Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Investigation Of The Soil Composites Materials Mechanical Properties

Manvendra Verma [1]

[1] *Corresponding Author, Assistant Professor, Department of Civil Engineering, GLA University, Mathura, Uttar Pradesh, India. 281406*
mv075415@gmail.com

The chemical composition of the soil is a crucial factor that determines its general qualities and usefulness, including its fertility, structure, and the kinds of flora it can sustain. The composition of soil is influenced by many elements, such as the parent material, climate, biol ogical activity, and human impacts.
Below is an in-
depth examination of the main constituents and characteristics of soil's chemical makeup.
This study is based on experimental investigation of materials before use in flexible pavement construction. In this experimental investigation, to check the quality of soil, coarse aggregates, and bitumen via various tests conducted in the laboratory. The proctor compaction test, sieve analysis test, liquid limit test, plastic limit test, and CBR test were conducted on the soil samples, whereas the crushing test, impact test, abrasion test, specific gravity, and water absorption test were conducted on the coarse aggregate. The penetration test and ductility test were conducted on the bitumen samples. After the experimental investigation, the optimum moisture content and maximum dry density, liquid limit, plastic limit, and CBR at 2.5mm and 5mm are 14% and 1.97gm/cc, 35%, 20%, 1.2%, and 1.4%, respectively. In the aggregate's investigation, the crushing value, impact value, abrasion value, specific gravity and water absorption are 14%, 10%, 16%, 2.62, and 0.55%, respectively. In the bitumen experimental investigation, the penetration and ductility of the bitumen are 64.9mm/10 and 57.35cm, respectively.

Key words: Soil composition; Aggregates; Bitumen; Laboratory Investigation; Mechanical Properties; Durability.

1. INTRODUCTION

Primary minerals refer to minerals that are naturally present in the parent rock, including quartz, feldspar, and mica. They have not experienced substantial chemical modification. Secondary minerals are formed as a result of the weathering process of primary minerals. They consist of clays such as kaolinite, illite, and smectite, as well as iron (Fe) and aluminium (Al) oxides [1], [2]. Soil organic matter comprises plant and animal leftovers in different stages of decomposition, as well as cells and tissues of soil organisms, and compounds produced by soil organisms. It has a crucial role in soil fertility by supplying vital nutrients and improving soil composition [3], [4]. The soil water, referred to as the soil solution, comprises dissolved nutrients and gases. The transfer of nutrients to plant roots and the occurrence of diverse chemical reactions inside the soil are crucial. Soil air fills the gaps between soil particles and is essential for the breathing of plant roots and soil microbes. The soil air composition closely resembles that of the atmosphere; however, it may exhibit elevated amounts of carbon dioxide (CO_2) and reduced levels of oxygen (O_2). Soil nutrients are essential for the development of plants and may be categorised into macronutrients and micronutrients, depending on the amounts needed by plants [5]–[8].

Nitrogen (N) is present in soil in the forms of ammonium (NH_4^+) and nitrate (NO_3^-). Protein synthesis and plant growth rely on it. Phosphorus (P) is present in the form of phosphate ions, namely $H_2PO_4^-$ and HPO_4^{2-}. It has a crucial function in the transmission of energy and the process of photosynthesis. Potassium (K) is found in the form of the potassium ion (K^+). Enzyme activation and osmoregulation in plants depend critically on it [9]–[12]. Calcium (Ca) is present in the form of calcium ions (Ca^{2+}). Cell wall structure and signalling are crucial. Magnesium (Mg) is present in the form of magnesium ions (Mg^{2+}). It serves as a pivotal element in the chlorophyll molecule and is important for the process of photosynthesis. Sulphur (S) is found in the form of sulphate (SO_4^{2-}). Amino acids and proteins are of utmost significance. Essential nutrients that are required by the body in small amounts, such as vitamins and minerals [13]–[16].

Iron (Fe) is necessary in small quantities, often as either Fe^{2+} or Fe^{3+}. Chlorophyll production and enzyme activity rely on it. Manganese (Mn) is found in the form of Mn^{2+}. It plays a role in the process of photosynthesis and the activation of enzymes. Zinc (Zn) is present in the form of Zn^{2+}. Enzyme activity and protein synthesis are crucial. Copper (Cu) is often found in the form of Cu^{2+}. Photosynthesis and respiration rely on it for their fundamental processes. Boron (B) is found in the form of borate ions, namely BO_3^{3-} and $H_2BO_3^-$. Cell wall development and reproductive expansion are crucial. Molybdenum (Mo) is present in the form of molybdate (MoO_4^{2-}). Nitrogen fixation and nitrate reduction are essential. Soil pH is a quantitative assessment of the level of acidity or alkalinity in the soil, which has a substantial influence on the accessibility of nutrients, microbial activity, and the general well-being of the soil.

Acidic soils, with a pH level below 7, may result in nutritional deficits such as phosphorus, calcium, and magnesium, while also possibly creating harmful quantities of aluminium and manganese. Alkaline soils, which have a pH greater than 7, may cause deficits in micronutrients such iron, manganese, zinc, and copper. Neutral soils, with a pH of around 7, are generally ideal for most plant development because they have a balanced nutrient supply. Soil organic matter (SOM) is an essential factor that affects the arrangement of soil particles, the presence of nutrients, and the capacity of soil to hold water. Decomposing Organic Material refers to the process of the gradual breakdown of fresh plant and animal leftovers [17]–[22].

