Improving clay soil for road construction by adding mechanical additives.

Prepared by
-Dana zubaidi
-Raghad Qarout

Introduction

Clay soil is one of the most difficult soil types for road construction due to its physical properties, such as high plasticity, shrinkage, swelling, and water retention. All of these properties lead to poor load-bearing capacity, causing cracks, subsidence, or premature failure of roads.

“In this project, we studied the possibility of improving the properties of clay soil by adding mechanical materials, such as:

- Sand
- Recycled Asphalt pavement (RAP)
- **Crushed** Glass
- Rubber

Project objectives:

01 Improve the properties of clay soil, such as load-bearing capacity and swelling.

02 Reducing swelling and shrinkage caused by changes in moisture content.

03 Studying the environmental and economic impact of reusing materials such as glass, rubber, RAP, and sand.

Classified soil:

-The poor performance and instability of asphalt roads built on clay soil represent a major challenge in civil engineering. Therefore, the focus was on the clay soil of Tulkarm city, which is classified as (A7) from the table.

الجدول تصنيف التربة حسب نظام الأشتو

General classification	Granular materials (35% or less of total sample passing No. 200)						
	A-1			A-2			
Group classification	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7
Sieve analysis (percentage passing)							
No. 10	50 max.						
No. 40	30 max.	50 max.	51 min.				
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.
Characteristics of fraction passing No. 40							
Liquid limit				40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		NP	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Stone fragments, gravel, and sand		Fine sand	Silty or clayey gravel and sand			
General subgrade rating	Excellent to good						

General classification	Silt-clay materials (more than 35% of total sample passing No. 200)			
Group classification	A-4	A-5	A-6	A-7 A-7-5[a] A-7-6[b]
Sieve analysis (percentage passing)				
No. 10				
No. 40				
No. 200	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40				
Liquid limit	40 max.	41 min.	40 max.	41 min.
Plasticity index	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Silty soils		Clayey soils	
General subgrade rating	Fair to poor			

[a] For A-7-5, $PI \leq LL - 30$

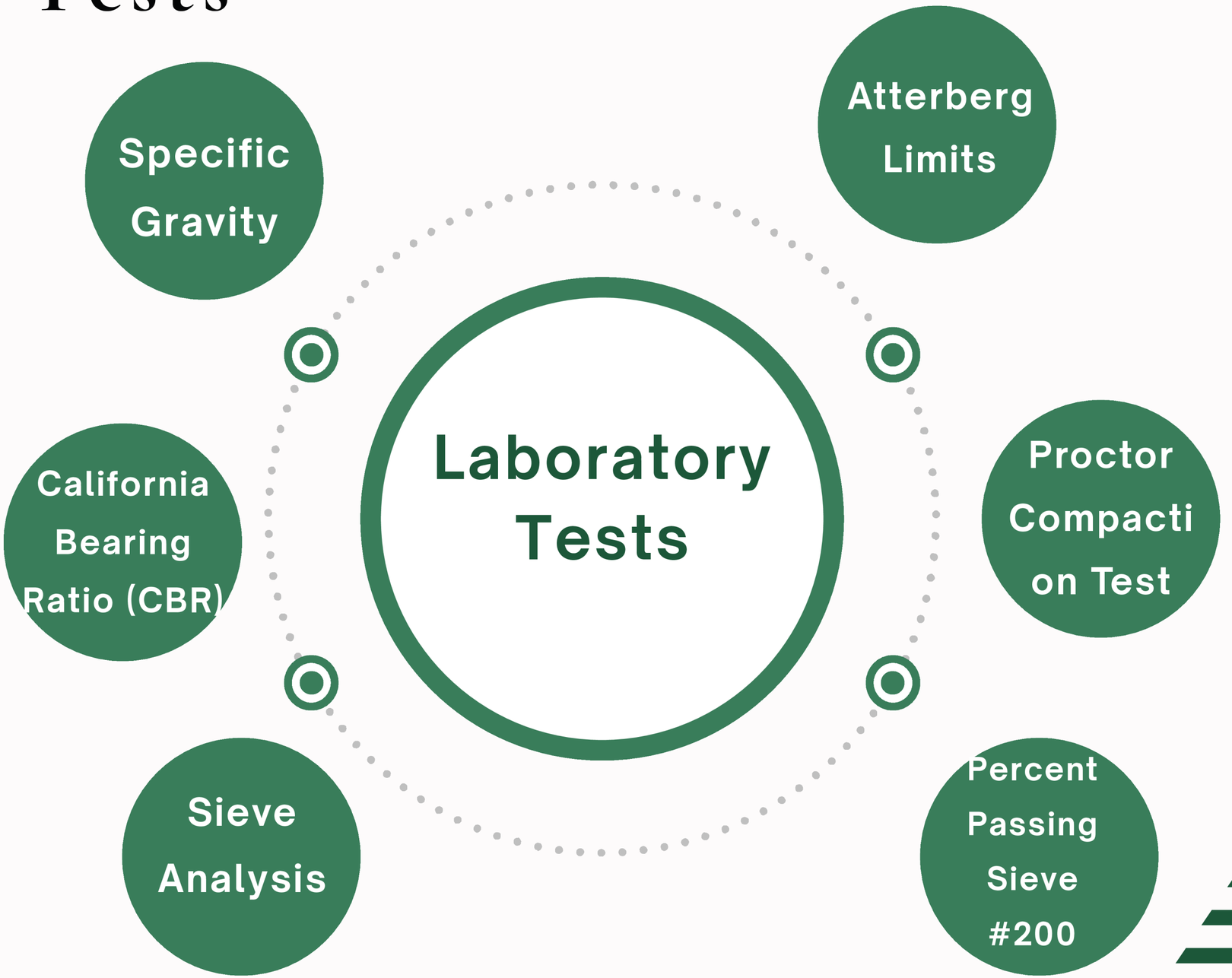
[b] For A-7-6, $PI > LL - 30$

الخامس التربة الفصل تصنيف

Pure clay

Source: As previously mentioned, the clay soil was collected from Tulkarm city and the largest particle size measured was less than 0.002 mm

Laboratory Tests



Pure Clay Tests Results

	Min. spec. For subgrade an PSS*	Test result	OK/Not Ok
swelling (%)	NA	21	-
CBR test (%)	Min. 20%	2.08	Not Ok
Plasticiy index	Max. 12%	27.37	Not Ok
Spicific gravity	NA	2.74	-
Percent finer sieve # 200	Max. 18%	92.4	Not Ok
OMC (%)	NA	18.79	-
Proctor test (maximum density)	Min. 1.7 gm/cm^3	1.76	OK

Recycled Asphalt Pavement (RAP)

Source: RAP samples were obtained from a road rehabilitation project in Ramallah.

- milled using a Wirtgen large cold milling machine.

Mixing Proportions for Samples

Sample No.	% Clay	% RAP
R1	90	10
R2	80	20
R3	70	30
R4	60	40
R5	50	50
R6	40	60

Sieve Analysis of Rap Material:

Test	Pure Clay	10% RAP	20% RAP	30% RAP	40% RAP	50% RAP	60% RAP
CBR (%)	2.08	2.25	2.81	3.1	4.16	5.22	6.29
Swelling (%)	21	14.5	10	9	8	7	6
PI	27.37	27.49	28.04	27.2	25.92	23.68	22.62

Sand

Source: The sand used in this study was sourced from a local supplier in Nablus city, originating from Ashdod, Palestine (1948 lands).

