



# ROHINI

**COLLEGE OF ENGINEERING AND TECHNOLOGY**

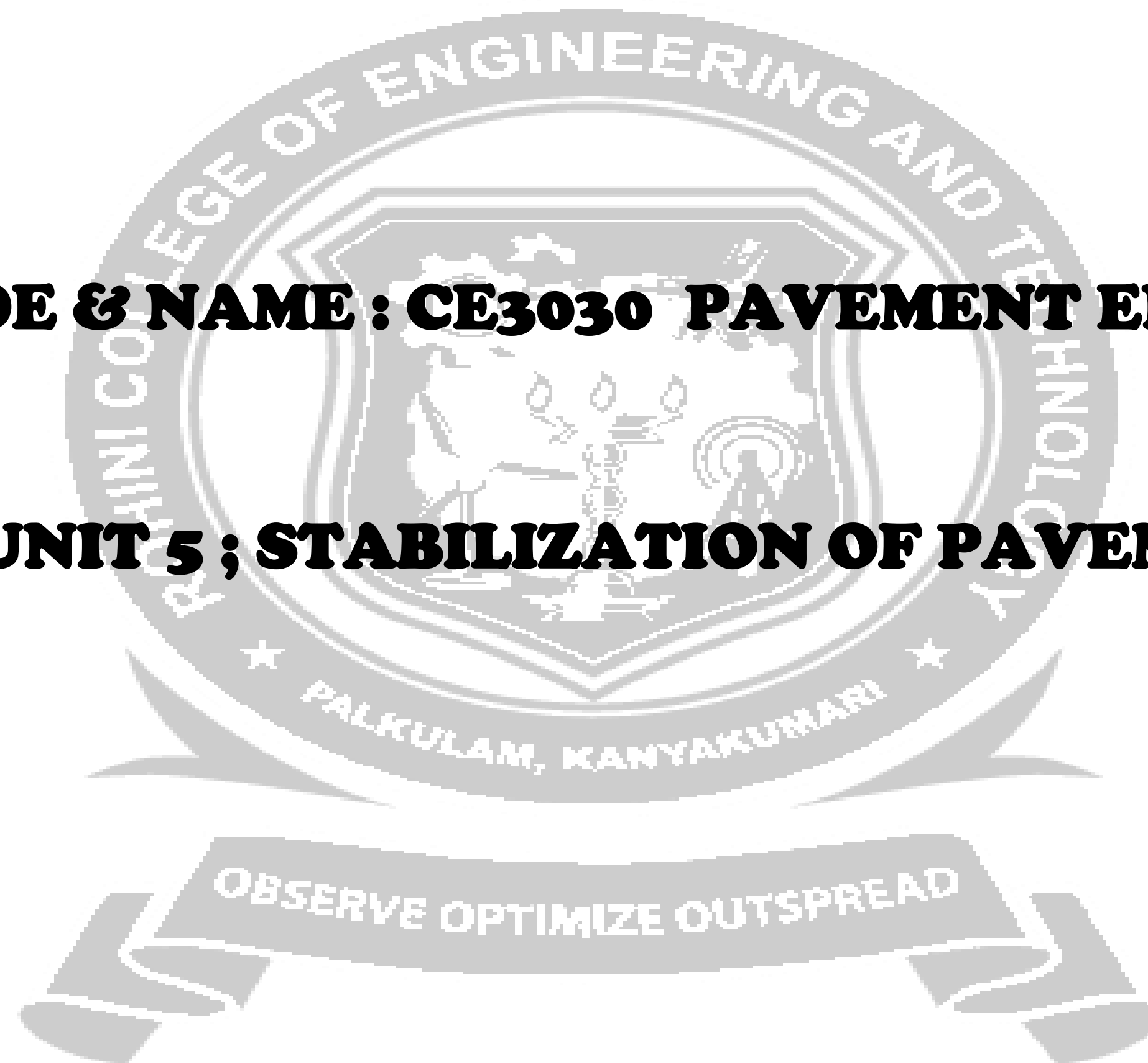
Approved by AICTE and affiliated to Anna University, (An ISO Certified Institution)

Accredited by NAAC with A+ Grade



**COURSE CODE & NAME : CE3030 PAVEMENT ENGINEERING**

**UNIT 5 ; STABILIZATION OF PAVEMENTS**



## CHAPTER 2.3: STABILIZED PAVEMENT MATERIALS

### I. An Introduction to Stabilization

- Pavement Design is based on the premise that specified levels of quality will be achieved for each soil layer in the pavement system.
- So that each layer must:
  - resist shearing within the layer,
  - avoid excessive elastic deflections, and
  - prevent excessive permanent deformation through densification.
- Hence, the quality of the material in each layer should meet the specification requirement.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

- However, in many instances fulfilling the specification requirement is challenging due to:
  1. The absence of quality material in the project vicinity.
  2. The higher cost of transporting quality materials.
- Hence, improving the property of the available material will become mandatory or economical.
- **Stabilization** is the process of altering/ improving the properties of sub-grade and pavement materials either by blending and improving particle gradation (**Mechanical Stabilization**) or by using stabilizing additives to meet the specified engineering properties (**Chemical Stabilization**).



