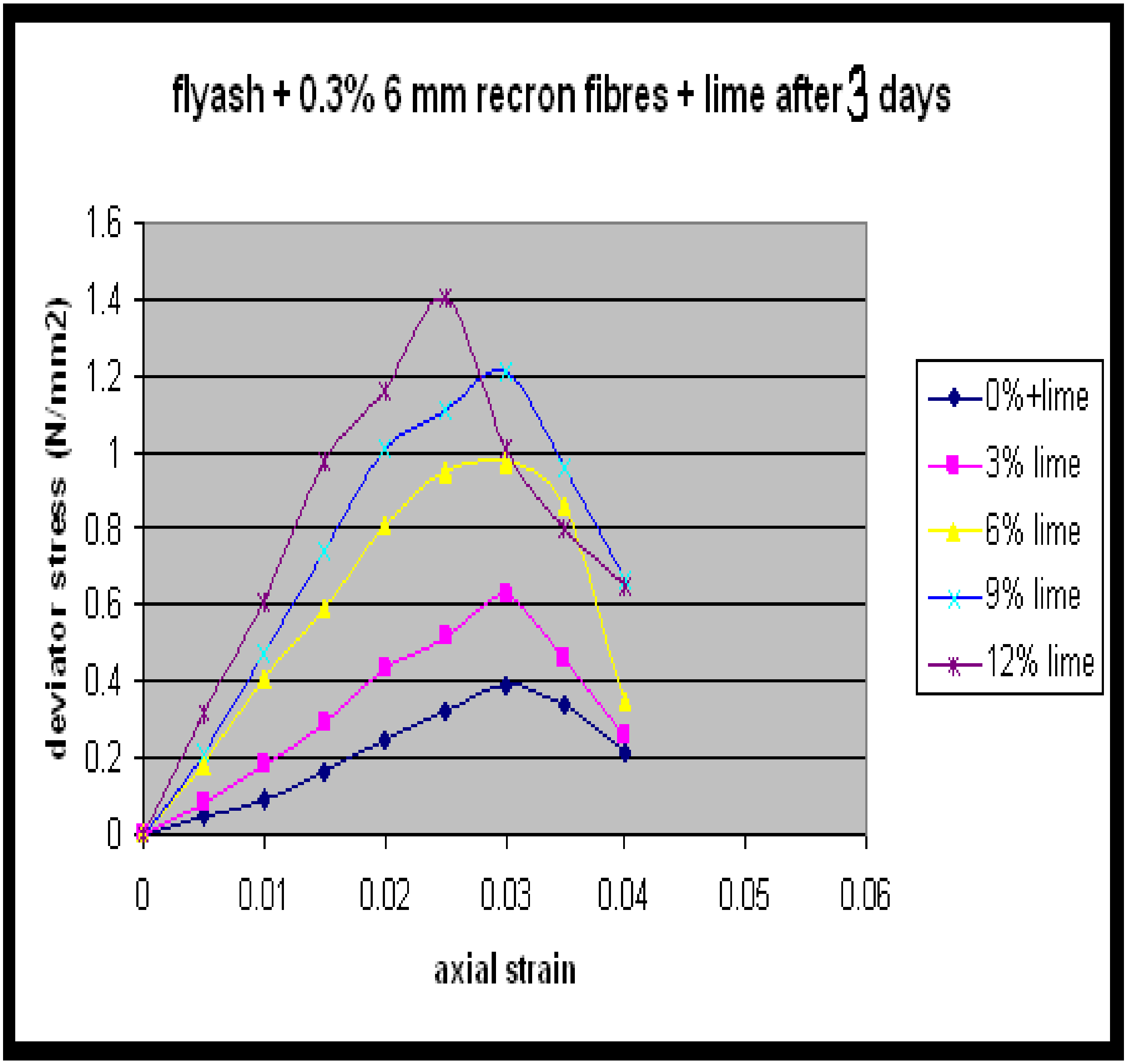


Fig 4.15: stress – strain relationship of lime stabilized reinforced flyash

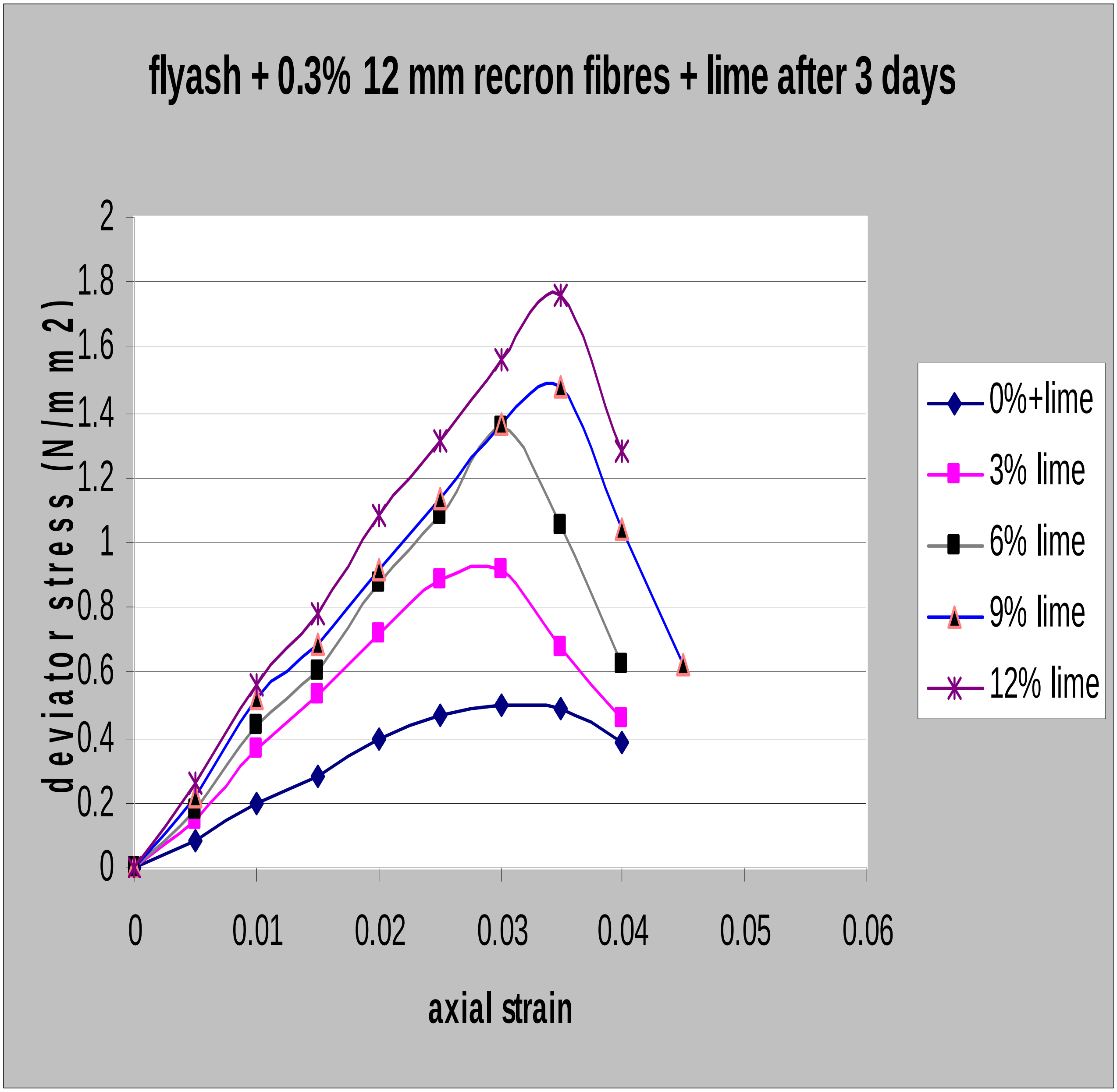


Fig 4.16: stress – strain relationship of lime stabilized reinforced flyash