Humus refers to the organic matter that has undergone extensive decomposition, resulting in a stable form that improves the availability of nutrients and the structure of the soil. Soils may also harbour pollutants originating from either natural sources or human activity, which might include: Heavy metals, such as lead (Pb), cadmium (Cd), and arsenic (As), may be found in the environment due to industrial pollution or the usage of fertilisers that are polluted. Pesticides and herbicides: Residues resulting from agricultural operations. Resulting from the use of salty water for irrigation, causing soil salinization. Soil has a complex chemical composition that includes minerals, organic matter, water, air, and other nutrients and pollutants. Comprehending its composition is crucial for effectively overseeing soil health, fertility, and sustainability in agricultural and environmental settings. The chemical

composition of soil has a direct impact on the development of plants, the functioning of ecosystems, and its capacity to sustain life.
Indian roads are the largest in the world (over 5.8 million km at present). For administrative purposes, Indian roads are divided into five groups: national highways (N.H.), state highways (S.H.), major district roads (MDR), other district roads (ODR), and village roads (V) (V.R.). Passengers and cargo may use the National Highways to go from one mid-sized city to the next throughout the nation. Transportation between major cities is an essential function of state roads. In addition to the main district roads, communities may use the other district and village roads to meet their daily transportation requirements and to transport agricultural products to nearby markets. Additionally, major district roads link major highways with backcountry routes [23]–[25].
All-weather road pavements may be given with any of the following kinds of pavements depending on their structural behaviour: Pavement is classified as either flexible, stiff, or semi-rigid. Flexible pavements derive their name from the fact that the whole pavement structure deflects or bends when underweight. Multiple layers of material are often used in the building of flexible pavements. A load is sent down to a lower layer from a higher one through a series of distribution layers. The greatest load-bearing capacity material (and the costliest) is placed on top of the stack, while the lowest load-bearing capacity material (and the least expensive) is placed at the bottom. A typical flexible pavement construction consists of the following components: a) The surface course is the layer that is in direct contact with traffic and is the first layer. One or more HMA sub-layers may be present. Aggregates are often used to make up the base course, which is the layer underneath the HMA (either stabilised or unsterilized). The layer (or layers) is immediately below the foundation layer. A sub-base isn't always essential. There are four levels of soil subgrade, which are layers of natural soil that serve as a foundation for the layers of pavement materials that follow [26]–[28].
Flexural strength and flexure rigidity are high in stiff pavements. Stresses are not transmitted to the bottom layer from grain to grain as they are with flexible pavement layers [29]–[31]. Plain, reinforced, or prestressed Portland cement concrete is used to build stiff pavements. Because of the slab effect of the firm pavement, tyre load strains may be distributed across a greater area. Because the cement concrete pavement may be utilised as a wear course and an effective base course, the stiff pavement does not conform to the bottom surface's curvature. Concrete slabs with a granular basis or subbase are often used to build stiff pavements [32]–[34].
For example, pozzolanic concrete (lime-fly ash-aggregate mix) or lean cement concrete (or soil-cement) in the base course or sub-base course layer gives the pavement a substantially greater flexural strength than the normal flexible pavement layer. The flexural strength of these pavement materials, on the other hand, is lower than that of cement concrete. This intermediate class of materials is used in the base or sub-base course layer of semi-rigid pavements. In general, it's not evident why one form of pavement is favoured over the other [35], [36]. A mix of policy and economics is often used by state transportation authorities when selecting pavement types. Flexible pavements need maintenance or reconstruction every 10 to 15 years. When compared to flexible pavement, rigid pavements may survive up to 40 years with little upkeep and restoration. As a consequence, the use of firm pavements in high-traffic areas in cities should come as no surprise. However, compromises must always be made [37]. Flexible

pavements, for example, are generally less costly and quicker to repair than rigid pavements when major restoration is required.

2. EXPERIMENTAL TEST SETUPS

In the tests, setups were created for the quality assurance of the soil, coarse aggregates, and bitumens.

2.1 Tests setups for soil

2.1.1. Procter Compaction Test

Compaction is the mechanical packing of soil grains by reducing the air spaces. Mechanical techniques of compaction include rollers, vibrators, and rammers. This contrasts compaction from consolidation, which is a long-duration loading process that results in the removal of water from saturated soil pores and produces the soil's consolidation by decrease in volume, as the primary precondition for compaction. A certain quantity of water must be injected at the moment of compaction to get the greatest results from rolling the soil. Using less or more than this won't allow us to achieve maximal dry density in compacted soil. Maximum dry density d (max) refers to the highest possible value of dry density achieved by compaction, while optimum moisture content refers to the highest possible level of water content achieved through compaction (OMC).

Using a standard test designed by Proctor in 1911, the OMC and d (max) values may be calculated in the laboratory. Wet soil is filled into a cylindrical mould of a standard size; the test is to fill and compact the wet soil in three stages, each layer squeezed by the falling hammer to a set standard degree of compaction. Soil dry density is then computed using the soil's water content [38].

The attained dry density at various water contents may be estimated by repeating the test at various water contents (gradually rising) and creating a curve between water content and obtained dry density. Dry density rises first as moisture content increases and then reduces as moisture content climbs more. The highest possible value of dry density is d. (max) [39].

Compaction is a term used to describe the process of reducing air spaces in soil by employing mechanical methods. Mechanical compaction techniques include the use of rollers, vibrators, and rammers, for instance. Repetitive loading is an essential component of compaction, while consolidation is a long-term loading process that results in the removal of water from the pores of saturated soil and produces its consolidation through volume reduction. A certain quantity of water must be injected at the moment of compaction to get the greatest results from rolling the soil. Using less or more than this won't allow us to achieve maximal dry density in compacted soil. Maximum dry density d (max) refers to the highest possible value of dry density achieved by compaction, while optimum moisture content refers to the highest possible level of water content achieved through compaction (OMC).

Using a standard test designed by Proctor in 1911, the OMC and d (max) values may be calculated in the laboratory. Wet soil is filled into a cylindrical mould of a standard size; the test is to fill and compact the wet soil in three stages, each layer squeezed by the falling hammer to a set standard degree of compaction. Soil dry density is then computed using the soil's water content [36], [40].

The attained dry density at various water contents may be estimated by repeating the test at various water contents (gradually rising) and creating a curve between water content and obtained dry density. Dry density rises first as moisture content increases, and then reduces as moisture content climbs more. The highest possible value of dry density is d. (max) [41].