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### ▪ Objective of Stabilization:

- To *improve the strength* of weak pavement materials. e.g. subgrade, subbase, base and low cost road surface.
- To *improve volume stability, shrinkage and swelling* of highly plastic materials under moisture.
- To *improve durability*: increase resistance to erosion, weathering or traffic.
- To *improve high permeability, poor workability*, etc. of the existing pavement materials.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### Methods of Stabilization

Stabilization is achieved by two methods:

1. **Mechanical Stabilization** is stabilization where the stability of the soil is improved by blending the available soil with imported soil or aggregate to obtain the desirable particle size distribution.
  - It is achieved by blending and grading with imported materials.
2. **Chemical Stabilization** is stabilization where stabilizing agents/ chemicals are used for bringing desired properties of the pavement materials.
  - It is achieved by using stabilizing agents: Bitumen and Hydraulic Binders (e.g. Lime, Lime-Pozzolana, Cement, etc.).



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### **Factors Considered in Selection of Stabilization**

- Even though we have different methods of stabilizations, a proper selection among the alternatives should be made based on the following factors:

Factors affecting the selection of Stabilizing Agent:

1. Physical properties of the materials to be stabilized (PI & Gradation).
2. Availability of the stabilizing agent.
3. Economic feasibility of the different methods.
4. Ease of work procedure and workmanship or construction method.
5. Site condition, safety, curing time, etc.



## Chapter 3: Stabilized Pavement Materials

- Hence, according to ERA Pavement Design Manual, the selection of stabilizer based on the PI and gradation requirement:

Type of Stabilizer	Soil/ Material's Property					
	>25% Passing the 0.075mm Sieve			<25% Passing the 0.075mm Sieve		
	PI $\leq$ 10	10 $\leq$ PI $\leq$ 20	PI $\geq$ 20	PI<6 and PP<60	PI $\leq$ 10	PI>10
Cement	Yes	Yes	*	Yes	Yes	Yes
Lime	*	Yes	Yes	NO	*	Yes
Lime-Pozzolana	Yes	*	NO	Yes	Yes	*

- Note:1. \* Indicate that the stabilizer will have marginal effectiveness  
 2. PP (Plasticity Product) = PI X % passing 0.075mm sieve



	More than 25% Passing 75 $\mu$ m			Less than 25% Passing 75 $\mu$ m		
Plasticity Index	PI $\leq$ 10	10 $\leq$ PI $\leq$ 20	PI $\geq$ 20	PI $\leq$ 6 (PI $\times$ % passing 0.075 mm $\leq$ 60)	PI $\leq$ 10	PI $\geq$ 10
<b>Form of Stabilization</b>						
Cement and Cementitious Blends						
Lime						
Bitumen						
Bitumen/Cement Blends						
Granular						
Miscellaneous Blends						
Key	Usually suitable		Doubtful		Usually not suitable	



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

According to the above table and diagram:

1. If the soil has high plasticity, this indicate that it contains more clay minerals which can readily react with lime, hence lime is the best stabilizing agent.
2. Cement is more difficult to react with high plastic materials but good stabilizing agent for low plastic materials.
3. Reactive silica in the form of pozzolana (Lime-Pozzolana) can be added to the soil with low plasticity to make them suitable for lime stabilization.
4. Bitumen is more suitable for granular materials with low PI.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### II. Lime Stabilization

- Lime is a cementing material found in different forms:
  1. Hydrated (Slaked) lime [Calcium Hydroxide  $\text{Ca(OH)}_2$ ]
  2. Quicklime [Calcium Oxide ( $\text{CaO}$ )]
  3. Dolomite lime (Calcium-Magnesium Carbonate)
  4. Agricultural lime (Calcium Carbonate)
- Agricultural lime is not suitable for stabilization, and dolomite lime is not usually as effective as hydrated lime or quicklime.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

- Hence, the commercially available lime for Stabilizations are:
  - a. Hydrated lime in dry very fine powder form
  - b. Hydrated lime in slurry form
  - c. Quick lime

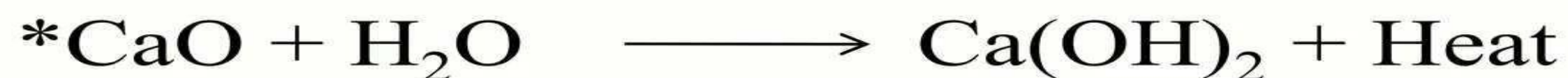


## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

- The following table summarizes the properties of the above mentioned lime forms:

	Hydrated Lime	Quick Lime	Slurry Lime
Composition	Ca(OH) <sub>2</sub>	CaO*	Ca(OH) <sub>2</sub>
Forms	Very fine powder	Granular	Slurry
Equivalent Ca(OH) <sub>2</sub> / Unit Mass	1	1.32	0.56 to 0.33**
Bulk Density (tone/m <sup>3</sup> )	0.224 -0.271	0.507	0.608

NB:



\*\* Moisture Content of slurry may vary from 80% to over 200%















## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### ■ Mechanism of Stabilization by Lime [Chemical Reaction]

Untreated clays have a molecular structure similar to some polymers, and give plastic properties. The structure can trap water between its molecular layers, causing volume and density changes.



**Clay after treatment with lime**



**Un-stabilized Clay Particles**

In treated clays, Calcium atoms (from Lime) have replaced Sodium and Hydrogen atoms producing a soil with very friable characteristics. On-going reaction with available Silica and Alumina in the soil forms complex cementitious materials (the pozzolanic effect).