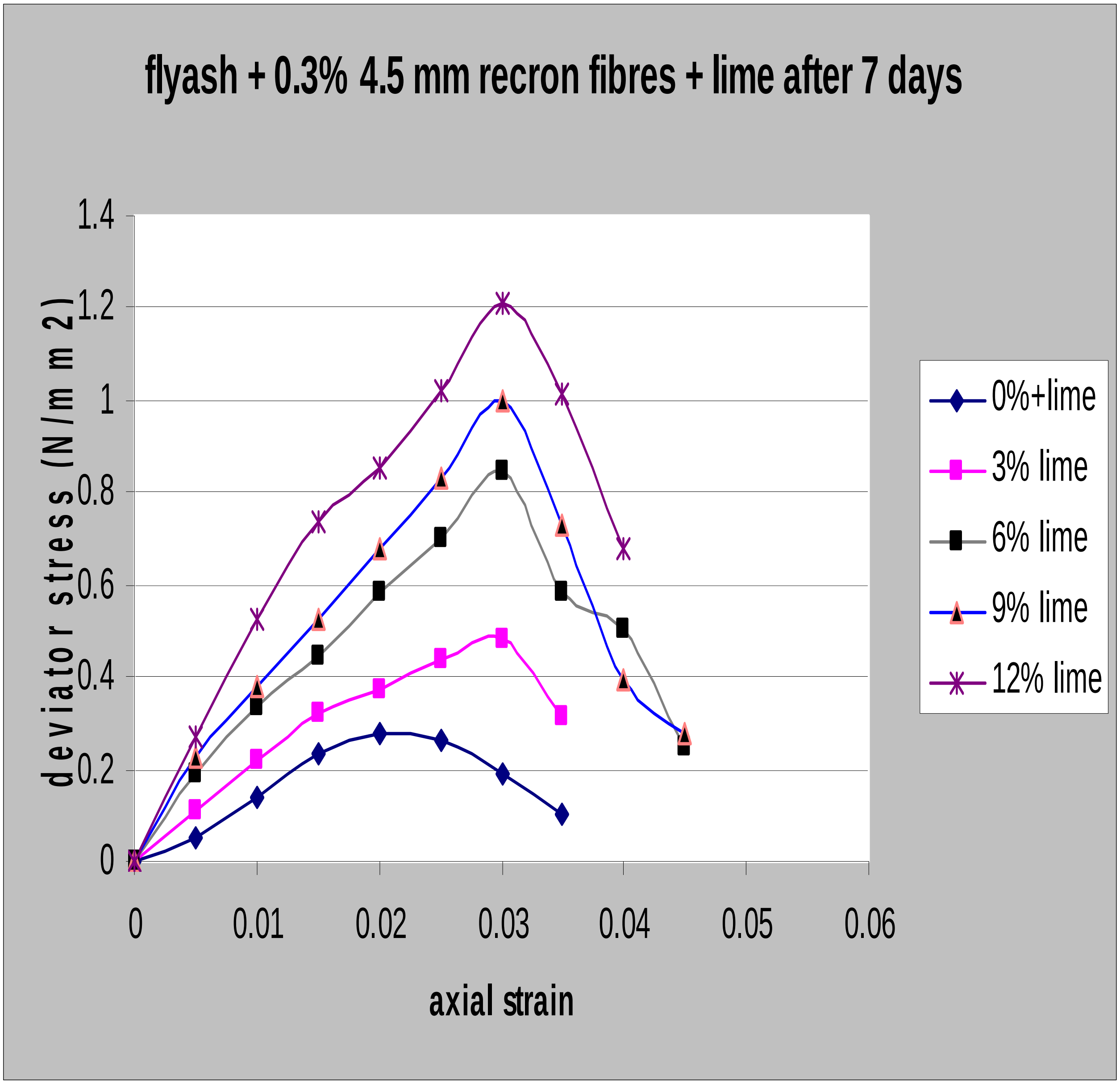


Fig 4.17: stress – strain relationship of lime stabilized reinforced flyash

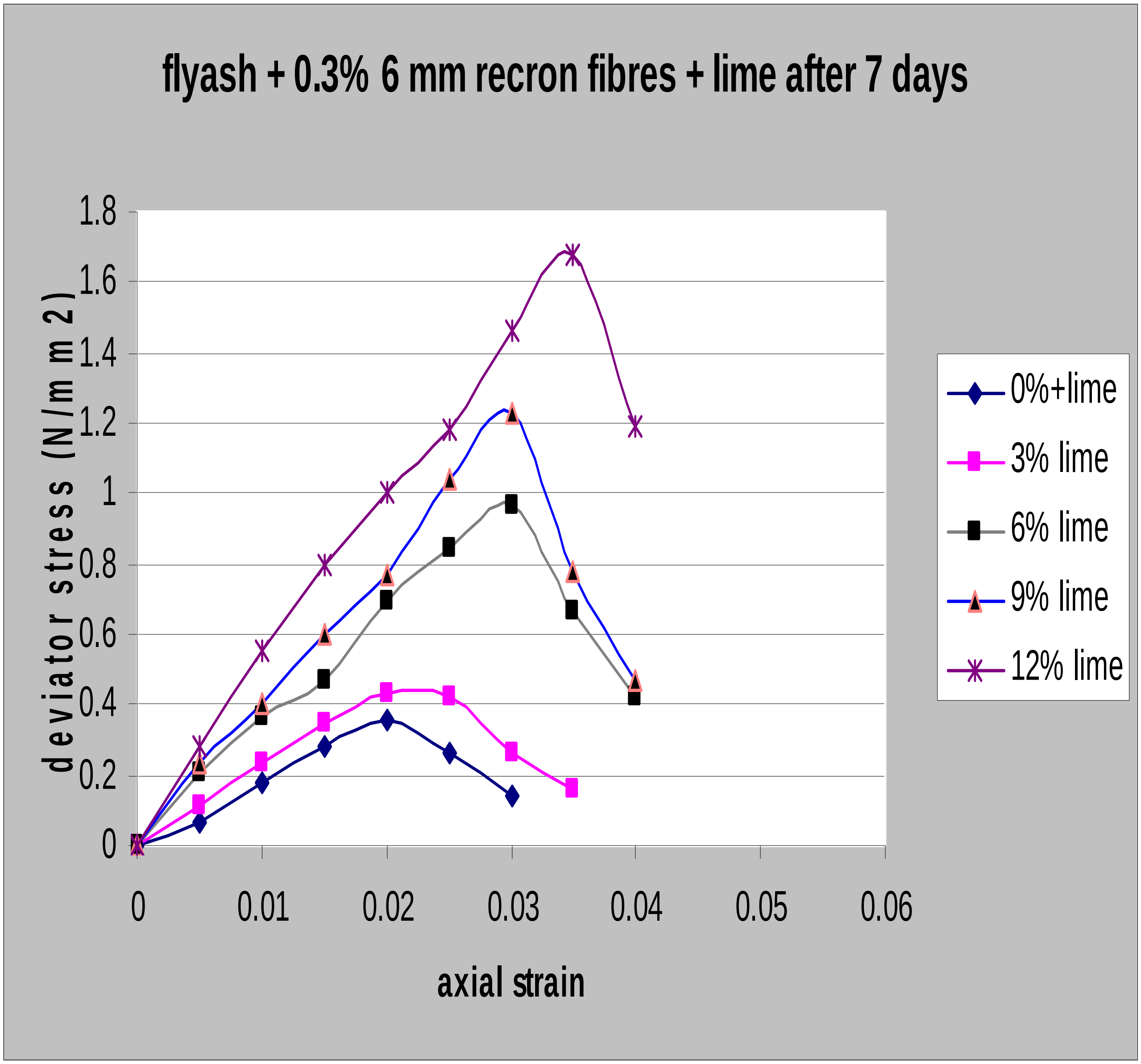


Fig 4.18: stress – strain relationship of lime stabilized reinforced flyash