2.1.2. Sieve Analysis Test

According to IS 460-1972, coarse grain soils have particles larger than 75 microns (0.075 mm) in diameter (updated). Coarse-grained soils have a variety of sizes from which to choose: Coarse-grained soils include sand, gravel, cobble, and boulder. The following are the options: 1) More than 300 mm; 2) 80 mm to 300 mm cobble; 3) 4.75 mm to 80-mm gravel; and 4) 0.075-0.75 mm sandy sand. As the name suggests, fine-grained soils have a grain size of less than 0.075 mm (75 microns). Coarse-grained soils will contain varying proportions of coarse particles of different sizes and relatively little fines, as the term implies (silt and clay sizes). The soil is commonly sieved through a succession of sieves of increasing diameters (0.075 mm to 300 mm) to measure the proportion of various coarse particles. In the coarse size range, the following two sets of I.S. sieves are available: As a starting point, we'll choose a set that includes sieves with openings of different diameters (the first set includes sieves with opening widths of 30 cm, 60 cm, and 15 cm). (2) a second set consisting of sieves ranging in size from 2 mm to 0.750 mm (0.075 mm) in the following sizes: 0.850 mm (850), 0.600 mm (600), 0.440 mm (425), 0.300 mm (300), 0.212 mm (75). After the required coarse soil has been sieved through the two sets of sieves listed above to determine the percentage finer than the various sieve sizes, the grain size distribution curve is shown. Using the grain size distribution curve, it is possible to determine the percentage of various coarse soils, such as boulders, gravel, and sand. There are other percentages for coarse sand, medium sand, and fine sand. Curvature (Cc) and uniformity (Cu) values may also be determined using the formulae outlined in the footnote below. For coarse soils with fewer than 5% particles (silt and clay sizes), dry sieving is used; for coarse soils with more than 5% fines, wet screening is employed (silt and clay sizes). The cohesive bond between fine and coarse soil particles may be broken by wetting [16].

2.1.3. Liquid Limit Test

If you want to know how much water can be held in the soil before it breaks down, this test might help you out. "Liquid limit" is a term used to describe the water content at which fine-grained soil behaves like a fluid yet has poor shear strength. Liquid flow can close a groove in Casagrande's limit device in a matter of 25 blows. Liquidity is created when water is introduced to fine soil, and this liquid-like behaviour occurs even when the material has no shear strength. Soil changes from a liquid to a plastic state when its water content decreases over time. When the soil is plastic, it gains a significant amount of shear strength. Clay toys are manufactured from plastic soil (i.e. earth in its plastic form), which is sticky dirt that can be moulded into different shapes. Generally, the letter L denotes the water concentration at which the soil simply transforms from a liquid to a plastic state. In physical words, it is the water content at which soil transitions from zero to infinite shear strength. Using a traditional liquid limit apparatus, 25 blows may be used to determine the soil's liquid limit, which is defined as the water content at which the soil has low shear strength and flows to close a groove of standard dimensions. To classify fine-grained soils, it is necessary to know the soil's liquid limit and its plastic limit [42].

2.1.4. Plastic Limit Test

During the process of reducing the soil's moisture content, it moves from a liquid state to a plastic one. The dirt gains a lot of shear strength and stickiness while it's in the plastic stage, allowing it to be moulded into different forms. Semi-solid soil forms as the earth's moisture level drops even lower. As soon as we attempt to form the soil into an arbitrary shape when it is semi-solid, it starts to crumble. Plastic limit refers to the moisture content at which a material transitions between plastic and semisolid. That which causes a soil sample to collapse when moulded is the water content (P) at which the soil is no longer flexible. The plastic limit is the water content at which a soil begins to disintegrate when rolled into a 3 mm diameter thread in the laboratory, according to the definition. As a general rule, soil behaves like a plastic material in the water content range between its liquid limit (L) and plastic limit (P). Because of this, the plasticity index is named after it (I.P.). When exposed to varying water concentrations, plastic soils have a high I.P. and act like a plastic substance. In order to classify fine-grained soils, it is necessary to take into account the soil's liquid limit and its plastic limit [43].

2.1.5. California bearing ratio (CBR) Test

It was developed by the California Division of Highways to identify and assess flexible pavement soil-subgrade and base course materials using the California Bearing Ratio (CBR). The CBR measures a material's resistance to being penetrated by a standard plunger under controlled circumstances of density and wetness. At a speed of 1.25 millimetres per minute, an iron plunger with a diameter of 50 millimetres is pressed into a pavement component. 2.5 mm and 5 mm load records are preserved. At each deformation level, the CBR value is calculated as a percentage of the standard load value. Table 1 lists the standard load values based on the average of several experiments on various crushed stones [20], [44], [45].

Table 1 Standard Load values on Crushed Stones

Penetration of plunger (mm)	**Standard load (kg)**
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

2.2. Coarse Aggregates

2.2.1. Crushing Value Test
Surface abrasion resistance and resistance to crushing beneath the roller are the two most important mechanical characteristics of road stones. Road aggregate crushing strength is an important requirement in India because of the high surface stresses caused by inflexible tyre rims of highly laden animal-drawn vehicles. A road stone's crushing strength may be tested on aggregates or carved-out cylindrical specimens made of rock. To put it another way: these two tests use quite distinct methods and report their findings in two very different ways. It is important that aggregates used in road building can resist the weight of driving wheels. If the aggregates are weak, the pavement construction will be unstable. The strength of coarse aggregates may be assessed using the aggregates crushing test. A material's resistance to crushing under a steadily increasing compressive stress is gauged by its aggregate crushing value. To get high-quality pavement aggregate, it is preferable to use crushed aggregate with a low crushing value [46].

2.2.2. Impact Test
A material can endure impact that determines its toughness. As a consequence of the pounding action or impact caused by heavy traffic, the road stones are in danger of breaking apart. Therefore, the road stones must be strong enough not to shatter when struck. A road stone impact test measures the stone's resistance to fracture under impact, which is a measure of toughness. The Page Impact test uses cylindrical stone specimens, while the Aggregate Impact test uses stone aggregates. When calculating aggregate impact values for certain aggregates, the aggregate impact value is used as a relative assessment of an aggregate's ability to withstand a sudden shock or impact. The test technique covers the process of figuring out the aggregate impact value of coarse aggregates [46].