Mixing Proportions for Samples

Sand was added to the clay soil in varying proportions as shown in the table. These proportions were obtained from previous studies.

Sample No.	% Clay	% Sand
S1	90	10
S2	80	20
S3	70	30
S4	60	40
S5	50	50
S6	40	60

Test	Min. spec. For subgrade an (PSS)*	Pure Clay	10% Sand	20% Sand	30% Sand	40% Sand	50% Sand	60% Sand
CBR (%)	Min. 20%	2.08	2.6	2.9	3.3	3.7	4.1	5
Swelling (%)	NA	21	17	14	11	9.8	9	7
PI	Max. 12%	27.37	17.27	12.14	10.96	6.8	1.36	NP

Mix Design

Both glass and rubber were added to the clay soil in varying proportions, as shown in the table. These proportions were obtained from previous studies.

Sample No.	% Clay	% Glass	Sample No.	% Clay	% Rubber
G1	90	10	R1	85	15
G2	80	20	R2	80	20
G3	70	30	R3	75	25
G4	60	40	R4	70	30
G5	50	50	R5	65	35
G6	40	60	R6	60	40
G7	30	70			


MIX DESIGN

Glass

Source

Received from Nablus, a shop specializing in front and rear car window repair.

01 **Outer Glass Layer**

02 **Middle Plastic Layerof polyvinyl butyral (PVB)**

03 **Inner Glass Layer**

Why was glass chosen as a material to improve clay soil?

- Non-plastic → Reduces soil plasticity.
- Non-water-absorbent → Reduces swelling and shrinkage.
- Improves granular gradation → Improves density and shear resistance.
- Environmentally friendly when recycled instead of being thrown into landfills

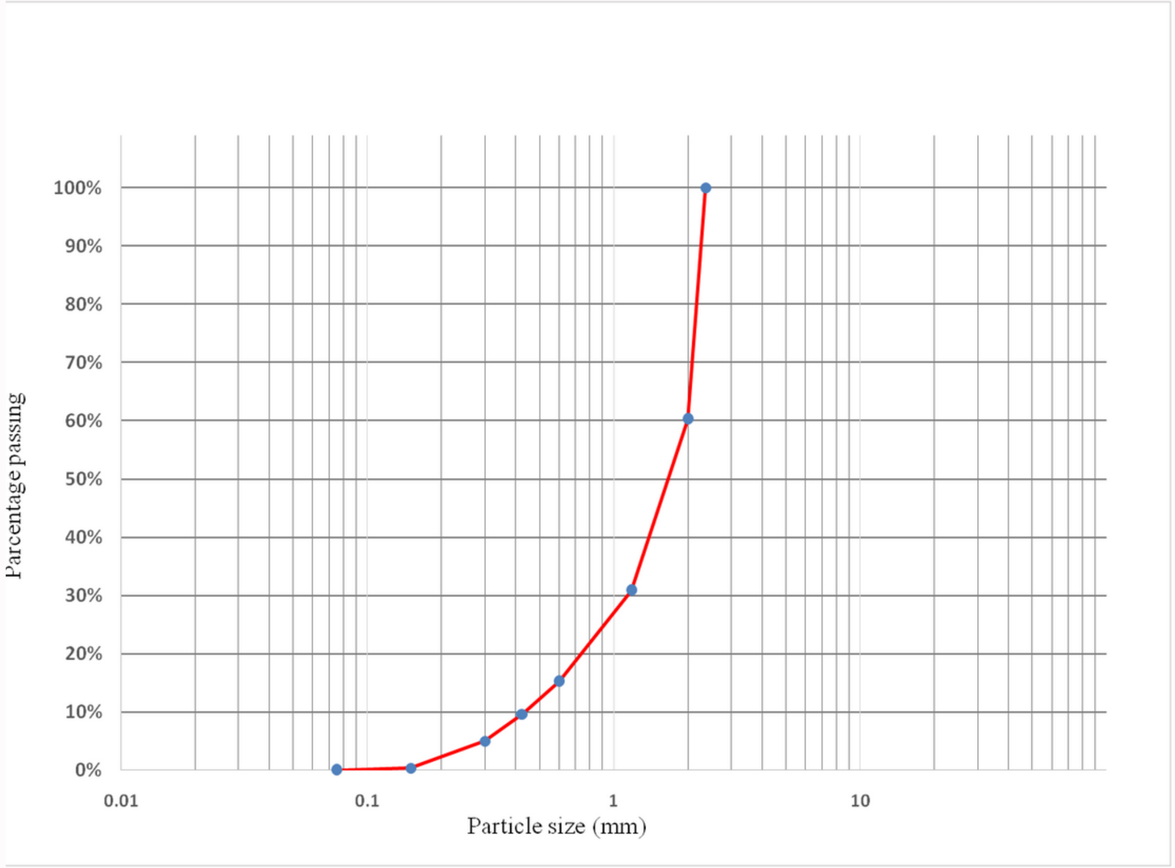
SIEVE ANALYSIS OF GLASS MATERIAL

-well graded sand-size .
-fine crushed glass,

sizes ranging from approximately 0.075 mm to 2.36 mm.

1- improving the interlocking of the particles

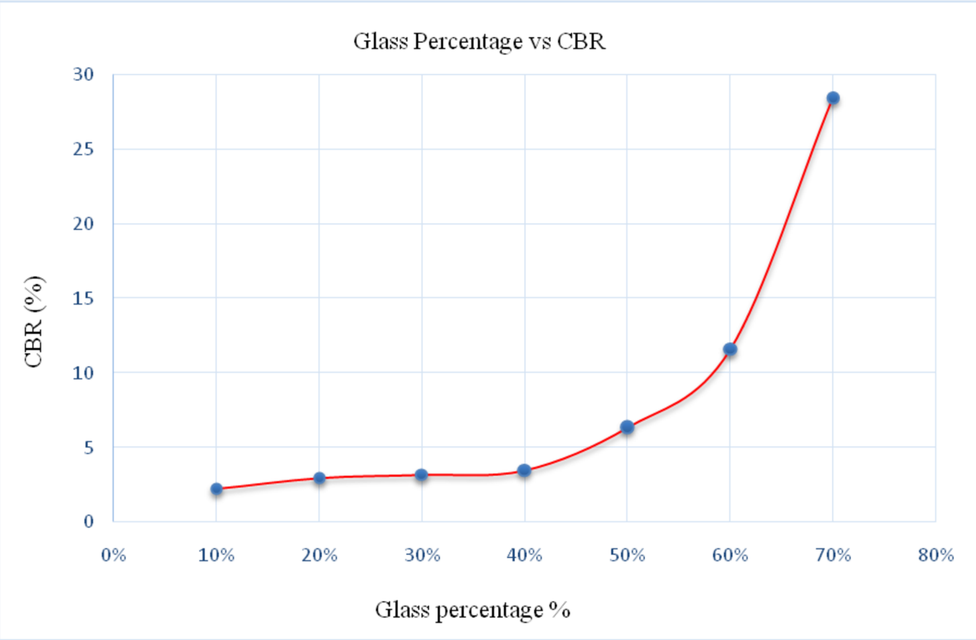
2- reducing ductility.



1-Effect of Glass on California Bearing Ratio (CBR)

Original clay soil: 2.08% (not suitable for road layers according to specifications).