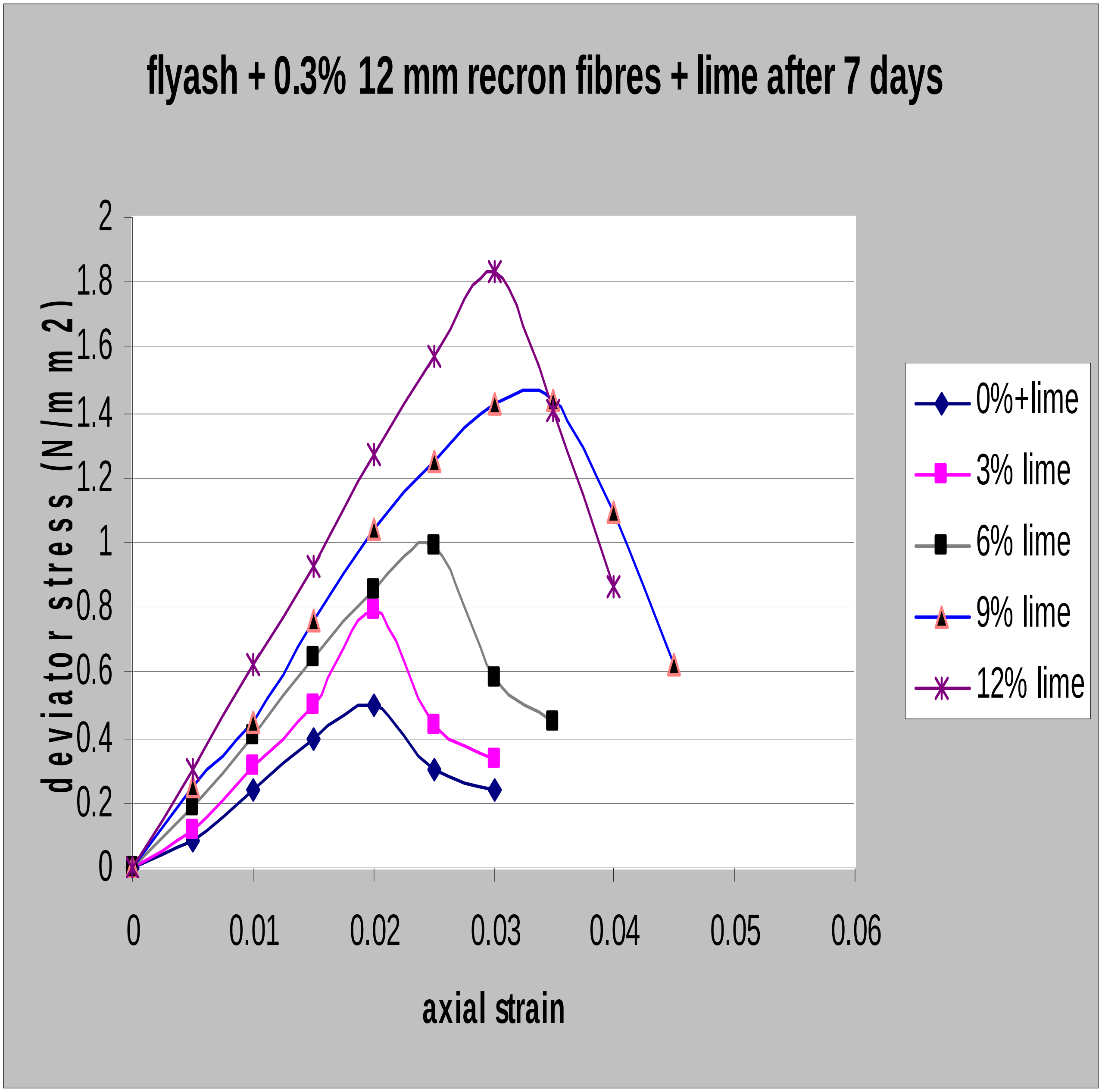


Fig 4.19: stress – strain relationship of lime stabilized reinforced flyash

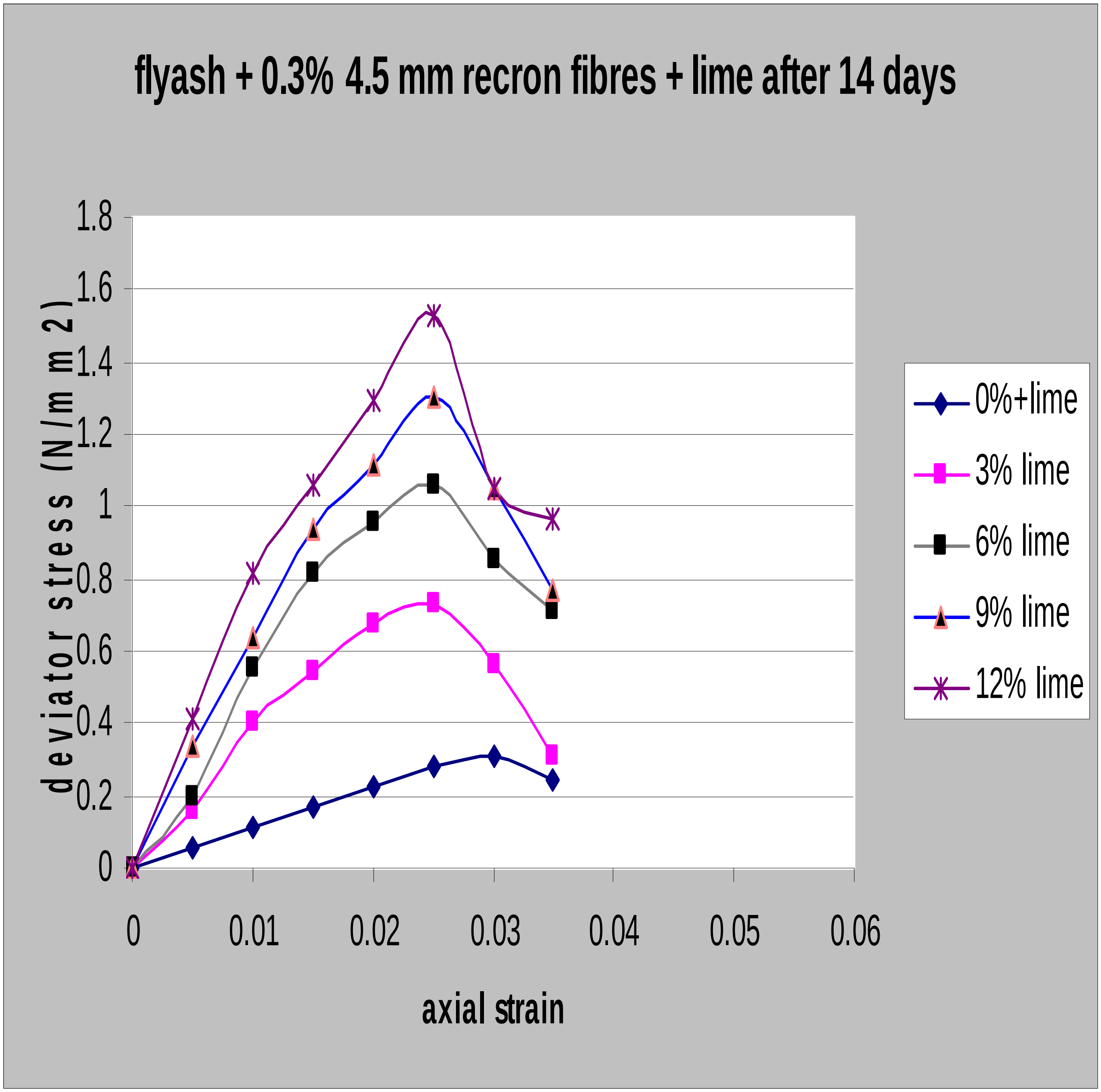


Fig 4.20: stress – strain relationship of lime stabilized reinforced flyash