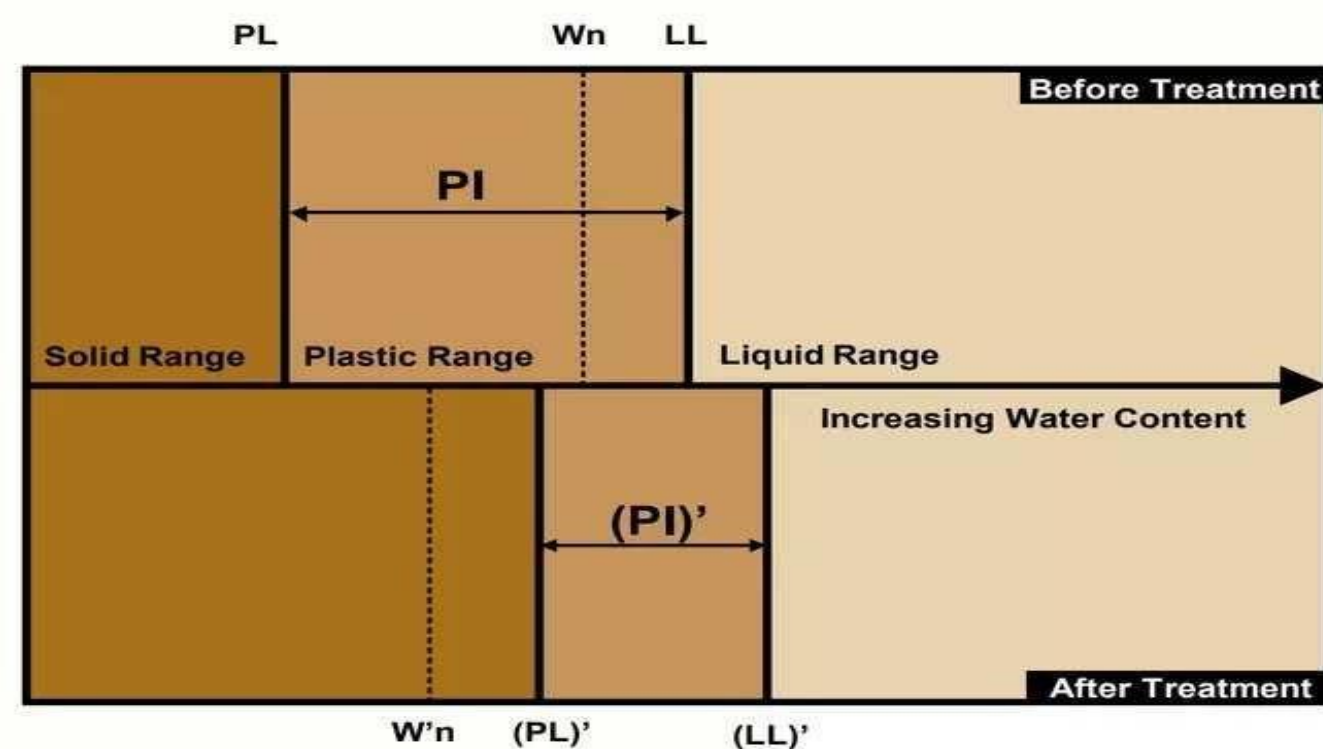
# Soil Before And After Treatment





# EFFECT OF LIME ON ENGINEERING PROPERTIES OF SOILS

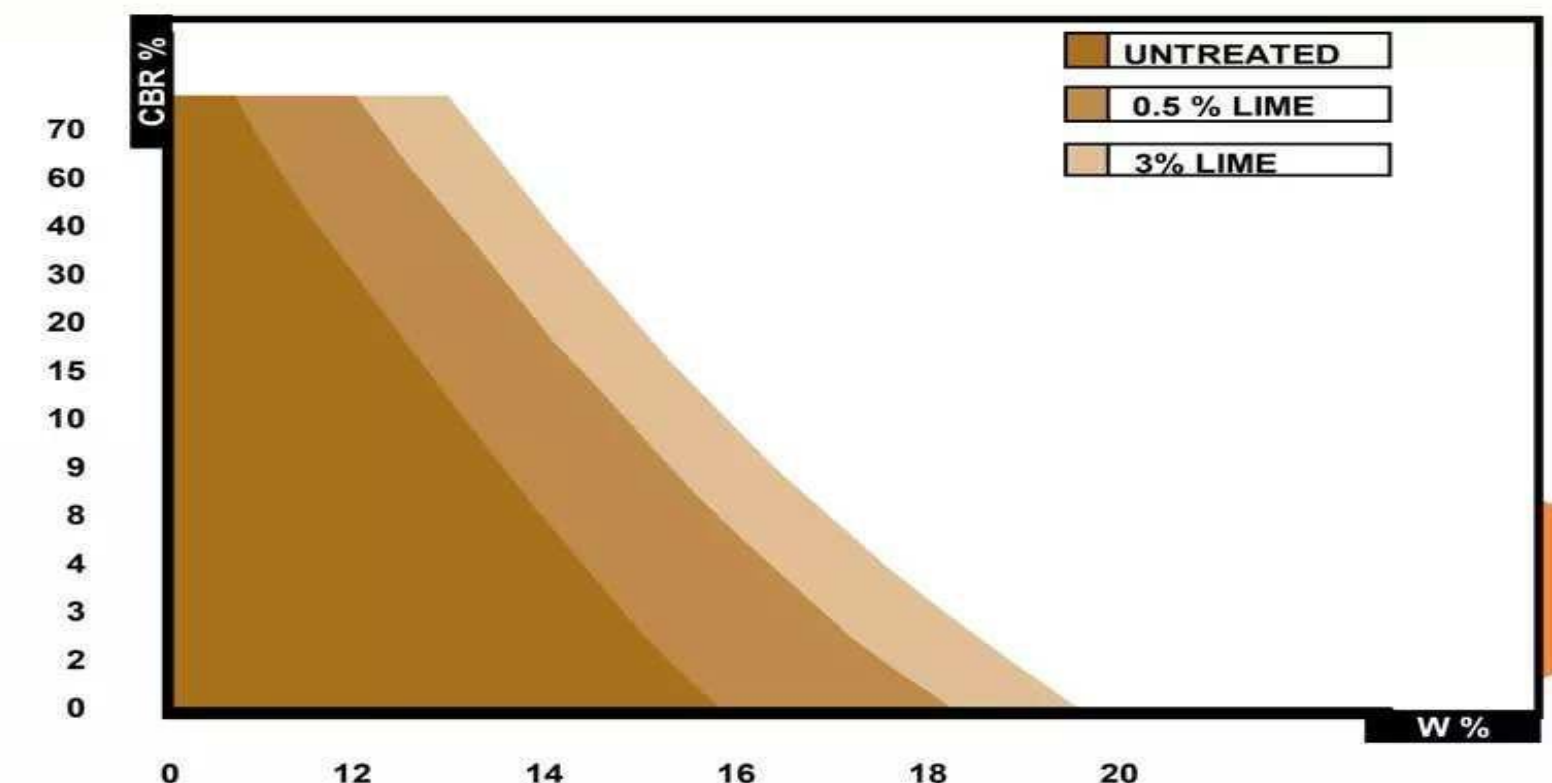
## Immediate Impact on **Plasticity, Workability,** and **Load Bearing Capacity**



**Drying:** The water content is reduced from W<sub>n</sub> to W'<sub>n</sub>

**Plasticity:** Treatment with lime displaces the