2.2.3. Abrasion Test
The tops of the road stones used in the surfacing course are worn away by driving. Since road aggregates are often used in the wearing course, hardness or wear resistance is critical. As a consequence, road stones must be durable enough to endure the abrasion of passing vehicles. Aggregate abrasion tests are often carried out with one of the following techniques: Abrasion tests include the Los Angeles, Deval, and Dorry varieties all of which use abrasives. As a result, the Los Angeles abrasion exam has been the most often utilised of these tests. The ISI recommends using the Los Angeles abrasion test wherever practical.
During the Los Angeles abrasion rest test, steel balls are utilised as an abrasive charge and the pounding action of these balls is also present to assess the percentage of wear induced by the relative rubbing action between the aggregates and the balls. The rubbing and pounding action simulate field conditions that induce wear and damage, according to some studies. The Los Angeles abrasion test has been standardised by ASTM, AASHO, and ISI. A standard specification for Los Angeles abrasion values is also offered for several kinds of pavement construction.

2.2.4. Specific Gravity & Water Absorption Test
A material's strength or quality is determined by its specific gravity. Stones with low specific gravity tend to be weaker than those with higher specific gravity values. The specific gravity test may be used to identify different types of stones. The strength of a rock may be gauged by looking at how well it absorbs water. In general, porous stones are considered undesirable unless they pass tests for strength, impact, and hardness [47].

2.3. Bitumen Tests

2.3.1. Penetration Test
A range of grades and types of bituminous materials may be found based on their origin and refining procedure. These materials may be graded based on how far a standard needle can penetrate vertically in millimetres or centimetres under prescribed stress, duration, and temperature conditions using a penetration test. Hence, a conventional needle penetration test (in units of one-tenth of a millimetre) is carried out by measuring the bitumen sample at 25 °C for five seconds, with a total weight of 100 g. If the bitumen is softer, the penetration will be higher. Bitumen is graded using the penetration test, which is widely used across the globe. The ISI has established a standard for penetration testing equipment and procedures [48].

2.3.2. Ductility Tests
The binders used in flexible pavement construction must form ductile thin films surrounding the aggregates when using bitumen as a binder substance. This is a good binder for improving the aggregates' physical interconnecting. A permeable pavement surface would develop if the binder material lacked sufficient ductility. As a result, the structural integrity of the pavement is compromised. Precise correlations between bitumen's chemical makeup and ductility have been hypothesised by several authorities, although this is incorrect in other cases. Thus, it is feasible that the bitumen meets penetration but not ductility standards. As far as bitumen paving engineers go, they'd like to see both test standards completed in the field. Penetration and ductility are crucial in any case. The ductility of a bitumen briquette is gauged by how far the thread can be stretched before snapping, expressed in centimetres. At a temperature of 27 0.5 °C and a draw rate of 50 2.5 mm per minute, the test is carried out [36], [38], [40].

3. RESULTS AND DISCUSSION
This section describes the results that came out from the testing in the laboratories.

3.1. Soil Investigation
In the soil investigation section, to test the properties of soil by various tests conducted in the laboratory.

3.1.1. Optimum moisture content and dry density
The optimum moisture content and dry density of soil were found through the proctor compaction test. The results of optimum moisture content and dry density were found through the sequential samples test conducted in the laboratory by continuously increasing the water content. The detailed calculation and values of tests are elaborated in **Table 2. Equation 1** is

used to find the dry density of soil samples. **Fig.1** shows the graphical representation between the dry density and water content.

$$\gamma_d = \left(\frac{\text{Mass of moist soil in the mould}}{\text{The volume of the mould}}\right)\left[\frac{1}{1+\omega}\right]$$
(1)

Table 2 Calculation sheet of dry density

Container no.	**01**	**02**	**03**	**04**	**05**
Mass of mould + wet soil in grams.	6032	6128	6208	8286	6188
Mass of mould in grams.	4045	4045	4045	4045	4045
Mass of wet soil in grams.	1987	2083	2163	2241	2143
The volume of mold in the cc	1000	1000	1000	1000	1000
Wet density of soil in grams/cc	1.987	2.083	2.163	2.241	2.143
Mass of wet soil + container in grams.	61.37	65.87	68.72	67.98	68.53
Mass of dry soil + container in grams.	58.74	62.59	65.04	63.20	63.20
Mass of water in grams.	2.63	3.28	3.68	4.78	5.33
Mass of container in grams.	27.09	29.49	32.28	28.08	28.80
Mass of dry soil in grams.	31.65	33.10	32.76	35.12	34.40
Water content in percentage.	8.30	9.90	11.22	13.60	15.50
Dry density in grams/cc	1.835	1.895	1.945	1.973	1.885

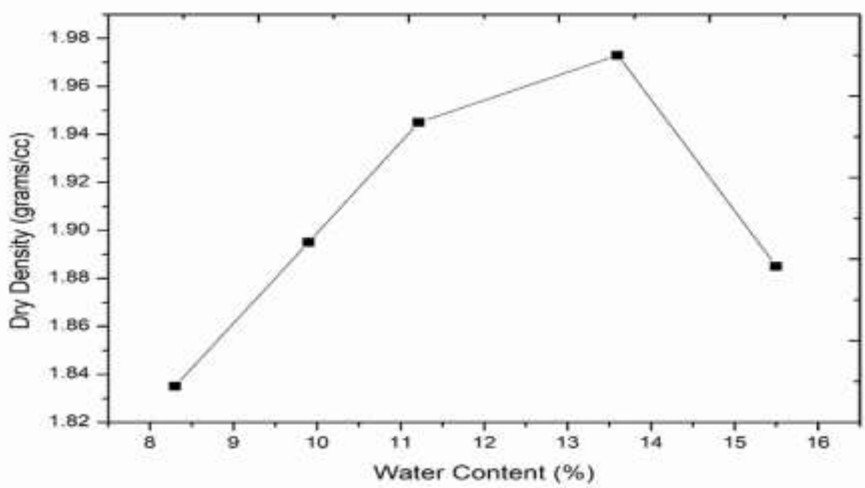

Fig. 1 The graph between the dry density and water content

3.1.2. Gradation of Soil particles

The gradation curve of the soil samples is found through the sieve analysis tests, in which different sizes of sieve are used to find the passing percentages of samples. **Table 3** describes the various sieve sizes with passing and retaining percentages of soil samples. All the particles' sizes lie below the 300-micron size sieve.