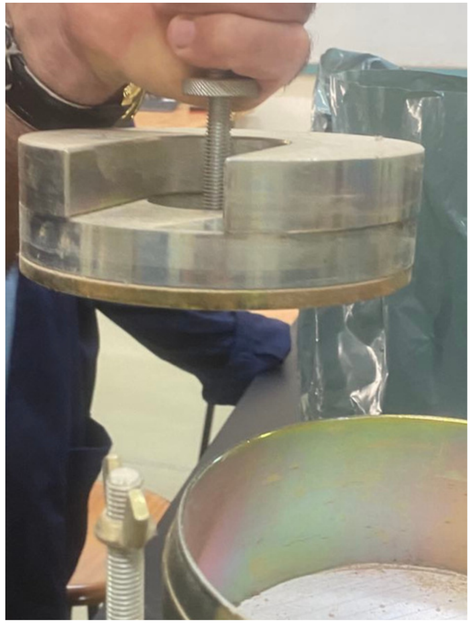
- **After adding 60% glass = 11.6%.**

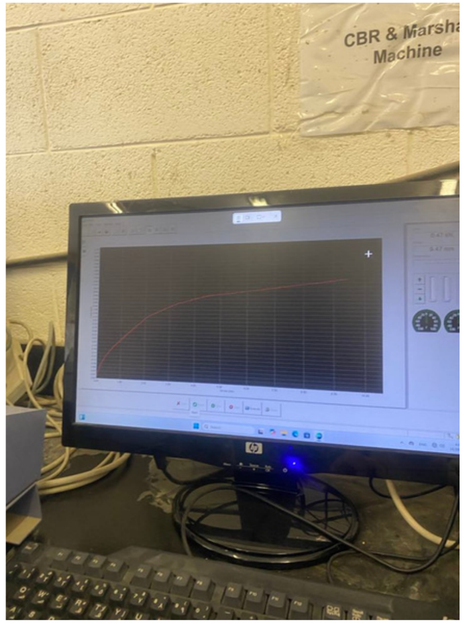


Is non-deformable.

Increases granular density.

Reduces the effect of water.




CBR & Marsha
Machine

2- EFFECT OF GLASS ON SWELLING PERCENTAGE

For original clay soil: 21% (very high).

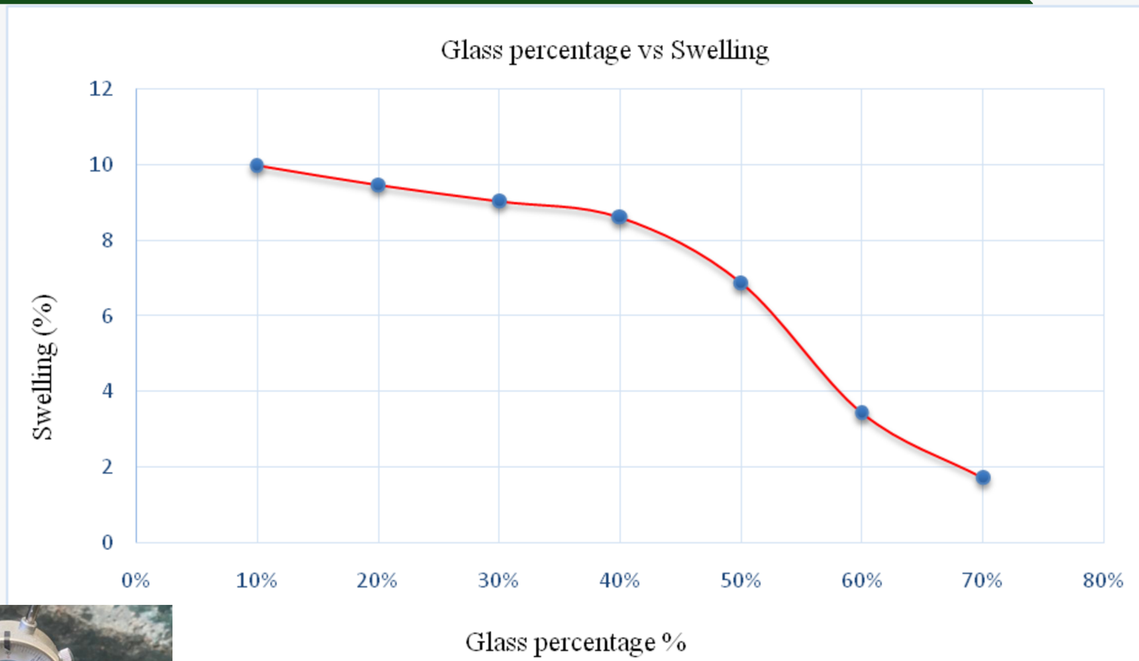
-When adding glass at a rate of 60%= 1.72%.

✅ Analysis:

1- Glass does not absorb water

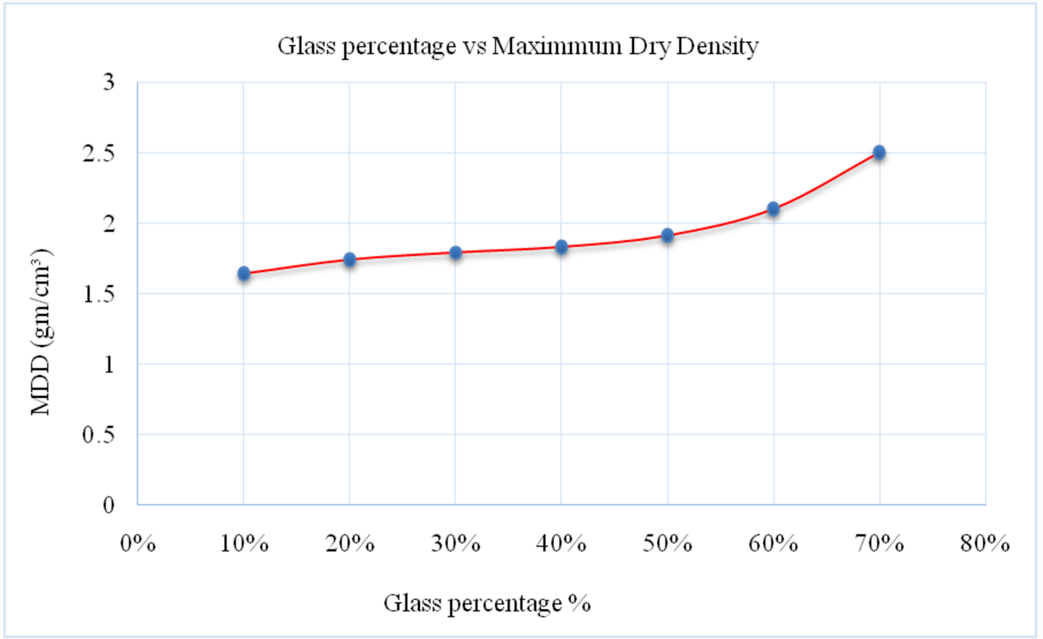
2-does not expand

3- reduces the soil's expansive behavior.



3-EFFECT OF GLASS ON PROCTOR MAXIMUM DRY DENSITY (MDD)

-pure clay =1.76 gm/cm³,
-60%= 1.92gm/cm3.