solid range to the right. This enables the soil to accept a higher water content while remaining solid. The plasticity index  $PI = LL - PL$  is reduced.

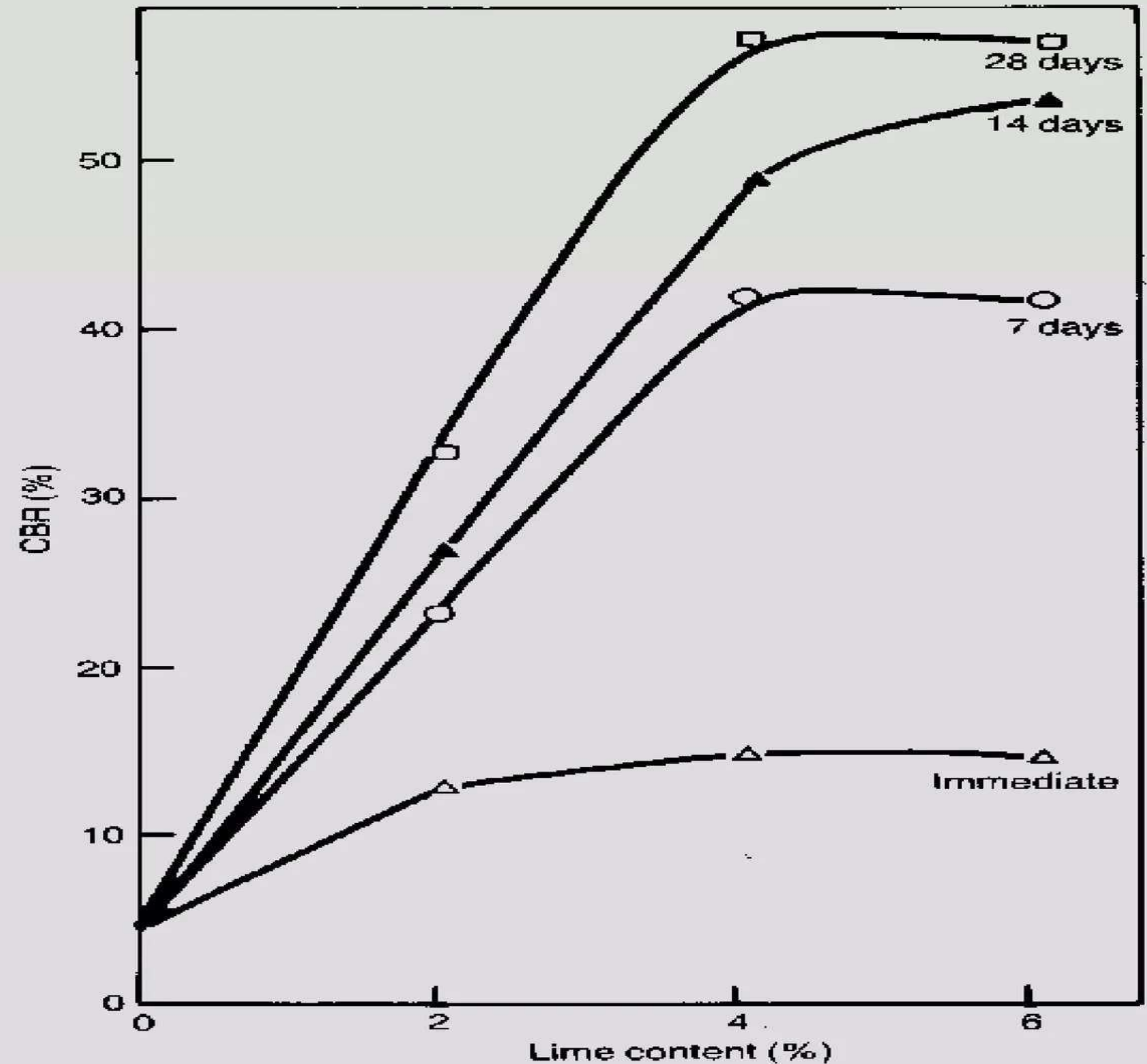
**Increase in carrying capacity after liming:** After 2 hours with an initial water content of 14% the CBR index increased from 9 to 30 (0.5% lime added) and 70 (3% lime added) respectively.