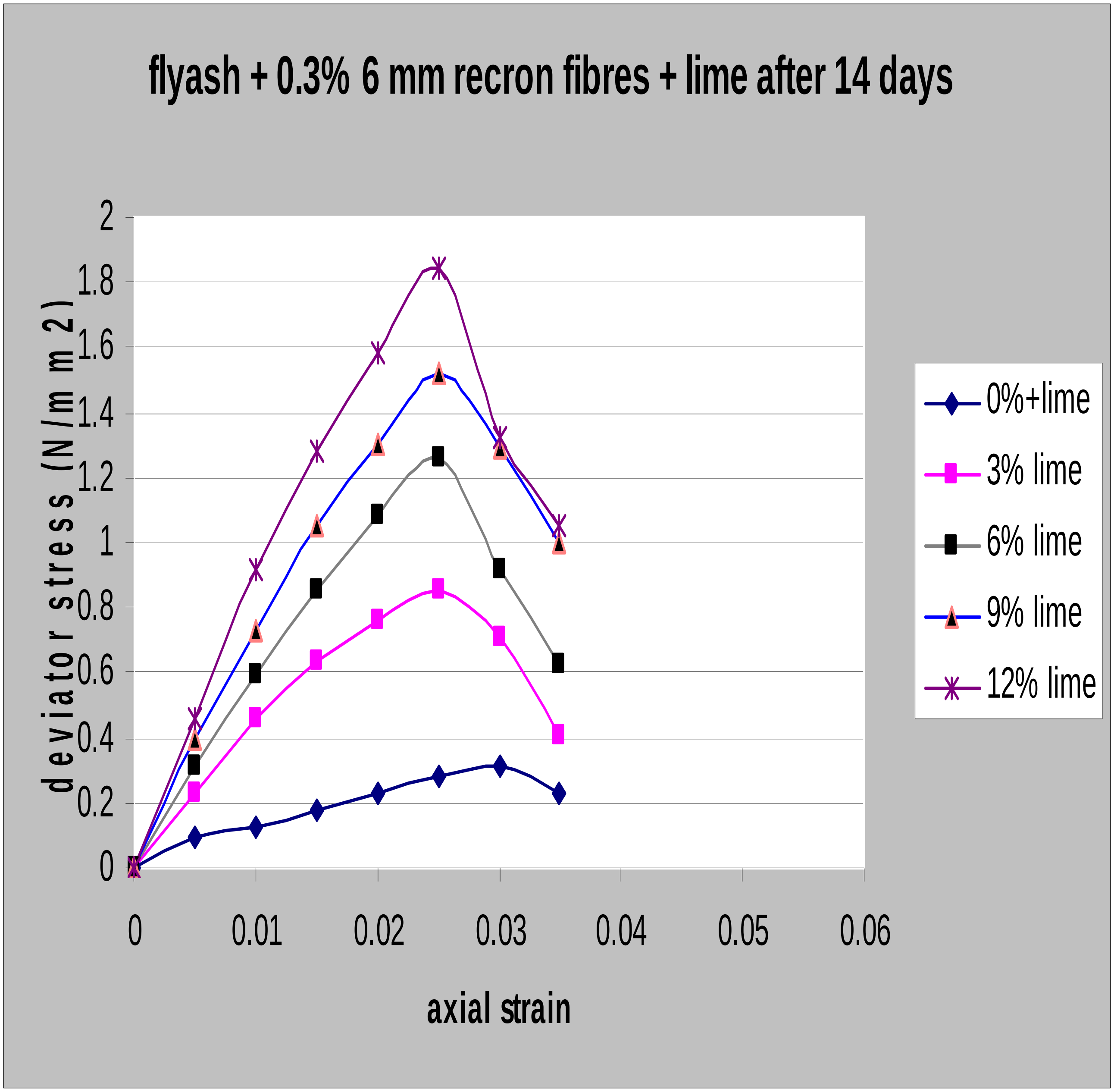


Fig 4.21: stress – strain relationship of lime stabilized reinforced flyash

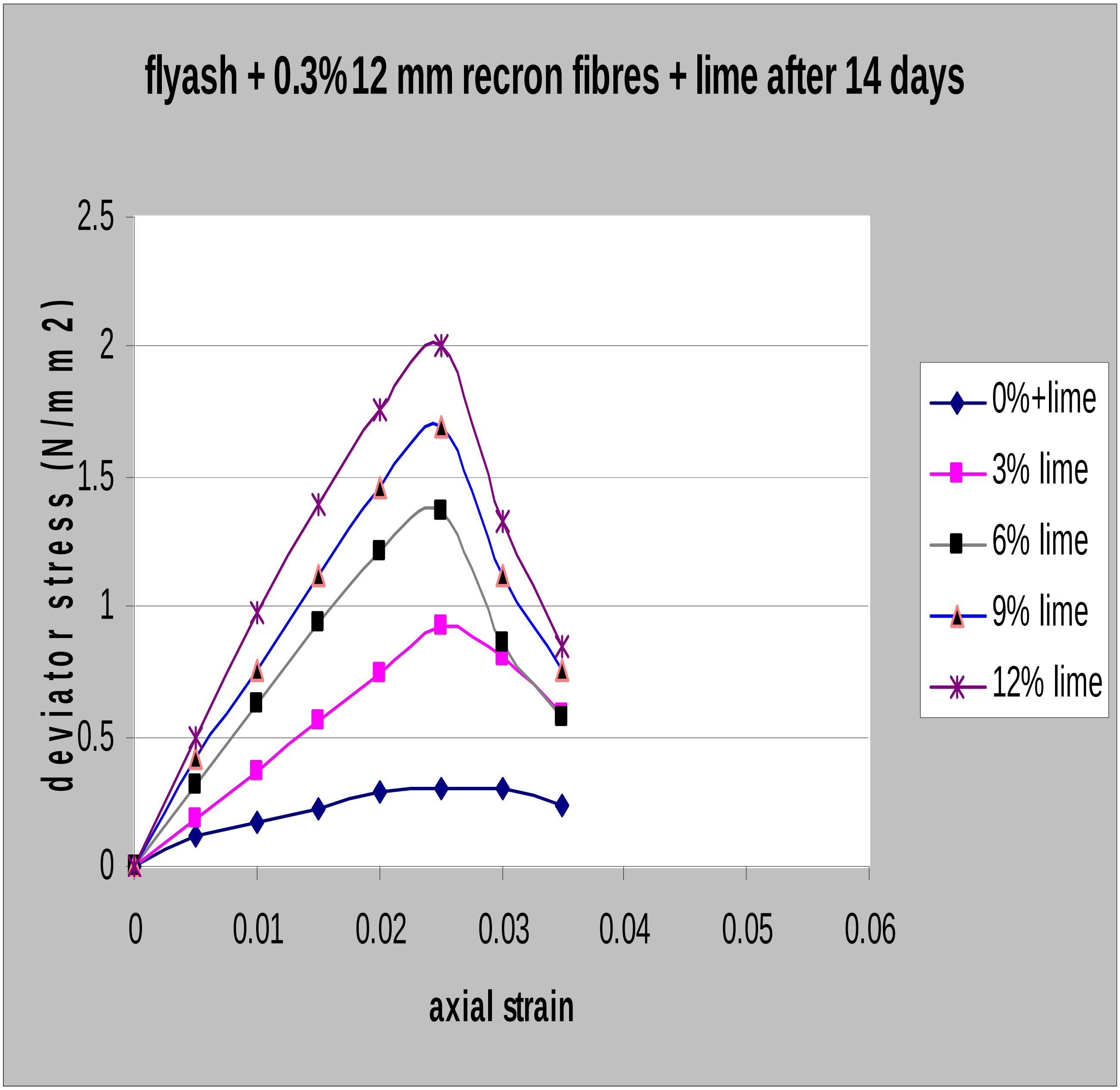


Fig 4.22: stress – strain relationship of lime stabilized reinforced flyash

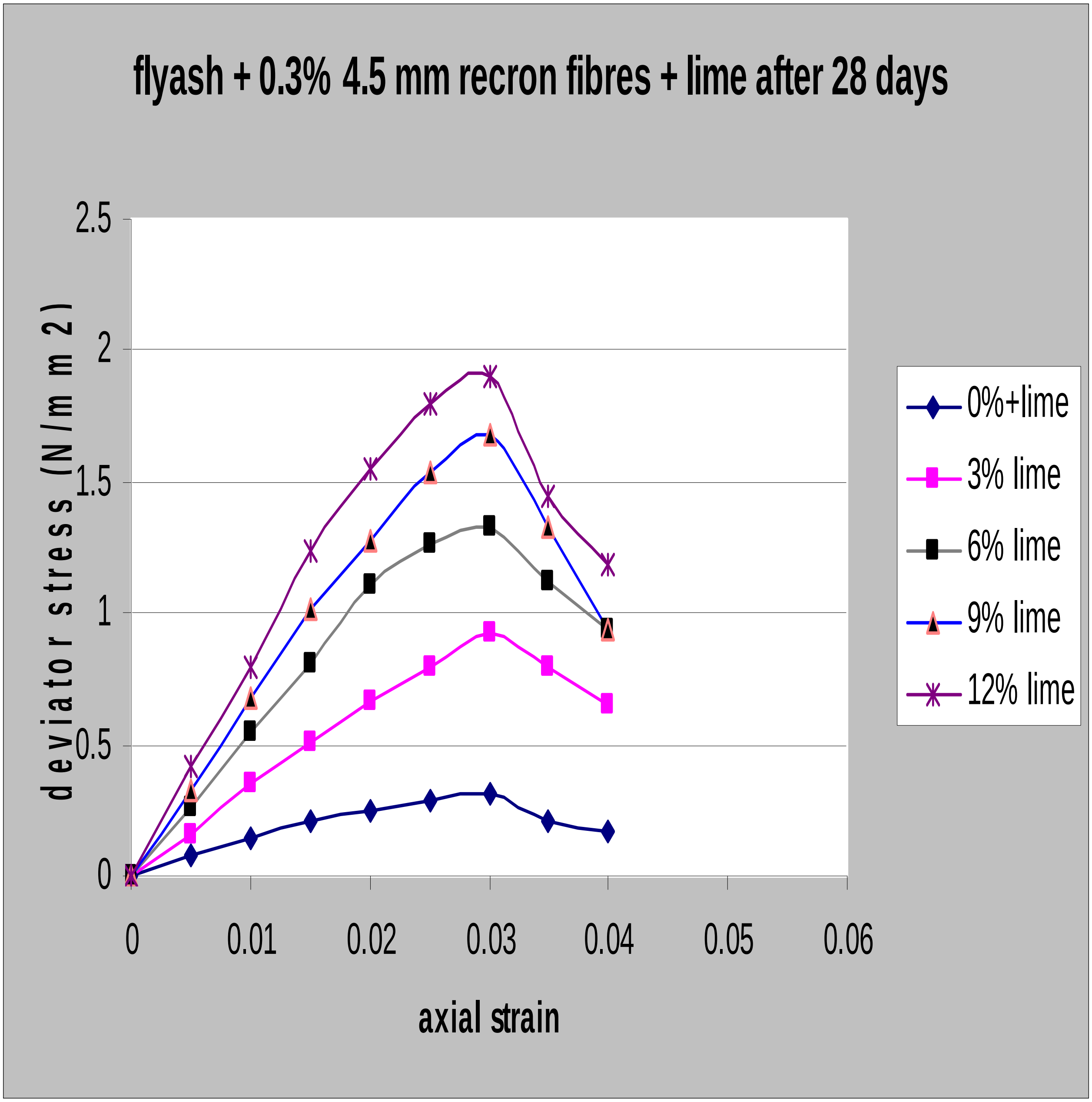