Table 3 Sieve analysis of soil sample

Sieve size (micron)	Mass of soil retained in gm.	Percentage retained	Cumulative percentage retained	Percentage passing
600	0	0	0	100
425	0	0	0	100
300	0	0	0	100
212	2	0.4	0.4	99.6
150	12	2.4	2.8	97.2
75	140	28.0	30.8	69.2
PAN	346	69.2	100	0

3.1.3. Liquid limit and plastic limit

The liquid and plastic limit tests on soil samples are conducted in the laboratory. The plastic limit shows that a point or limit water content with soil samples starts the plastic nature or changes the state from solid to plastic. The liquid limit shows the limiting point from where to soil sample paste changes from the plastic phase to liquid phase. **Table 4** shows the detailed experimental values that came from testing in the laboratories.

Table 4 Liquid limit calculation sheet

Container no.	Mass of wet soil + container in gm.	Mass of dry soil + container in gm.	Mass of water in gm.	Mass of empty containers in gm.	Mass of dry soil in gm.	Plastic limit moisture content in %
1	30.47	30.16	0.31	28.61	1.55	20
2	34.91	34.58	0.33	32.93	1.35	20

3.1.4. California bearing ratio

CBR (California bearing ratio) test is conducted to evaluate the bearing capacity of soil samples. It is a very important test in the field of soil. **Table 5** describes the detailed experimental values of the CBR test. There are three tests conducted on the three different samples. After the tests, take the average of all test results for the final [49].

3.2. Aggregates investigation

The aggregates are investigated, to check the properties of the available coarse aggregates before usage in pavement construction.

3.2.1. Crushing value

There must be sufficient resistance to traffic-induced surface abrasion and appropriate resistance to crushing beneath the roller for road stones to meet the fundamental mechanical requirements. Road aggregate crushing strength is required in India because of the excessive surface stresses on rigid tyre rims caused by heavily loaded animal-drawn vehicles. Aggregates or cylindrical specimens cut from rocks may be used to measure the crushing strength of road stones. Both the testing process and the way the data are presented vary greatly between the two studies. To withstand the crushing force of traffic wheels, road-building aggregates must be crush-resistant. Instability in the pavement's foundation may be traced back to weak aggregates. It is used to determine the strength of coarse aggregates via the use of crushing tests. The resistance of a material to crushing when subjected to increasing compressive stress is reflected in its aggregate crushing value. A low aggregate crushing value should be suggested to generate high-quality pavement aggregate. Table 6 shows the outcomes of the tests that were conducted.

Table 5 California bearing ratio testing and results detail

Instrument No.		**50kN**		Proving Ring Capacity in Kgs.		**5000**	
				Proving Ring Least Count:		**1 Div = 5.525**	
Plunger Area:				Surcharge Load During Test in Kgs:		**5**	
Penetration In mm	**Total Standard Load (Kgf) & Unit Standard Load (Kg/Cm2)**	**Test 1**		**Test 2**		**Test 3**	
		Dial Gauge Reading	**Load (Kgf) & Load (Kg/Cm2)**	**Dial Gauge Reading**	**Load (Kgf) & Load (Kg/Cm2)**	**Dial Gauge Reading**	**Load (Kgf) & Load (Kg/Cm2)**
0.5		5	27.625 1.414	5	27.625 1.414	5	27.625 1.414
1		9	49.725 2.53	10	55.250 2.81	10	55.250 2.81
1.5		14	77.350 3.94	14	77.350 3.94	14	77.350 3.94
2		17	93.925 4.78	19	104.975 5.34	20	110.500 5.63

2.5	1370 70	23	127.075 6.47	24	132.600 6.75	25	138.125 7.03
4		34	187.850 9.56	35	193.375 9.85	37	204.425 10.41
5	2055 105	42	232.050 11.82	45	248.625 12.66	45	248.625 12.66
7.5		58	320.450 16.32	60	331.500 16.88	60	331.500 16.88
10		66	364.650 18.57	69	381.225 19.41	66	364.650 18.57
12.5		74	408.850 20.82	76	419.900 21.38	73	403.325 20.54

Table 6 Crushing value calculation sheet

Description	**Sample No.**	
	1	**2**
Total weight of dry sample taken 'A' (gm)	3000	3000
Weight of sample passing through 2.36 mm 'B' (gm)	468	395
Aggregate Crushing Value ($\frac{B}{A}$ x 100) (%)	15.6	13.2

3.2.2. Impact value

Toughness is a metric used to assess a material's ability to withstand a blow. Stones may be broken into smaller pieces due to the pounding action or impact they get as a consequence of heavy traffic loads. Therefore, road stones need to be able to withstand the force of contact without breaking. The hardness of a road stone may be assessed using an impact test on the stone. Page Stone aggregates are used in Aggregate Impact testing rather than cylindrical specimens for impact tests [35], [50], [51]. Relative to its resistance to continuous compressive stress, a material's impact value is a measure of how well it can withstand an unexpected shock or impact. Aggregate impact values for coarse aggregates are calculated using the test method described here. Table 7 presents the impact test findings on the sample aggregates as a percentage.