1- improves particle distribution

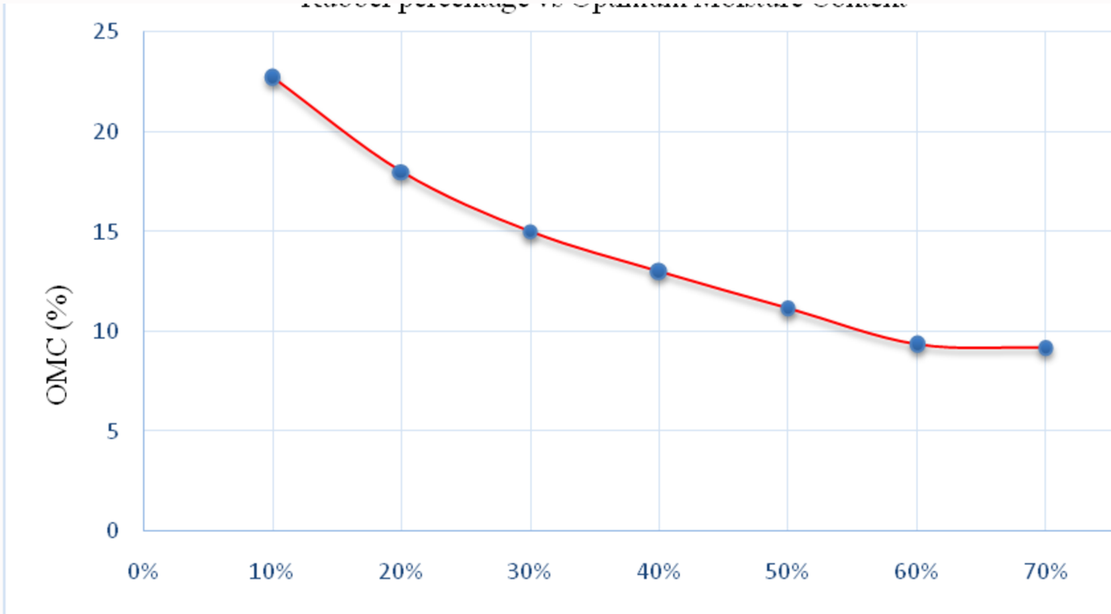
2- reduces gaps between particles

3- increases compaction efficiency

4-EFFECT OF GLASS ON PROCTOR OPTIMUM MOISTURE CONTENT (OMC%)

-18.79% (at Pure clay)
-9.36% (at 60% glass)

glass is a non-absorbent material unlike clay soil.

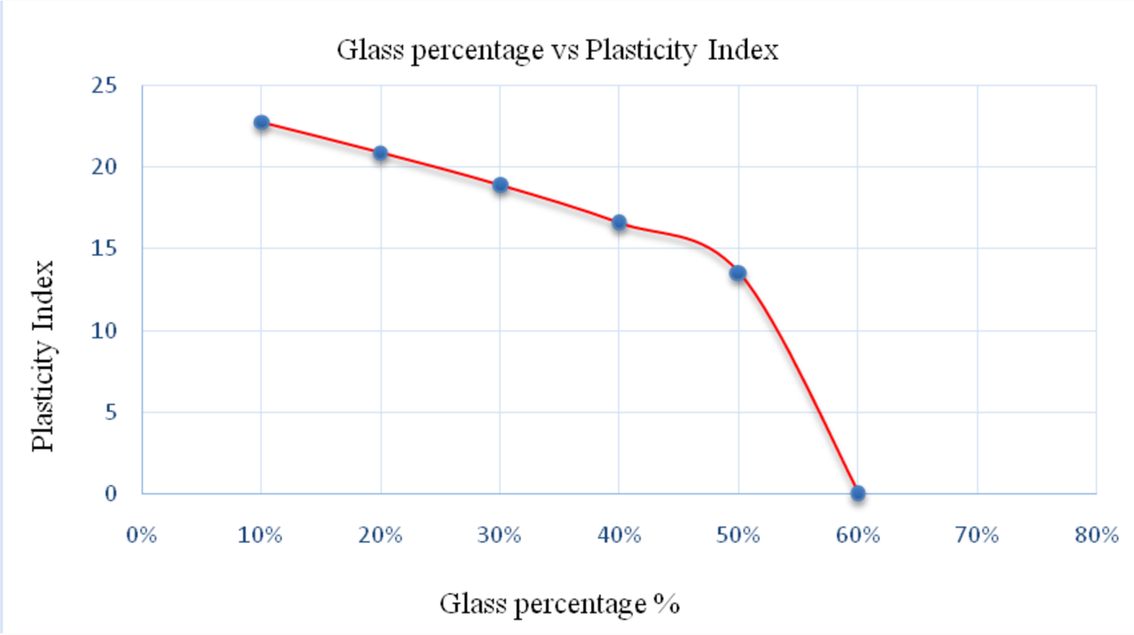


5- EFFECT OF GLASS ON PLASTICITY INDEX (PI)

The PI value decreases with increasing glass content in the mixture (from 27.37% for pure clay to 13.52% with the addition of 50% glass).

- At higher glass contents (60%), the sample became "non-plastic," indicating a shift in behavior from **clayey to sandy.**

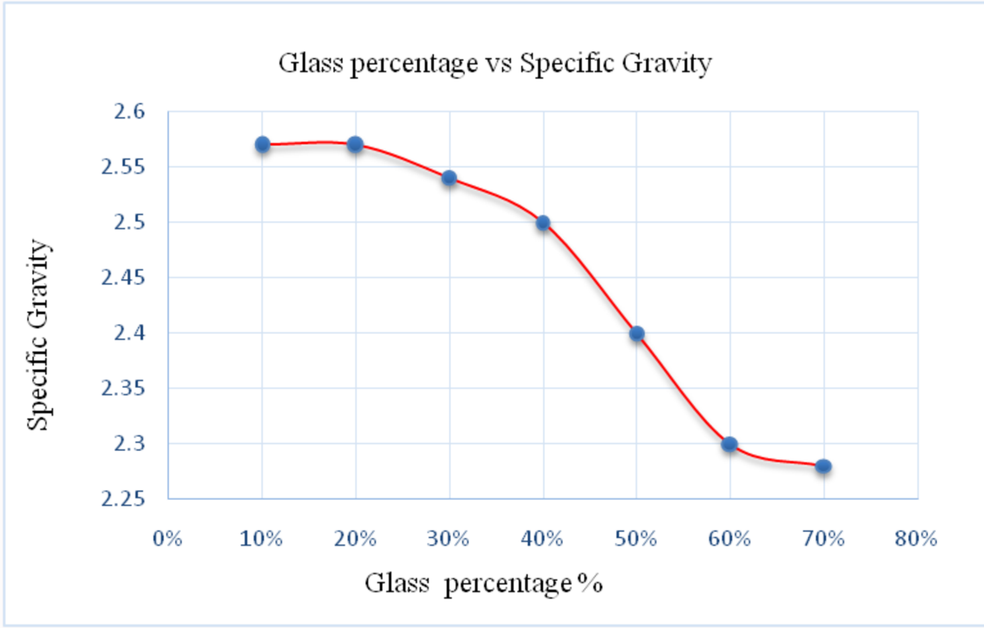
- This decrease in PI indicates an improvement in soil properties, as the mixture becomes less susceptible to volumetric changes with changes in water content.



6- EFFECT OF GLASS ON SPECIFIC GRAVITY (SG)

The SG value = 2.74 (pure clay)
- 2.3 (60% glass).