### ○ ***Lime stabilization:***

- Effect of lime content and time on the CBR values of lime stabilised soil.





## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### III. Cement Stabilization

- **Cement Treated Base:** an intimate mixture of native and/or manufactured aggregates with measured amounts of cement and water that hardens after compaction and curing form a strong and durable paving material.
- There are two types cement stabilized materials in highway construction:
  1. **Soil Cement:** it contains enough cement (usually  $> 3\%$ ) to pass standard durability tests and achieves significant strength increase.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

**2. Cement Modified Soil** an unhardened or semi-hardened mixture of soil, water, and small quantities of cement.

- There are different types of cement in use.
- However, regardless of the type, cement acts both as a **cementing agent** and a **modifier**.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

- In primarily coarse graded soils, the cement paste bonds the soil particles together by surface adhesion forces between the cement gel and the particle surfaces.
- In fine-grained soils, the clay phase may also contribute to the stabilization process through reaction of the free lime from the cement.
- In the second case, cement acts as a modifier by reducing the plasticity and expansion properties of the soil.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### *Soils Suitable for Cement Stabilization*

- As discussed before a wide range of soil types may be stabilized using cement. However, it is generally more effective and economical to use it with:
  1. Granular soils due to:
    - the ease of pulverization and mixing
    - the smaller quantities of cement required
  2. Fine grained soils of low to medium plasticity can also be stabilized, but not as effectively as coarse-grained soils.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### ○ **Cement Stabilisation:**

*General guidelines on cement requirement to stabilise soil:*

Soil type	Amount of cement (%)	
	By weight	By volume
A-1-a	3-5	5-7
A-1-b	5-8	7-9
A-2	5-9	7-10
A-3	7-11	8-12
A-4	7-12	8-13
A-5	8-13	8-13
A-6	9-15	10-14
A-7	10-16	10-14