Table 7 Impact value calculation sheet

Description	**Sample No.**

	1	2
Total weight of dry sample taken 'A' (gm)	538	543
Weight of sample passing through 2.36 mm 'B' (gm)	52	56
Aggregate Impact Value ($\frac{B}{A}$ x 100) (%)	10.35	9.69

3.2.3. Abrasion value

Due to traffic, the surface course's road stones are susceptible to wear near the top. Since road aggregates are utilised in the wearing course, they must have high wear resistance or hardness to be effective. The conclusion is that roads should be resistant to the wear and tear generated by automobiles. The following procedures are typically used to perform aggregate abrasion tests: Los Angeles abrasion, Deval abrasion, and Dorry abrasion tests are all examples of abrasion tests. One of the most often utilised abrasion examinations is the Los Angeles abrasion exam because it has been linked to academic performance [52]. The Los Angeles abrasion test should be used whenever possible, according to the ISI. Aggregate samples' findings are shown in Table 8.

Table 8 Abrasion value calculation sheet

Description	**Sample No.**	
	1	**2**
Total weight of dry sample taken 'A' (kg)	10	10
Weight of sample retained on 1.70 mm I.S. sieve 'B' (kg)	8.227	8.547
Aggregate Abrasion value ($\frac{A-B}{A}$ x 100) (%)	17.7	14.53

3.2.4. Specific gravity and absorption

A material's specific gravity is used to determine its strength or quality. Stones with a low specific gravity are often weaker than those with a high specific gravity. The specific gravity test can be used to identify stones. The capacity of a rock to absorb water reveals its strength. More porous stones absorb more water and are typically considered undesirable unless they pass strength, impact, and hardness tests. **Table 9** describes the specific gravity and absorption detail of the samples.

Table 9 Specific gravity and water absorption detail

Description	**Sample No.**	
	1	**2**
Weight of saturated aggregate and basket in water = W1 (gm)	3911.3	3743.2
Weight of basket in water = W2 (gm)	2674.9	2674.9
Weight of saturated surface dry aggregates in air = W3 (gm)	1995.9	1658.1
Weight of oven-dried aggregate in air = W4 (gm)	1982.0	1650.3
Specific gravity = $\frac{W4}{W3-(W1-W2)}$	2.60	2.64
Water Absorption = $\frac{(W3-W4)}{W4}$ x 100%	0.7%	0.4%

The average value of Specific Gravity $= \frac{2.60+2.64}{2} =$ **2.62**

The average value of Water Absorption= $\frac{0.7+0.4}{2}$ = **0.55 %**

3.3. Bitumen

The preliminary tests were conducted on the bitumen sample to check the quality of the material by various tests.

3.3.1. Penetration

Bituminous materials are separated into several grades and classifications based on their origin and refinement process. The penetration test is used to determine the quality of these materials. By measuring the vertical penetration depth (in millimetres or centimetres) to which a standard needle can penetrate vertically under given stress, duration, and temperature conditions. This means that the essential premise of the penetration test is that a standard needle will penetrate a bitumen sample kept at 25 °C for five seconds and be measured in units of a tenth of a millimetre. The needle assembly weighs 100 grammes. Penetration will increase if the asphalt is softer. Throughout the globe, the penetration test is used to classify bitumen. The tools and techniques for penetration testing have been standardised by the ISI. Table 10 lays forth the details of the penetration testing.

Table 10 Detail of penetration test

Readings	**Sample No.**		
	1	**2**	**3**
Penetrometer dial reading (i) Initial	12.5	10.4	11.6
(1/10 mm) (ii) Final	71.1	82.8	75.3
Penetration Value, (1/10mm)	58.6	72.4	63.7

The average value of penetration $= \frac{58.6+72.4+63.7}{3} =$ **64.9 mm/10**

So, the bitumen grade suggested by the above observations is that 60/70& may be designated as A 65.

3.3.2. Ductility

Bitumen binders are required to make ductile thin films surrounding the aggregates when they are employed to create flexible pavements. This is a great binder for increasing the aggregates' physical interconnecting. Insufficient ductility in the binder material would result in a permeable pavement surface. This has a negative impact on the pavement's structural integrity. If the chemical composition and crude source of the bitumen differs from that stated by certain experts, then penetration and ductility may not always be synonymous. Bitumen may meet penetration requirements but not the ductility ones. Bitumen paving engineers, on the other hand, would prefer that both requirements be achieved in the area of operation. Penetration and ductility cannot be interchangeable in any situation. If you test bitumen's flexibility in centimetres, you may determine how far a normal bitumen-coated briquette can be stretched before the thread breaks. At a draw rate of 50.25 millimetres per minute at a temperature of 27.05 degrees Celsius, the test is carried out. Detailed findings of the bitumen ductility test may be found in Table 11.

Table 11 Detail of ductility test

Test	**Briquette Number**	
	1	**2**
Ductility Value (cm)	53.5	61.2

Average value of Ductility of Bitumen $= \frac{53.5+61.2}{2}$ =57.35cm.

4. CONCLUSION

After the experimental investigation in the laboratories, the following conclusions are as:

- In soil investigation, the optimum moisture content and maximum dry density are 14% and 1.97gm/cc, respectively. The liquid limit and plastic limit are 35% and 20%, respectively. The CBR value are found at 2.5 mm and 5mm are 1.2% and 1.4%, respectively.
- In the aggregate's investigation, the crushing value, impact value, abrasion value, specific gravity and water absorption are 14%, 10%, 16%, 2.62, and 0.55%, respectively.
- In the bitumen experimental investigation, the penetration and ductility of the bitumen's are 64.9mm/10 and 57.35cm, respectively.

5. REFERENCES

[1] I. Ismail, S. A. Bernal, J. L. Provis, S. Hamdan, and J. S. J. Van Deventer, "Microstructural changes in alkali-activated fly ash/slag geopolymers with sulfate exposure," Mater. Struct. Constr., vol. 46, pp. 361–373, 2013, doi: 10.1617/s11527-012-9906-2.

[2] S. Sureshkumar and A. Joseph, "Review on Structural Performance of Water Tanks Under Dynamic Loading," Int. Res. J. Eng. Technol., vol. 4, no. 4, 2017.

[3] IS 2720 (Part XXXV) -1974, "Methods of test for soils Part XXXV Measurement of negative pore water pressure," Bur. Indian Stand., vol. 4720, no. October 1974, 1995.