Fig 4.23: stress – strain relationship of lime stabilized reinforced flyash

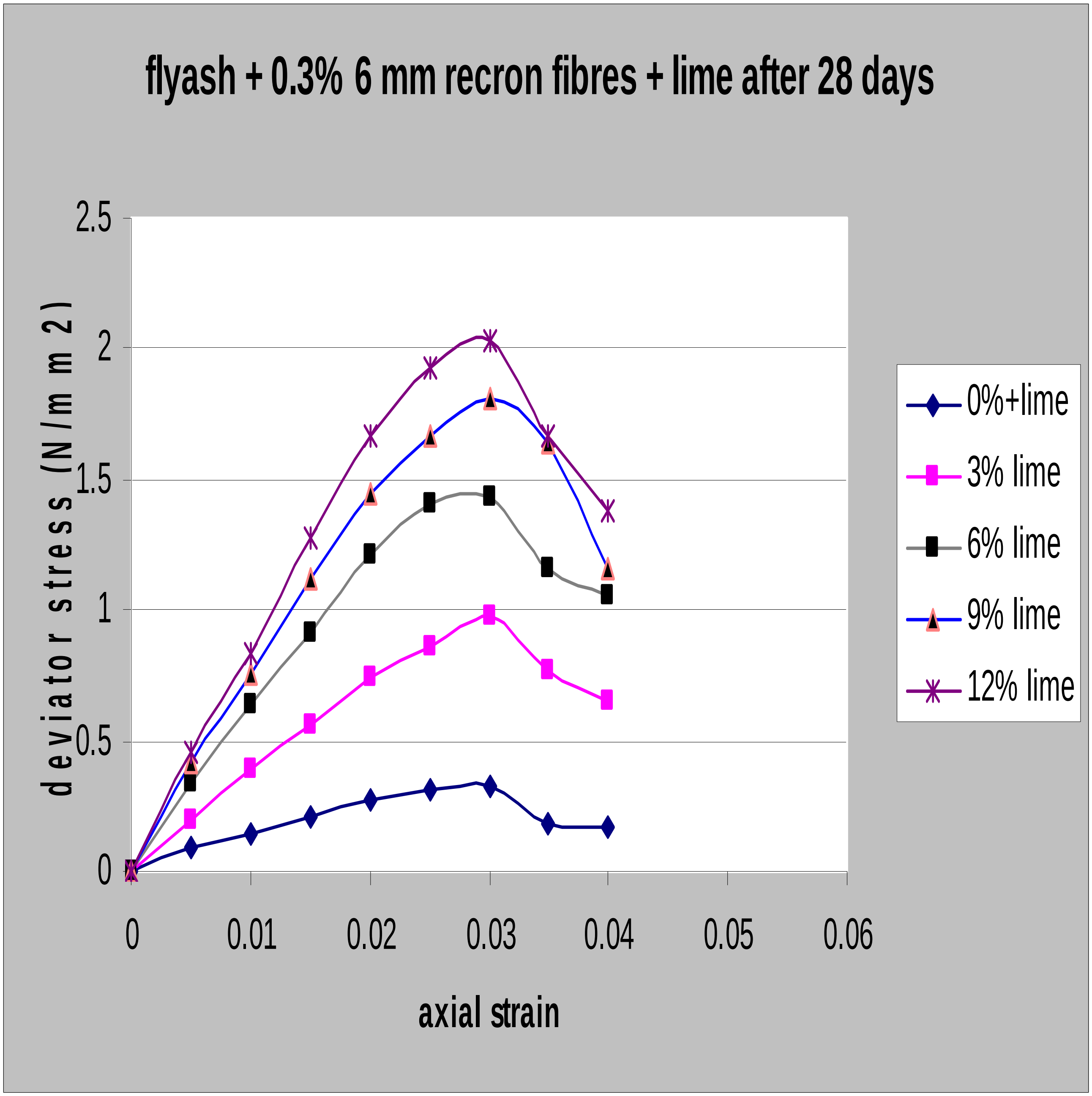


Fig 4.24: stress – strain relationship of lime stabilized reinforced flyash

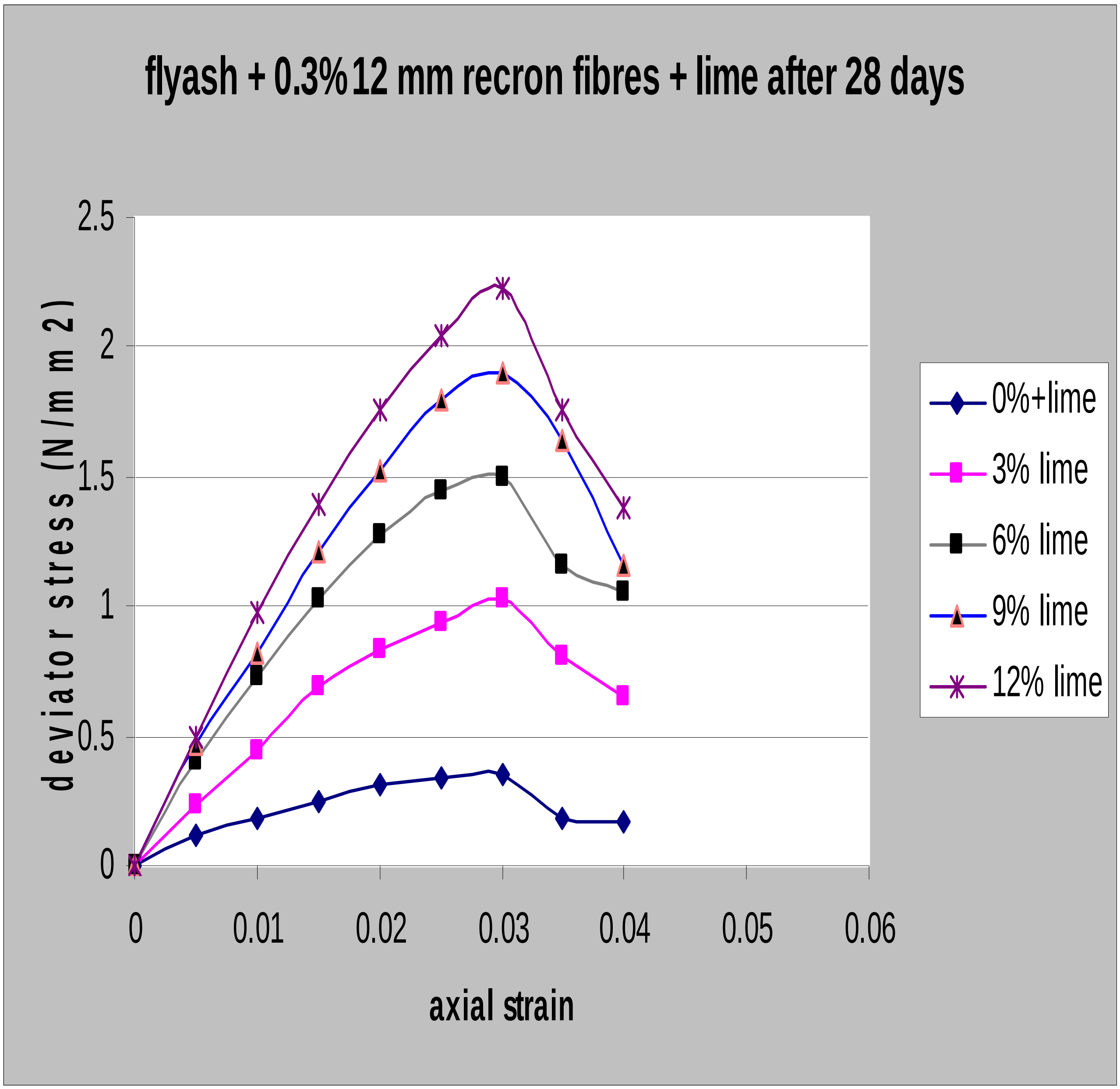


Fig 4.25: stress – strain relationship of lime stabilized reinforced flyash

CHAPTER 5

CONCLUSION

CONCLUSION

The effect of lime and fiber reinforcements in modifying the stress – strain properties of compacted flyash has been studied in a series of triaxial tests. The lime content in the compacted flyash was varied from 0% to 12 % and the fiber content was varied from 0% to 0.5%. Based on the findings of the present investigation the following main conclusion are arrived.:

- Flyash is a more or less well-graded material having low specific gravity compared to conventional earth material.
- Flyash possesses no plasticity, indicating that the inter-particular forces are either absent or negligible.
- Addition of lime increases the OMC of the mix.
- These stress-strain curves show three distinct portions. Initially the stress increases linearly with axial strain, thereafter, a mild ono-linear increasese of stress occurs up to a peak value and finally the deviator stress tend to decrease with further increases in axial strain.
- At a given confining pressure and cement the increase in the fiber content in the mix increases the failure stress. Initially the rate of increases is high which then slows down.

Both lime and Recron fibres are effective in increasing the strength of the compacted flyash. This also modifies the stress-strain behaviour of the mass. The utilization of flyash in conjunction with fiber reinforcement and lime as a stabilising agent in geotechnical costructions will solve problems in one effort viz. elimination of solid waste and provision of a much needed construction material.

CHAPTER 6

REFERENCES

REFERENCES

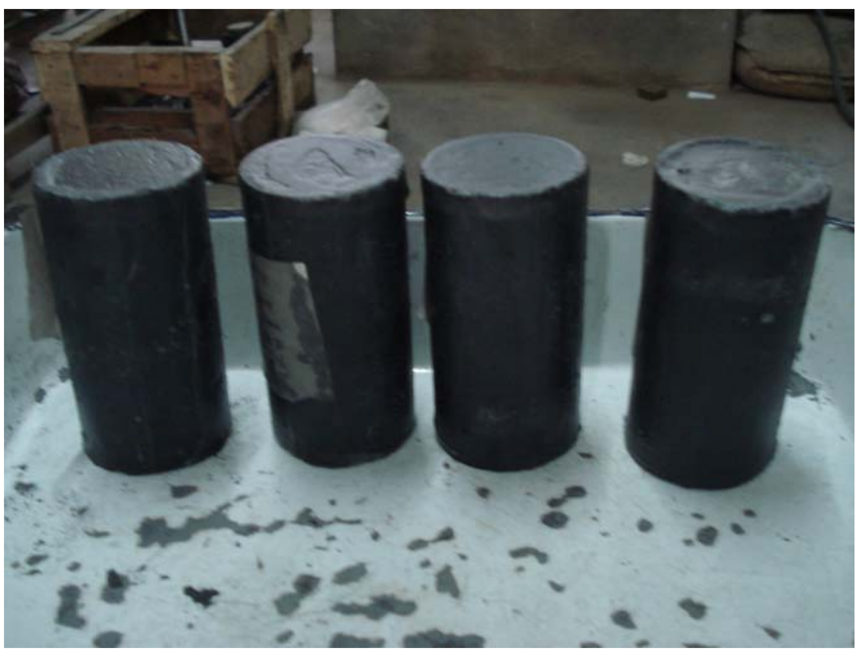
1. Dr. B.C. PUNMIA, "Soil Mechanics and Foundation Engineering".
2. G.V.RAO, K.K. GUPTA AND R. KACHAHAWAH, "Triaxial behaviour of Geotextile reinforced sand".
3. GOPAL RANJAN, R.M. VASAN and H.D. CHARAN,"Mechanism of fiber reinforced soil state of art".
4. S.P. SINGH, D.P.TRIPATHY and M. SAI HARESH, " Response of Reinforced flyash under Triaxial Loading".
5. IS:2720(part II) "Undrained Triaxial Test"
6. IS:2720(part III) "Determination of Specific gravity"

CHAPTER 7

PHOTOGRAPHS

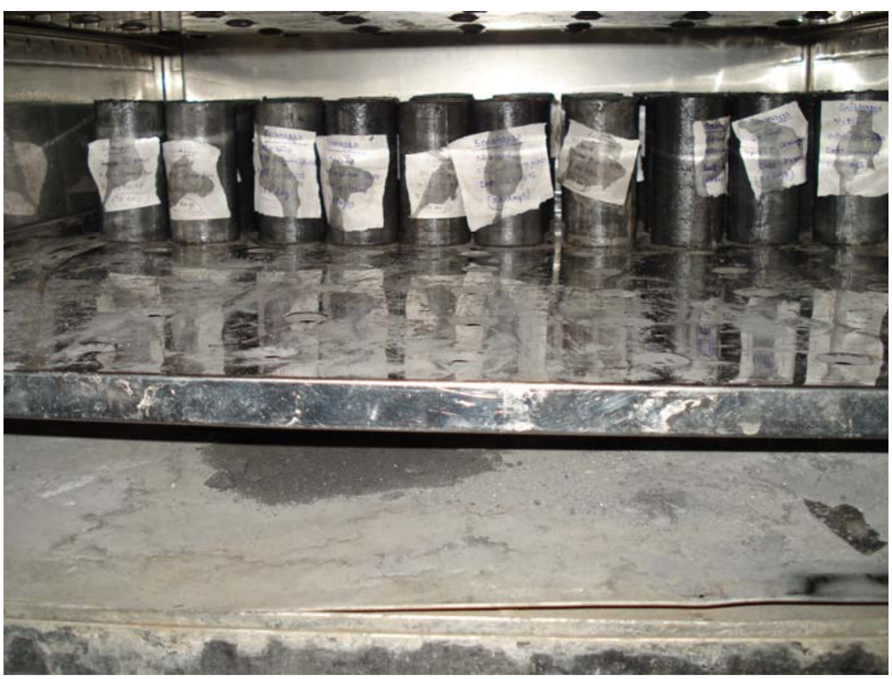
Triaxial testing Machine

Testing of sample



Samples

Samples after failure



Samples inside humidity chamber