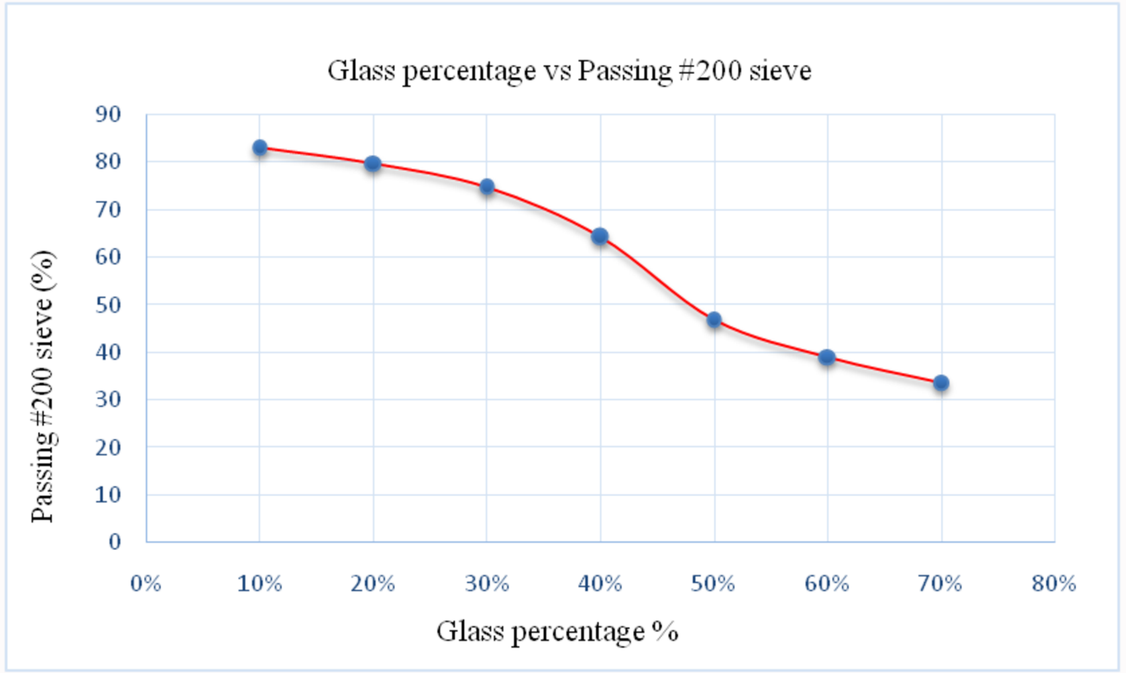
This decrease reflects the lower density of the components (glass is less dense than clay).



1-improves workability
2- reduces plasticity.

7- EFFECT OF GLASS ON % PASSING SIEVE #200

- 92.4% (for pure soil)
- 39.1% (at 60% glass)



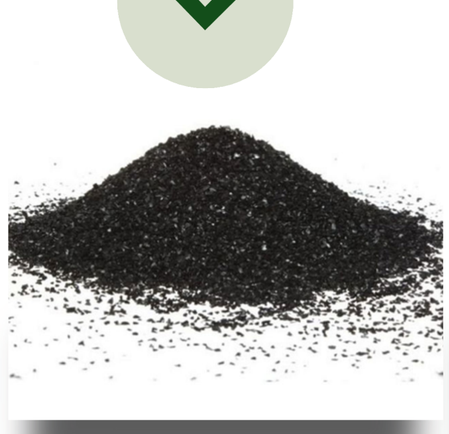
1-improved drainage
2- reduced plasticity
3- increased permeability.

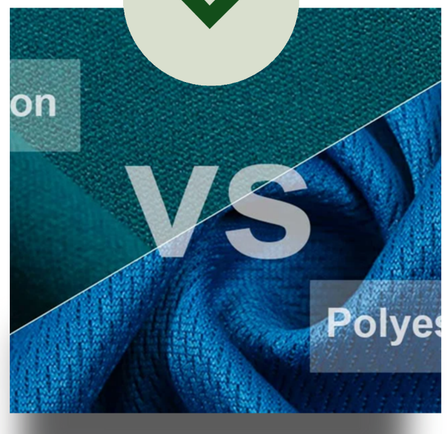
Rubber

Source: Obtained from a rubber manufacturing company in Ramallah.

Composition of Playground Rubber

- Recycled car tires
- Carbon black
- **Synthetic fibers such as nylon or polyester**





Mixing Proportions for Samples

Rubber was added to the clay soil in varying proportions as shown in the table. These proportions were obtained from previous studies.

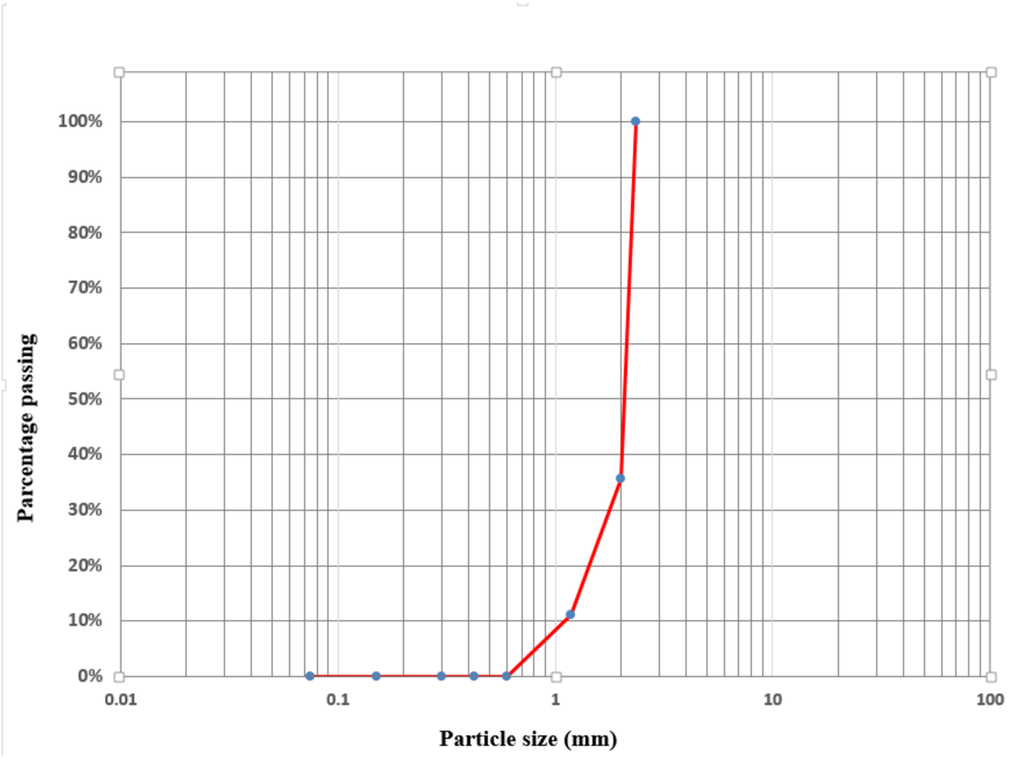
Sample No.	% Clay	% Rubber
R1	85	15
R2	80	20
R3	75	25
R4	70	30
R5	65	35
R6	60	40

Sieve Analysis of rubber Material

The rubber particle size distribution curve shows a **(uniformly graded)** material. The curve has a steep slope, indicating that the rubber particles fall mainly within the **medium size range**, with a small presence of fine and coarse particles.