[4] IS 4332 (Part VIII) -1969, "Methods of test for stabilized soils Part VIII Determination of lime content of lime stabilized soils," Bur. Indian Stand., 1995.

[5] IS 4332 (Part IX) -1970, "Indian Standard Methods of test for stabilised soils Part IX Determination of the bituminous stablizer content of btiminous and tar stabilized soils," Bur. Indian Stand., 1995.

[6] IS 2720 (Part XXXIX/sec 2) -1979, "Methods of test for soils Part XXXIX direct shear test for soils containing gravel Section 2 In-situ shear test," Bur. Indian Stand., vol. 2720, no. November 1979, 1997.

[7] IS 4332 (Part IV) -1968, "Methods of test for stabilized soils Part IV wetting and drying, and freezing and thawing tests for compacted soil-cement mixtures," Bur. Indian Stand., 1995.

[8] IS 2720 (Part XXI) - 1977, "Method of test for soils part XXI determination of total soluble solids," Bur. Indian Stand., 1995.

[9] H. M. Somasekharaiah, E. N. Dharmesh, and M. Ghouse, "A Comparative Study on RC Frame Structure Considering Lead Rubber Bearing and Triple Friction Pendulum Bearing," Artic. Int. J. Innov. Res. Sci. Eng. Technol., vol. 3297, pp. 14907–14918, 2016.

[10] L. Raghava Naidu, H. Sudarsana Rao, and V. G. Ghorpade, "Seismic analysis of RC elevated water tank in different seismic zones," Int. J. Civ. Eng. Technol., vol. 10, no. 2, pp. 2354–2364, 2019.

[11] A. Arulrajah, T.-A. Kua, C. Phetchuay, S. Horpibulsuk, F. Mahghoolpilehrood, and M. M. Disfani, "Spent Coffee Grounds–Fly Ash Geopolymer Used as an Embankment Structural Fill Material," J. Mater. Civ. Eng., 2016, doi: 10.1061/(ASCE)MT.1943-5533.0001496.

[12] I. Ismail, S. A. Bernal, J. L. Provis, S. Hamdan, and J. S. J. Van Deventer, "Microstructural changes in alkali activated fly ash / slag geopolymers with sulfate exposure," Mater. Struct. Constr., vol. 46, pp. 361–373, 2013, doi: 10.1617/s11527-012-9906-2.

[13] IS 11593 - 1986, "Specification for shear box (large) for testing of soils," Bur. Indian Stand., 1995.

[14] IS 4332 (Part VI) -1972, "Indian Standard Methods of test for stabilized soils Part VI Flexural strength of soil-cement using simple beam with third point loading," Bur. Indian Stand., 1995.

[15] IS 2720 (Part XXXIX/Sec 1) -1977, "Method of test for soils Part XXXIX Direct shear test forsoils containg gravel Section 1 laboratory test," Bur. Indian Stand., no. February 1978, 1997.

[16] IS 2720 (Part III/Sec 1) -1980, "Indian Standard Methods of test for soil Part III Determination of specific gravity Section 1 Fine grained soils," Bur. Indian Stand., vol. 2720, 1997.

[17] IS 2720 (Part 31) - 1990, "Methods of test for soils Part 31 Field detrmination of california bearing ratio," Bur. Indian Stand., vol. 2720, no. March 1991, 1995.

[18] D. Or and T. A. Ghezzehei, "Modeling post-tillage soil structural dynamics: A review," Soil Tillage Res., vol. 64, no. 1–2, pp. 41–59, 2002, doi: 10.1016/S0167-1987(01)00256-2.

[19] IS 11229 - 1985, "Specification for shear box for testing of soils," Bur. Indian Stand., 1995.

[20] IS 2720 (Part 14) -1983, "Methods of test for soils part 14 Detreminaion of density index (relative density) of cohesionless soils," Bur. Indian Stand., vol. 2720, no. April 1984, 1995.

[21] IS 4332 (Part X) - 1969, "Indian Standard Methods of test for stabilised soils Part X Test for soil-bituminous mixtures," Bur. Indian Stand., 1995.

[22] IS 2720 (Part XXII) - 1972, "Methods of test for soils Part XXII Detremination of organic matter," Bur. Indian Stand., vol. 2720, 1995.

[23] Indian Roads Congress, "STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES SECTION : II LOADS AND LOAD COMBINATIONS," IRC 6-2016, no.

7, pp. 1–107, 2016.

[24] I. R. Congress, “GUIDELINES FOR THE DESIGN OF FLEXIBLE PAVEMENTS (Fourth Revision),” IRC:37-2018, no. 4, pp. 1–108, 2018.

[25] D. Moazami, H. Behbahani, and R. Muniandy, “Pavement rehabilitation and maintenance prioritization of urban roads using fuzzy logic,” Expert Syst. Appl., vol. 38, no. 10, pp. 12869–12879, 2011, doi: 10.1016/j.eswa.2011.04.079.

[26] Indian Roads Congress, “GUIDELINES FOR USE OF EXTERNAL AND UNBONDED PRESTRESSING TENDONS IN,” IRC:SP:67-2005, pp. 1–20, 2005.

[27] V. Astarita et al., “A Mobile Application for Road Surface Quality Control: UNIquALroad,” Procedia - Soc. Behav. Sci., vol. 54, pp. 1135–1144, 2012, doi: 10.1016/j.sbspro.2012.09.828.

[28] S. S. Shamsabadi, M. Wang, and R. Birken, “PAVEMON: A GIS-based data management system for PAVEment MONitoring based on large amounts of near-surface geophysical sensor data,” 27th Symp. Appl. Geophys. to Eng. Environ. Probl. 2014, SAGEEP 2014, pp. 130–133, 2014.

[29] U. Sharma, N. Gupta, A. Bahrami, Y. O. Özkılıç, and M. Verma, “Behavior of Fibers in Geopolymer Concrete : A Comprehensive Review,” Buildings, vol. 14, no. 136, pp. 1–28, 2024, doi: https://doi.org/10.3390/buildings14010136.