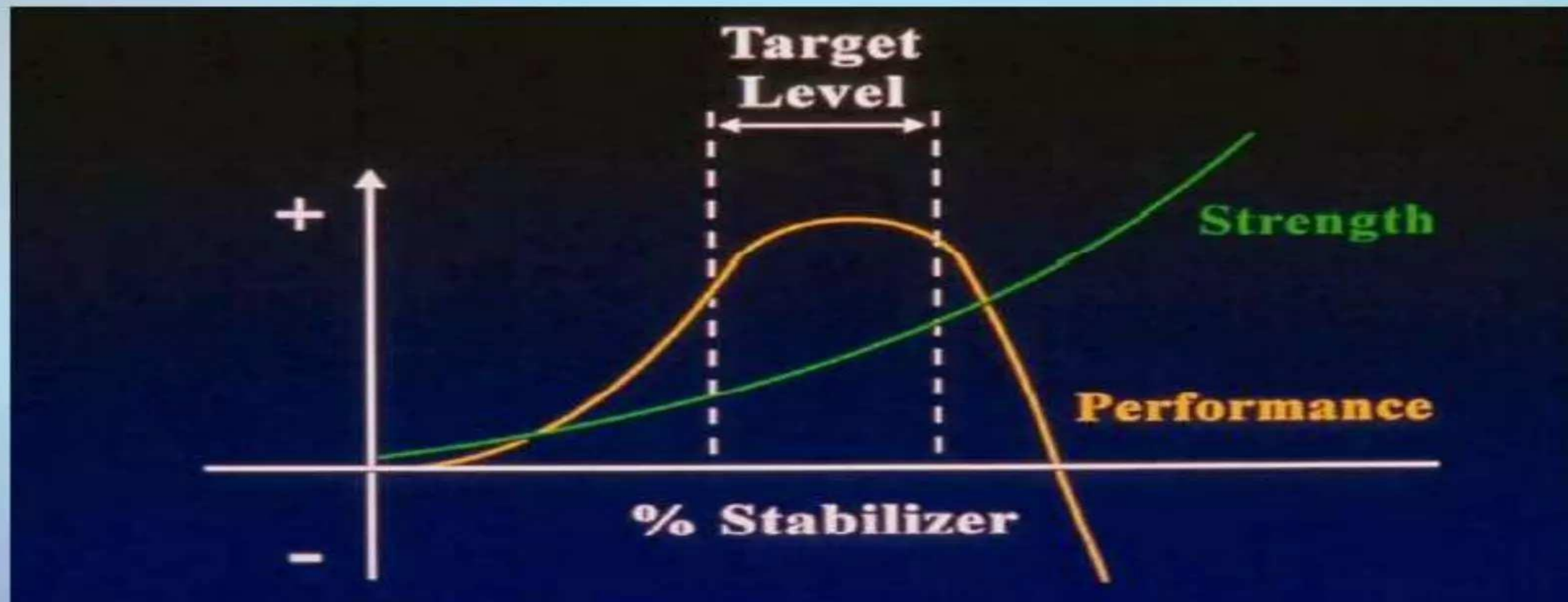


## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

- Advantages of Cement Stabilization:
  - Decreased pavement thickness compared to unbound aggregate base.
  - Structural properties maintained under varying moisture conditions.
  - High stiffness inhibits fatigue cracking and rutting of asphalt surface.
  - Sustainable paving option.

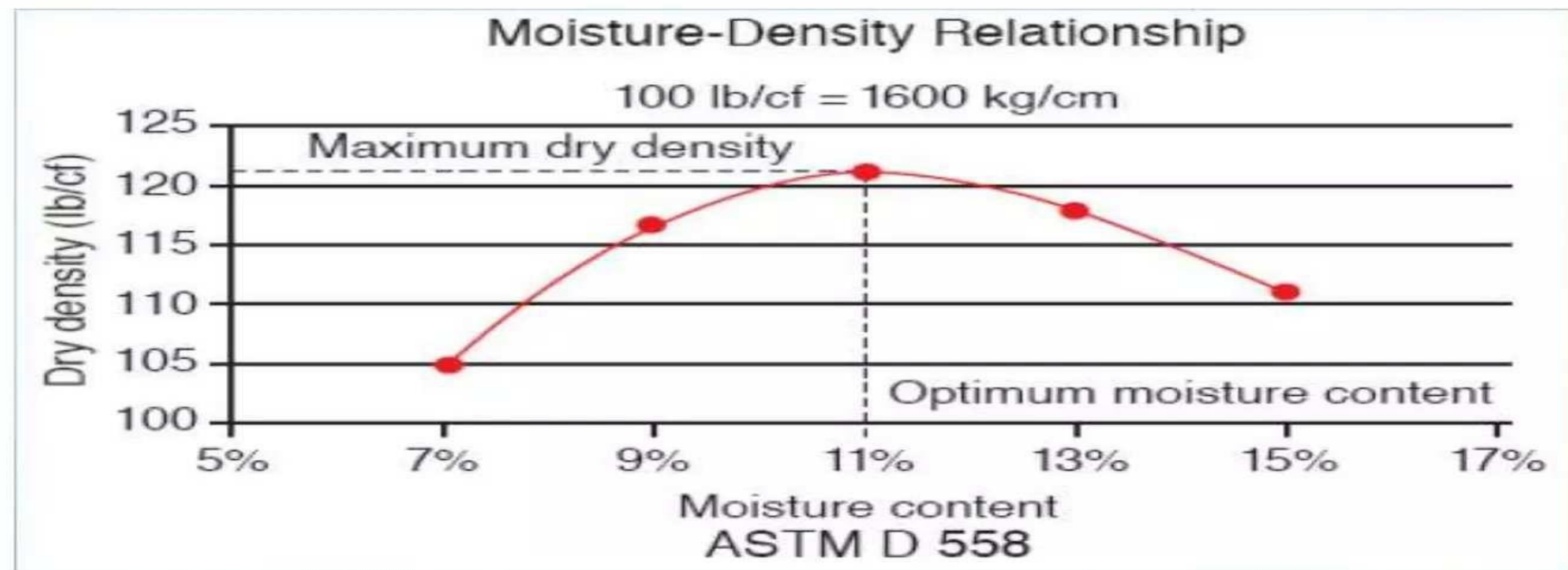


## MIX DESIGN PHILOSOPHY

**Strive for a Balance Between Strength and Performance**



- Mixture design step for ***Lime/ Cement Stabilized Materials***:
  1. Determine moisture-density relationship:
    - Select expected median cement content (e.g. 6% by estimated dry weight),
    - Perform standard or modified Proctor test,
    - Construct moisture-density curve,
    - Determine optimum moisture content and maximum dry density.