The particle size distribution curve reflects several engineering properties most notably:

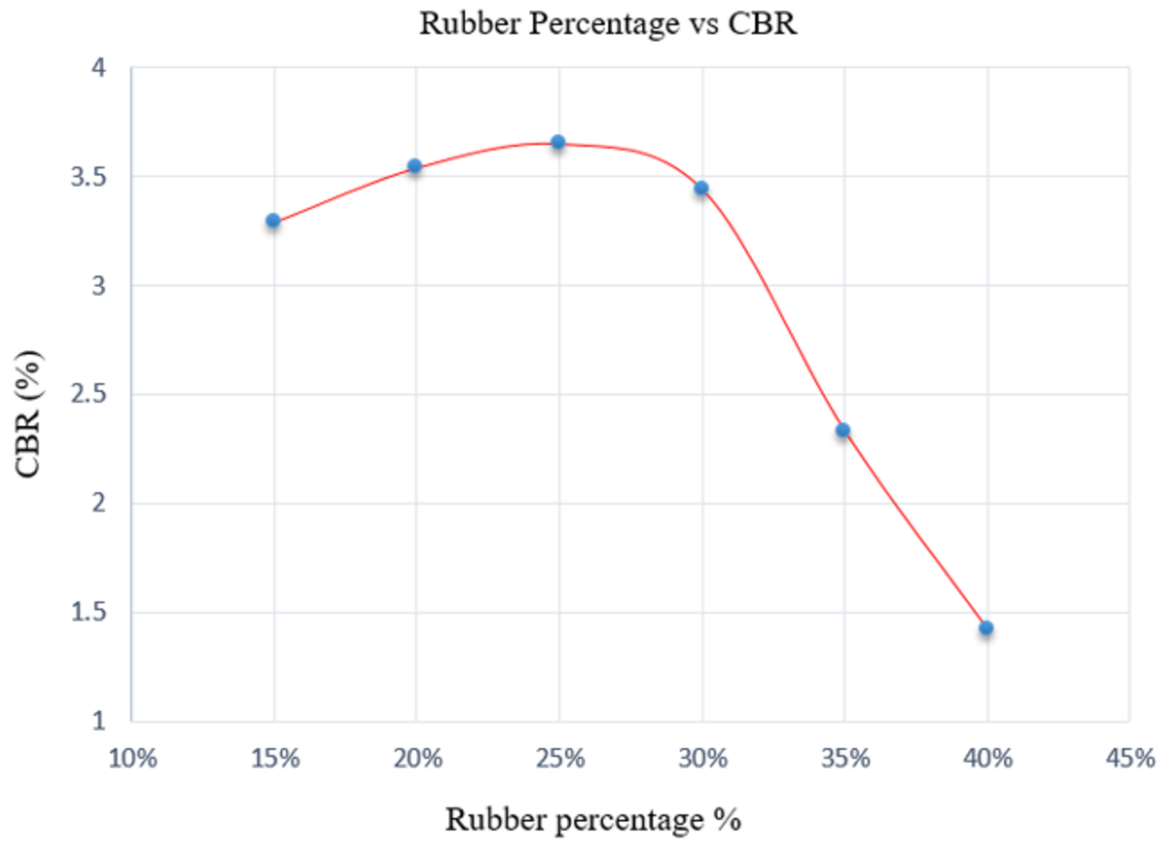
- Excellent drainage capacity due to its coarse nature and lack of fine particles.
- High permeability, making it suitable for applications requiring free movement of water, such as **backfilling in dam construction.**



1.Effect of Rubber on California Bearing Ratio (CBR)

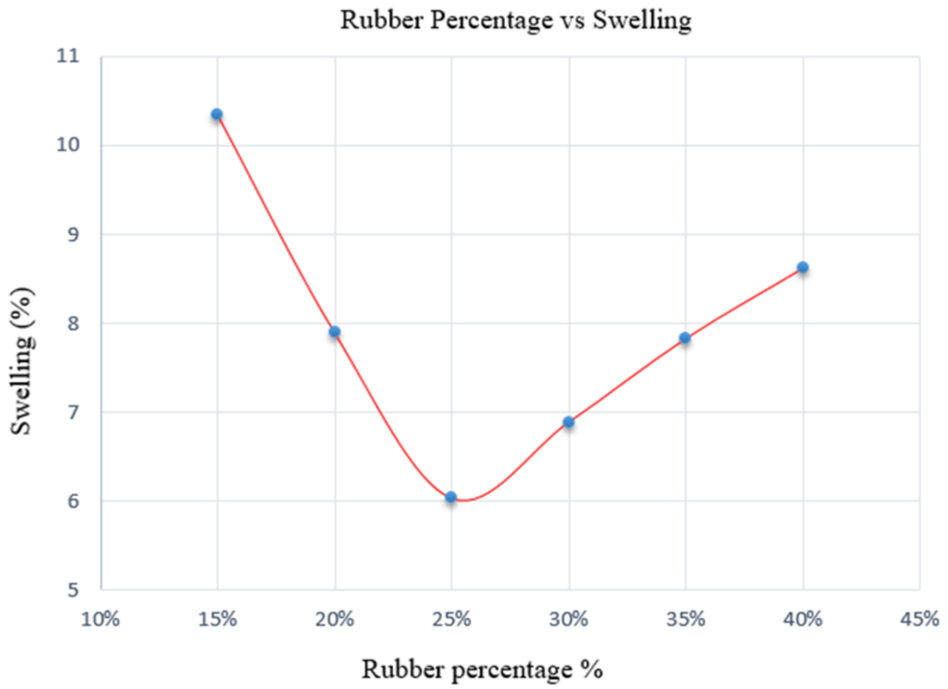
We observed that the CBR value initially increased but then decreased sharply with higher rubber content.

- **0% rubber: 2.08%**
- **25% rubber: 3.65%**
- **40% rubber: 1.42%**



2. Effect of Rubber on Swelling Percentage:

- **0% rubber: 21%**
- **25% rubber: 6.03%**
- **40% rubber: 8.62%**



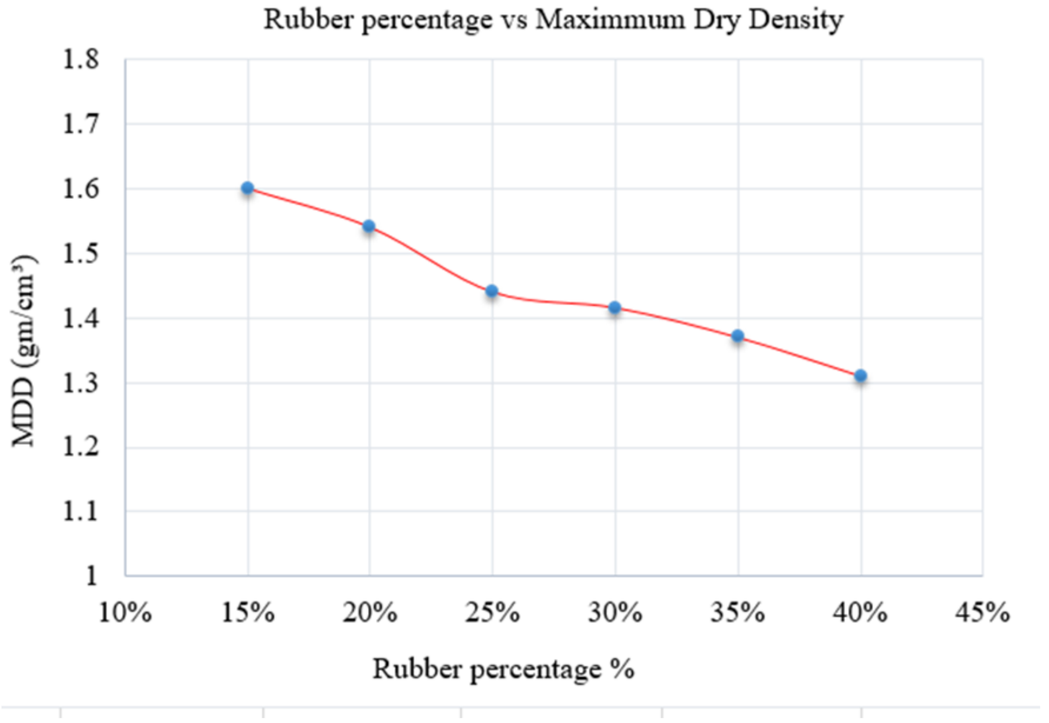
This initial decrease occurs because rubber particles replace expansive clay particles, reducing the soil's ability to absorb water. Additionally, coarse rubber particles improve drainage.