[30] U. Sharma, N. Gupta, and M. Verma, “Prediction of Compressive Strength of Geopolymer Concrete using Artificial Neural Network,” Asian J. Civ. Eng., vol. 24, no. 8, pp. 2837–2850, 2023, doi: 10.1007/s42107-023-00678-2.

[31] U. Sharma, N. Gupta, and M. Verma, “Prediction of compressive strength of GGBFS and Flyash-based geopolymer composite by linear regression, lasso regression, and ridge regression,” Asian J. Civ. Eng., vol. 24, no. 8, pp. 3399–3411, 2023, doi: 10.1007/s42107-023-00721-2.

[32] A. S. El-Wakeel, J. Li, A. Noureldin, H. S. Hassanein, and N. Zorba, “Towards a Practical Crowdsensing System for Road Surface Conditions Monitoring,” IEEE Internet Things J., vol. 5, no. 6, pp. 4672–4685, 2018, doi: 10.1109/JIOT.2018.2807408.

[33] R. Kumar, “Mechanical properties, shrinkage, abrasion resistance and carbonation of concrete containing recycled coarse aggregate of different size range,” Sustain. Constr. Mater. Technol., vol. 1, no. July, 2019, doi: 10.18552/2019/idscmt5014.

[34] G. Al-refai, H. Elmoaqet, and M. Ryalat, “In-Vehicle Data for Predicting Road Conditions and Driving Style Using Machine Learning,” Appl. Sci., vol. 12, no. 18, 2022, doi: 10.3390/app12188928.

[35] A. Chouksey, M. Verma, N. Dev, I. Rahman, and K. Upreti, “An investigation on the effect of curing conditions on the mechanical and microstructural properties of the geopolymer concrete,” Mater. Res. Express, vol. 9, no. 5, p. 55003, 2022, doi: 10.1088/2053-1591/ac6be0.

[36] R. Kumar, M. Verma, and N. Dev, “Investigation on the Effect of Seawater Condition, Sulphate Attack, Acid Attack, Freeze–Thaw Condition, and Wetting–Drying on the Geopolymer Concrete,” Iran. J. Sci. Technol. Trans. Civ. Eng. Civ. Eng., vol. 46, no. 4, pp. 2823–2853, 2022, doi: 10.1007/s40996-021-00767-9.

[37] N. Jayanthi, T. Ghosh, R. K. Meena, and M. Verma, “Length and width of low-light, concrete hairline crack detection.pdf,” Asian J. Civ. Eng., vol. 25, no. 3, pp. 2705–2714, 2024, doi: https://doi.org/10.1007/s42107-023-00939-0.

[38] R. Kumar, M. Verma, N. Dev, and N. Lamba, “Influence of chloride and sulfate solution on the long-term durability of modified rubberized concrete,” J. Appl. Polym. Sci., vol. 2022, no. 139, pp. 1–15, 2022, doi: DOI: 10.1002/app.52880.

[39] IS 2720 (Part VII) -1980, “Indian Standard Methods of test for soils Part VII Determination of water content-dry density relation usinglight compaction,” Bur. Indian Stand., vol. 2720, no. December 1980, 1997.

[40] R. Kumar, N. Dev, S. Ram, and M. Verma, “Investigation of dry-wet cycles effect on the durability of modified rubberised concrete,” Forces Mech., vol. 10, no. 2023, p. 100168, 2023, doi: 10.1016/j.finmec.2023.100168.

[41] IS 13468 -1992, “APPARATUS FOR DETERMINATION OF DRY DENSITY OF SOIL BY CORE CUTTER METHOD - SPECIFICATION,” Bur. Indian Stand., vol. 1992, no. July 1992, 1997.

[42] IS 2720 (Part 5)-1985, “Indian Standard Method of test for soils Part 5 Determination of liquid and plastic limit,” Bur. Indian Stand., 1995.

[43] IS 2720 (Part III/Sec 2) -1980, “Indian standard Methods of test for soils Part III Determination of Specific gravity,” Bur. Indian Stand., vol. 2720, 1980.

[44] IS 2720 (Part 15) -1986, “Methods of test for soils Part 15 Determination of consolidation properties,” Bur. Indian Stand., vol. 2720, no. May 1987, 2001.

[45] IS 2720 (Part 9) -1992, “Indian Standard Methods of tests for soils Part 9 Determination of dry density moisture ralation by constant mass of soil method,” Bur. Indian Stand., vol. 2720, no. July 1992, 1997.

[46] IS 2386 (Part III), “Methods of test for aggregates for concrete Part III Specific gravity, density, voids, absorption and bulking,” Bur. Indian Stand., vol. 2386, no. October 1963, 1997.

[47] IS 2386 (Part I), “Methods of test for aggregates for concrete Part I Particle size and shape,” Bur. Indian Stand., vol. 2386, 1997.

[48] IS 1201-1220 1978, “Methods for testing tar and bituminous materials,” Bur. Indian Stand., pp. 1–153, 1978.

[49] IS 2720 (Part 16) -1987, “Method of test for soils Part 16 Laboratory detetermination of CBR,” Bur. Indian Stand., 1997.

[50] N. Kumar, R. D. Raut, K. Upreti, M. S. Alam, M. Shafiuddin, and M. Verma, “Environmental Concern in TPB Model for Sustainable IT Adoption,” in International Conference on Information Systems and Intelligent Applications, Lecture Notes in Networks and Systems 550, 2023, pp. 59–70. doi: 10.1007/978-3-031-16865-9_5.

[51] M. Nigam and M. Verma, “Effect of Nano-Silica on the Fresh and Mechanical Properties of Conventional Concrete,” Forces Mech., vol. 10, no. 22, p. 100165, 2023, doi: 10.1016/j.finmec.2022.100165.

[52] K. Upreti et al., “Prediction of Mechanical Strength by Using an Artificial Neural Network and Random Forest Algorithm,” J. Nanomater., vol. 2022, pp. 1–12, 2022, doi: DOI: 10.1155/2022/7791582.