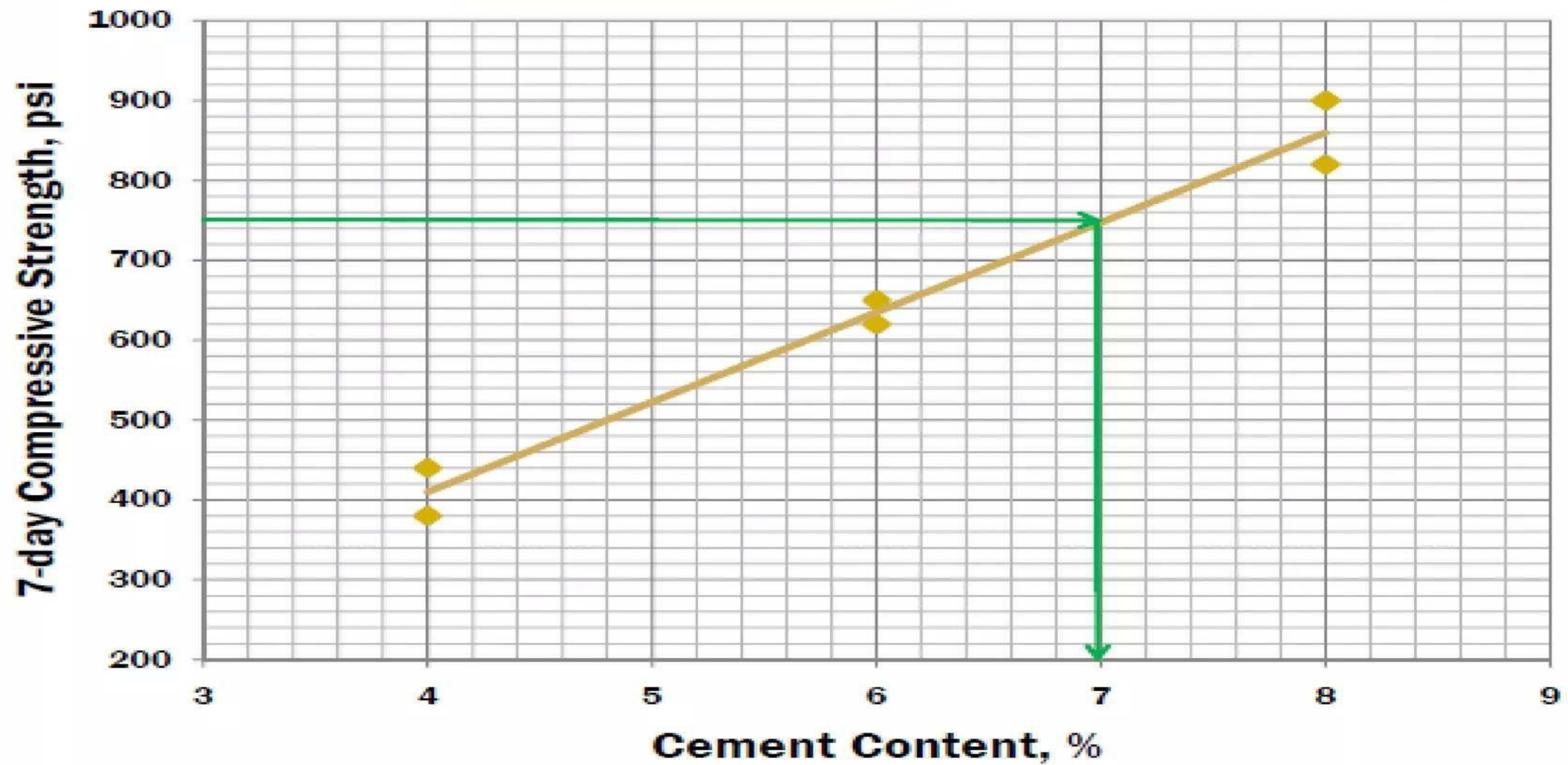
## 2. Mold specimens for compressive strength testing:

- Select range of cement contents (e.g. 4%, 6% and 8% by dry weight of material).
- Use OMC (Optimum Moisture Content) from Step 1 and mold two specimens per cement content.
- Perform compressive strength testing.
- Plot Cement content versus compressive strength.





# Strength vs. Cement Content





## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

3. Determine moisture-density relationship of target cement content.
  - Perform standard or modified Proctor test.
  - Construct moisture-density curve.
  - Determine optimum moisture content and maximum dry density.



## Chapter 3: Stabilized Pavement Materials

- There are two construction methods:
  1. Plant Mix
  2. Road Mix (in-place)
- 1. Plant Mix: Pug mill
  - High production.
  - High mobilization & demobilization cost.





## 2. Road Mix

- In-situ or mixed in place materials.
- Dry or slurry cement application method.



Slurry spread



Dry spread



- Road mix procedures:
  1. Spread the cement in predefined or calculated amount.
  2. Add water if necessary based on the method of mixing we use and then mix the cement-soil blend.
  3. Grade and compact using suitable rolling equipment.
  4. Cure the mixture.













## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### IV. Asphalt Stabilization

- Asphalt stabilization of pavement material is usually intended either to:
  - introduce some cohesion into non-plastic materials,
  - make a cohesive material less sensitive to loss of stability with increased moisture.
- The process is more successful with granular material than with cohesive material.
- Asphalt stabilization is therefore primarily used on base and, to a lesser extent, sub base materials.
- Typical binder contents range from 4% to 8%.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

- Bituminous stabilization may be carried out with any of the following materials:
  - Hot Asphalt Cement,
  - Cutback Asphalt,
  - Asphalt Emulsion, either as Cationic or Anionic Emulsion
- **Stabilization with Hot Asphalt Cement**
  - Foamed Asphalt Process



## Chapter 3: Stabilized Pavement Materials

- Stabilization can be carried out **in place or in a central plant.**
- Foamed asphalt allow only a **very short mixing time** while the asphalt is in a finely dispersed condition.
- The fine aggregate particles are substantially coated with asphalt, leaving the **coarse particles** relatively **uncoated** with asphalt.
- Materials with **maximum plasticity index of 6–15** can be stabilized using this type of treatment.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### ■ *Stabilization with Cutbacks*