The increase is due to rubber's elastic properties, which allow it to return to its original shape. When the rubber gets wet, it expands or swells slightly, contributing to a slight increase in swelling.

3. Effect of Rubber on Proctor Maximum Dry Density (MDD)

The graph clearly shows a steady decrease in maximum dry density (MDD) as the rubber content increases.

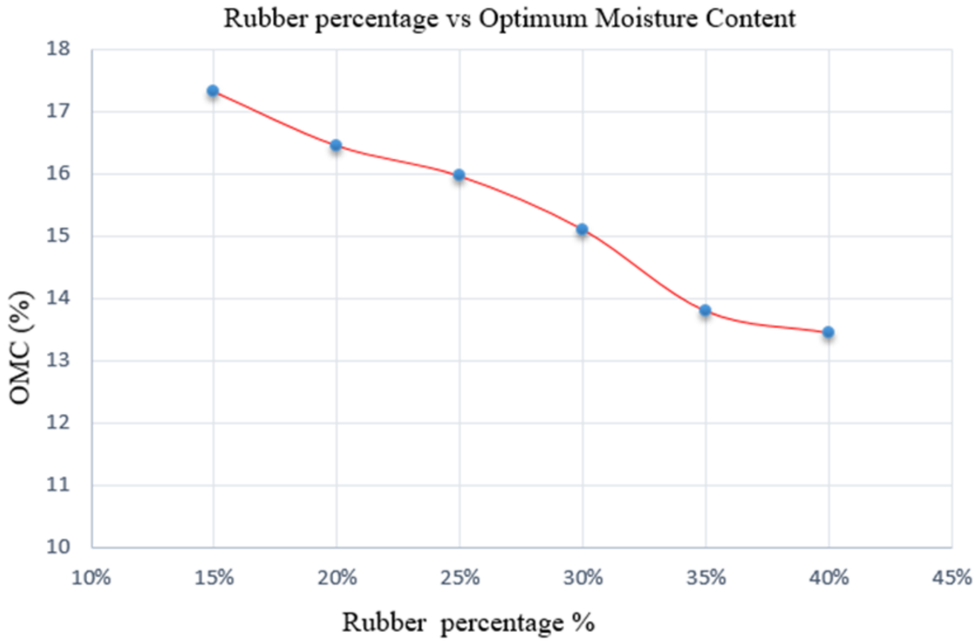
- MDD for pure clay = **1.76**
- MDD for 40% Rubber = **1.31**



- **First,** its lower specific gravity compared to the clay particles means that each added rubber particle reduces the overall density of the mixture.
- **Second,** the elastic nature of rubber causes it to deform under the influence of compressive energy.

4. Effect of Rubber on Proctor Optimum Moisture Content (OMC%)

- OMC % for pure clay = **18.79%**
- OMC % for 40% Rubber = **13.44 %**
- We notice from the curve a clear **decrease** in the OMC % value with increasing rubber content. The main reason for this behavior lies in the fundamental differences between clay and rubber particles. Clay particles are highly absorbent and retain water, while rubber particles are non-absorbent.

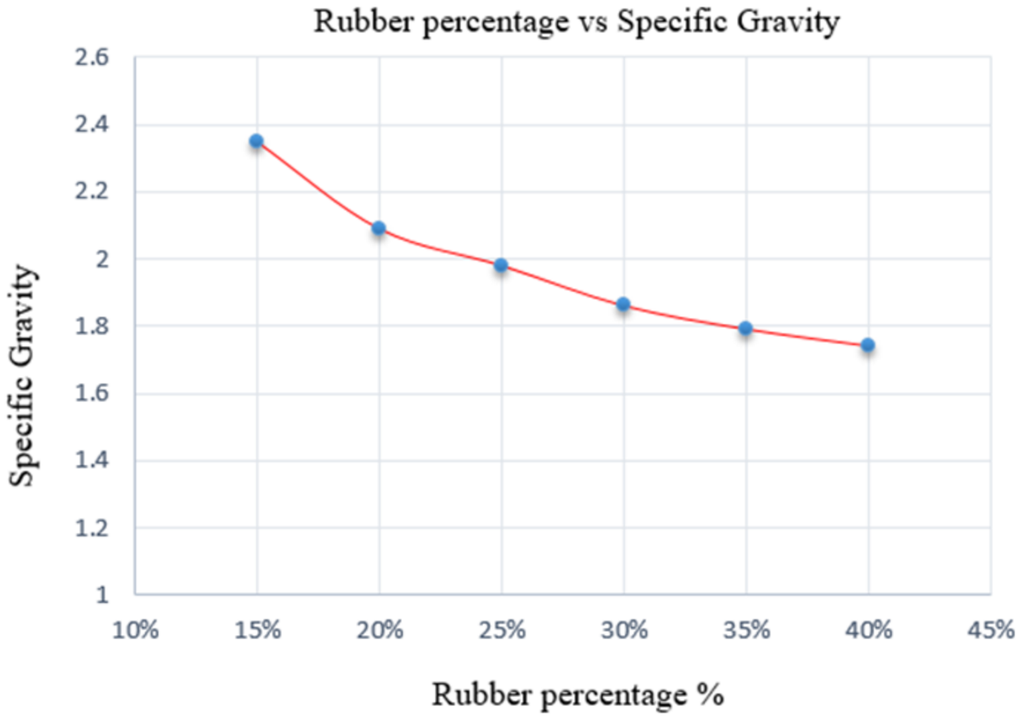


5. Effect of Rubber on Specific Gravity

- The curve also shows a decrease in the value of specific gravity with the increase in the addition of rubber.

- Specific gravity for pure clay = **2.74**
- Specific gravity for 40% sand = **1.74**

- The main reason for this decrease lies in the fundamental difference between clay and rubber particles. Clay particles have a relatively high specific gravity due to their dense crystalline structure. In contrast, rubber particles have a much lower specific gravity due to their porous polymer-based structure.

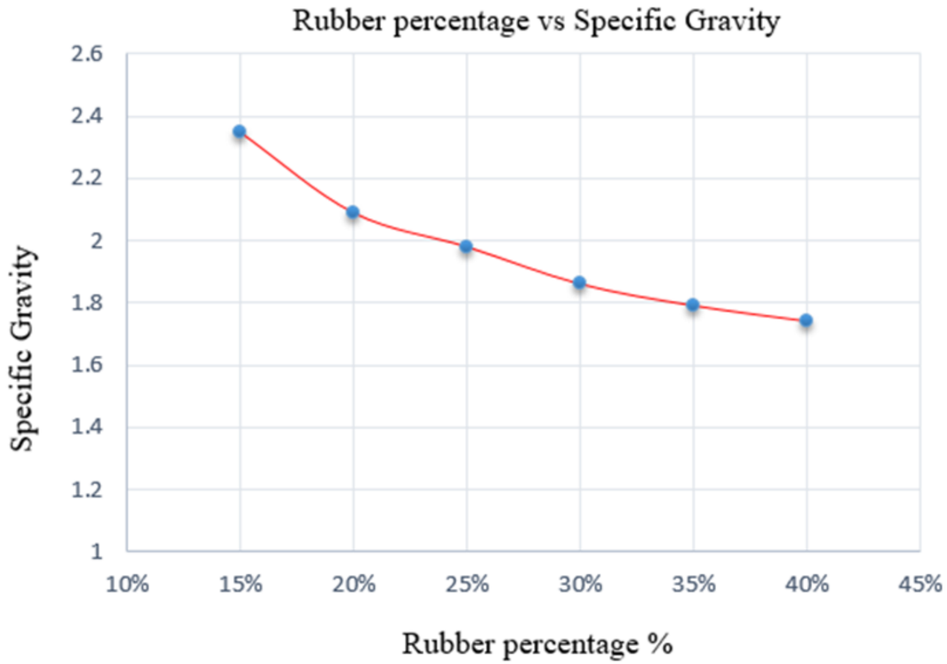


6. Effect of Rubber on Percent Passing Sieve #200

- The graph shows a clear decrease in the percentage of material passing through No.200 sieve.

- For pure clay = **92%**
- For 40% rubber =**55.4%**

- This is because rubber particles do not pass through the No. 200 sieve (due to their large size), and the reported pass percentages only represent the clay portion of each mixture.



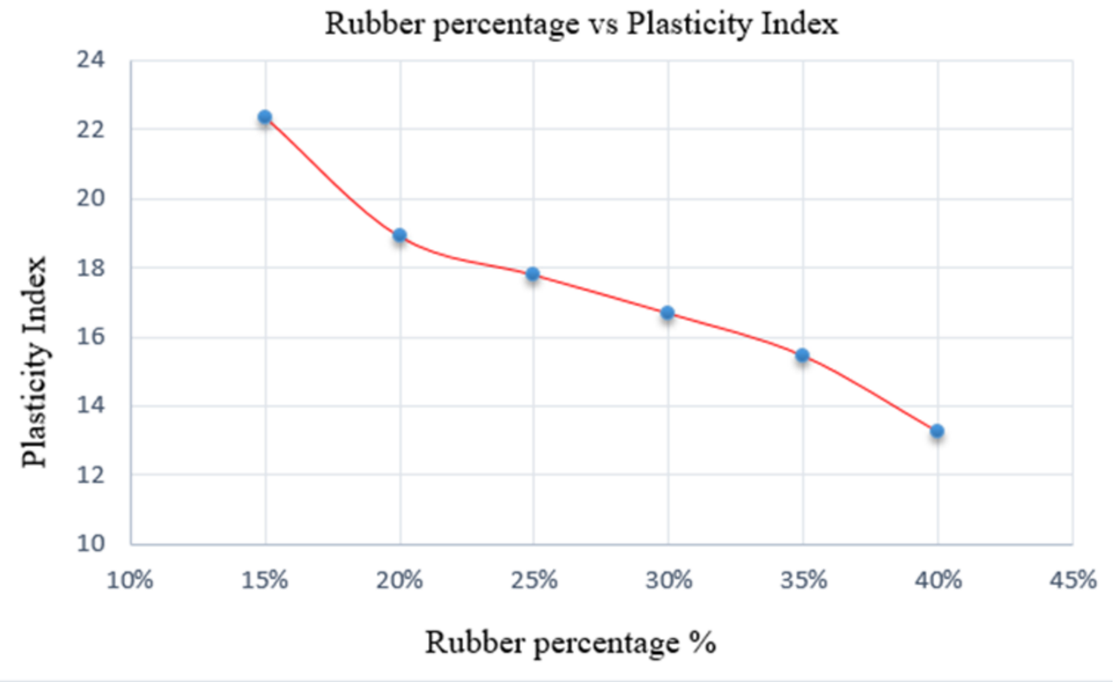
7. Effect of Rubber on Plasticity Index

- Experimental data show a clear **decrease** in the plasticity index (PI) with increasing rubber content.

- **For pure clay = 27.37**
- **For 40% rubber =13.25**

This decreases results from factor:

- The coarse rubber particles, which make the mixture more granular and less cohesive.



CONCLUSION:

Four materials used in clayey soil improvement

- **Crushed glass.**
- **Recycled asphalt paving (RAP).**
- **Sand.**
- **Recycled rubber**

were compared in terms of

1. **Engineering performance**
2. **Environmental impact**
3. **Economic feasibility**

Engineering perspective

Sand

- Effect on CBR was limited. (2.08%-5%)
- Eliminating plasticity.
- Reducing swelling. (21-7)

(Moderate)

RAP

- Moderately increasing in CBR. (2.08%-6%)
- Reduce swelling. (21-6)
- Noticeable in reducing PI (27.37-22.62)

(Good)

Crushed Glass

- Significantly increasing (CBR) (2.08%-11.6%)
- Eliminating plasticity.
- Reducing swelling. (21-3.44)

(Excellent)

Rubber

- Significantly reduced CBR (2.08%- 1.42%)
- Decreased noticeable in swelling and PI

(Weak)

Environmental perspective

Sand

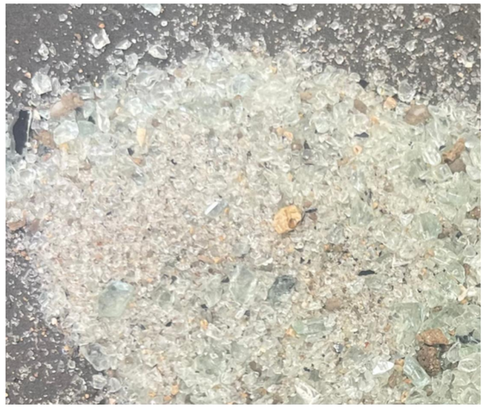
- Natural material but extraction may harm the environment.

(Neutral)

RAP

- Reuses construction and road waste.

(Excellent)



Crushed Glass

- Recycles non-degradable crushed glass waste.

(Excellent)

Rubber

- Recycles tires and reduces landfill/pollution.

(Good)

Economic perspective

Sand

- can be easily obtained from natural sites, without the need for complex processing

(Excellent)

RAP

- Widely available, minimal processing needed.

(Excellent)

Crushed Glass

- Raw material is cheap, but grinding adds cost.

(Moderate)

Rubber

- Requires special shredding and processing equipment.

(High cost)

Glass

Based on the above, crushed glass is the best and most balanced option in terms of **engineering performance** and **environmental sustainability**, even if it is relatively moderately costly.

THANK YOU