- The cutback asphalt can be sprayed cold or with slight heating and mixed with pre-moistened soil.
- This method of stabilization results in a material that gains strength very slowly and as a result, it is not used very frequently.
- Environmental constraints often limit the use of cutbacks in urban areas.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### ■ *Stabilization with Asphalt Emulsion*

- Asphalt emulsions may be readily mixed with damp soil to produce a good dispersion of asphalt throughout the soil.
- Asphalt emulsions are most widely used for soil stabilization.
- Asphalt emulsions are produced at three different grades: **Slow Setting(SS)**, **Medium Setting(MS)**, & **Rapid Setting(RS)** asphalt emulsions.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

- ***Construction Factors Affecting Design Considerations:***
- If you should stabilize with emulsion or cutback asphalts the following points guides the selection.
  - In hot and dry areas, medium to slow setting cutback/emulsion asphalts can be used, depending on the soil type,
  - In cooler areas, medium to rapid-setting cutbacks/emulsion would be used.
- However, foamed asphalt stabilization is not subject to climatic restrictions for mixing and compaction.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

- To achieve good results with asphalt stabilized materials in the field, you must:
  - thoroughly mix the stabilizing agent throughout the soil,
  - ensure that the soil is compacted at a uniform moisture condition, and
  - ensure adequate aeration of emulsion and cutback stabilized materials to allow the excess moisture and/or volatiles to escape.



## Chapter 3: Stabilized Pavement Materials

- The ERA Pavement Design Manual identifies three types of stabilized materials used in the design catalog. These are
  - Cement or Lime Stabilized Road Base 1 (CB1)
  - Cement or Lime Stabilized Road Base 2 (CB2)
  - Cement or Lime Stabilized Sub Base (CS)



## Chapter 3: Stabilized Pavement Materials

- The strength requirements of the cement/ lime stabilized materials is given in ERA Pavement Design manual as:

Code	Description	Unconfined compressive Strength (UCS) Mpa (for Cement stabilized)	Minimum CBR (%) (for lime Stabilized)
CB1	Stabilized base	3.0- 6.0	100
CB2	Stabilized base	1.5 -3.0	80
CS	Stabilized sub base	0.75 – 1.5	40

N:B: Strength test is conducted on 150mm cube.



## CHAPTER 3: STABILIZED PAVEMENT MATERIALS

### V. Mechanical Stabilization

- Is an improvement of an available material by blending it with imported materials to improve the **gradation** and **plasticity** characteristics of the material.
- Materials produced by blending (mechanically stabilized) are still unbound granular materials their characterizations and testing are similar to the conventional granular materials.
- The mix design of mechanically stabilized material is based on:
  1. Gradation requirement
  2. Plasticity property requirements
  3. Strength test requirements (**CBR**)



Sieve Designation Grading	A		B		C		D		E		F	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
2 in. (50mm)	100		100		-		-		-		-	
1 in. (25mm)	-		75	95	100		100		100		100	
3/8 in. (9.5mm)	30	65	40	75	50	85	60	100	-		-	
No. 4 (4.75mm)	25	55	30	60	35	65	50	85	55	100	70	100
No. 10 (2.00mm)	15	40	20	45	25	50	40	70	40	100	55	100
No. 40 (0.475mm)	8	20	15	30	15	30	25	45	20	50	30	70
No. 200 (0.075mm)	2	8	5	20	5	15	5	20	6	20	8	25

AASHTO Gradation limit for Soil –Aggregate sub base, base and surface course



$$\% \text{ Pass of Blend} = \frac{(\text{Proportion of Material "A"} \times \% \text{ Pass of Material "A"} + \text{Proportion of Material "B"} \times \% \text{ pass of Material "B"} + \dots\dots)}{\text{Proportion of "A"} + \text{Proportion of "B"} + \dots\dots}$$

$$\text{PI of Blend} = \frac{\{(\% \text{ A}) (\% \text{ Passing No.40, A})(\text{PI,A}) + (\% \text{ B}) (\% \text{ Passing No.40, B})(\text{PI,B})\}}{(\% \text{ A}) (\% \text{ Passing No.40, A}) + (\% \text{ B}) (\% \text{ Passing No.40, B})}$$



**QUIZ -1: (10 %)**

- It is desired to combine two materials A which is the soil at the existing road bed and B which is obtained from the near by borrow pit. If the required gradation is **AASHTO Grading "C"**. Determine the Blending Proportion and the resulting **PI** of the blended soil .

Property	Specification Requirement		Sub grade Soil (A)	Borrow Material (B)
	Min	Max		
<b>Mechanical Analysis</b>				
<i>2 in. (50mm)</i>	-			
<i>1 in. (25mm)</i>	100		100	100
<i>3/8 in. (9.5mm)</i>	50	85	68	45
<i>No. 4 (4.75mm)</i>	35	65	46	28
<i>No. 10 (2.00mm)</i>	25	50	36	17
<i>No. 40 (0.475mm)</i>	15	30	32	7
<i>No. 200 (0.075mm)</i>	5	15	17	3
<b>Plasticity Characterstics</b>				
<i>Liquidity Limit (%)</i>			40	13
<i>Plasticity Index (%)</i>			12	3



