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Sustainable Utilization of Kota Stone Slurry Powder for Black Cotton Soil Stabilization: A Review

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Abstract: The generation and disposal of Kota stone slurry powder (KSSP), a by-product of cutting, grinding, and polishing operations in the Kota stone industry, has become an important environmental and waste-management concern. The large quantity of slurry generated from stone-processing activities requires appropriate utilization to minimize its adverse impacts on land, water, and the surrounding environment. Sustainable utilization of this waste material in geotechnical engineering offers a potential alternative for improving problematic soils while reducing the demand for conventional stabilizing materials. Black cotton soil is an expansive soil characterized by significant swelling and shrinkage, low bearing capacity, and unfavorable engineering properties, which can adversely affect pavement subgrades and other infrastructure. This review paper examines the potential of Kota stone slurry powder as a sustainable stabilizing material for black cotton soil. The review consolidates available literature on the physical and chemical characteristics of KSSP, with particular emphasis on its calcium oxide content and its interaction with expansive soil. The effects of KSSP addition on key geotechnical properties, including compaction characteristics, strength, California Bearing Ratio (CBR), swelling behavior, and overall subgrade performance, are discussed. The paper also evaluates the environmental and sustainability benefits associated with converting Kota stone waste into a useful construction material. Based on the reviewed studies, KSSP demonstrates potential as an alternative or supplementary soil-stabilizing material for improving the engineering performance of black cotton soil. However, further research is required to establish optimum

proportions, long-term durability, field performance, and standardized methods for large-scale application. The utilization of KSSP can contribute to a waste-to-resource approach, supporting sustainable soil stabilization and environmentally responsible pavement construction.

Keywords : Stabilization, Kota Stone Slurry, Soil, Strength, California Bearing Ratio (CBR), Kota Stones Sludge, Granite Sludge, Marble Slurry, Building Stone, Replacement Material.

I. INTRODUCTION

Kota stone is a naturally occurring limestone that is extensively used as a building and construction material, particularly for floor finishes, wall cladding, paving, decorative applications, staircases, and other architectural purposes. It is widely preferred because of its attractive appearance, durability, abrasion resistance, low water absorption, non-slippery surface characteristics, and relatively good resistance to oil and weathering. Kota stone is generally available in the form of slabs and tiles and is processed into different sizes and thicknesses according to construction requirements. The major deposits of Kota stone are located in and around Kota and parts of Jhalawar District in Rajasthan, India. The stone-processing industry has therefore developed considerably in this region and contributes significantly to local economic activities and employment.

The processing of Kota stone involves several stages, including cutting, sawing, grinding, and polishing. During these operations, a considerable quantity of fine stone particles is generated. Water is commonly used during cutting and polishing operations to cool the machinery, reduce friction, and control the temperature of the cutting tools. The mixture of finely divided stone particles and water forms a semi-liquid waste commonly known as Kota stone slurry. After collection and drying, this slurry can be converted into a fine powdered material known as Kota Stone Slurry Powder (KSSP). The material consists predominantly of finely ground limestone particles and contains calcium-rich constituents, making it potentially useful for several engineering applications.

The generation and disposal of Kota stone slurry has become a significant environmental and land-management concern in the Kota region. It has been reported that approximately 3.0–3.25 lakh metric tonnes of stone slurry are generated annually from stone-processing activities. Large quantities of this waste are

commonly disposed of in open areas or at locally convenient dumping sites. Continuous accumulation of slurry occupies considerable amounts of potentially useful land and can result in the formation of large heaps and slurry deposits. Such uncontrolled disposal not only creates visual and land-use problems but can also generate environmental and economic concerns for the surrounding communities [1–2].

The improper disposal of stone slurry may affect the physical and chemical characteristics of the surrounding soil. The fine particles present in the waste can alter soil characteristics and may contribute to changes in soil alkalinity. Runoff and leaching from improperly managed disposal sites may also create a potential risk of contamination of nearby surface water and groundwater. Furthermore, once the slurry dries, its fine particles can become airborne and contribute to dust generation, potentially affecting air quality and creating occupational and environmental health concerns. The accumulation of slurry deposits can also reduce the productive use of land and may interfere with agricultural and other activities. Consequently, appropriate utilization and management of Kota stone slurry are necessary to reduce its environmental impact and convert this industrial waste into a useful resource.

At the same time, the stabilization of problematic soils is an important requirement in geotechnical and pavement engineering. Black cotton soil (BC soil) is a widely distributed expansive soil in several regions of India. It contains a significant proportion of expansive clay minerals and exhibits considerable volume changes in response to variations in moisture content. During wet conditions, black cotton soil tends to swell, while it undergoes shrinkage during drying. These repeated swelling–shrinkage cycles can result in cracking, differential deformation, and loss of bearing capacity, which may adversely affect the performance of roads, embankments, foundations, and other infrastructure constructed over such soils.

Soil stabilization is therefore commonly adopted to improve the engineering properties of expansive soils. Conventional stabilization techniques may involve the use of materials such as lime, cement, fly ash, and other chemical or industrial additives. Although these materials can effectively modify soil properties, their production, transportation, and application may involve considerable economic and environmental costs. Consequently, increasing attention is being given to the

utilization of locally available industrial and agricultural wastes as alternative or supplementary stabilizing materials. The use of waste materials for soil improvement provides a dual benefit by reducing waste-disposal problems while simultaneously improving the engineering performance of problematic soils.

Kota Stone Slurry Powder has considerable potential in this regard because of its fine particle size and calcium-rich composition. Its chemical and physical characteristics may influence the compaction, strength, bearing capacity, and volume-change behavior of expansive soil when incorporated in suitable proportions. The addition of KSSP can modify the soil matrix by introducing fine mineral particles and calcium-bearing constituents, potentially improving the interaction between soil particles and enhancing selected geotechnical properties. The effectiveness of the material, however, depends on factors such as its chemical composition, particle size, initial soil properties, moisture content, mixing proportion, curing conditions, and method of application.

The utilization of KSSP for black cotton soil stabilization therefore represents a waste-to-resource approach to sustainable geotechnical engineering. Instead of treating stone slurry solely as an industrial waste requiring disposal, it can potentially be converted into a value-added material for soil improvement. Such an approach can reduce the quantity of waste deposited in open areas, conserve natural resources, reduce dependence on conventional stabilizing agents, and provide an economical source of locally available material for infrastructure development.

In this context, the present review focuses on the sustainable utilization of Kota Stone Slurry Powder for the stabilization of black cotton soil. The review examines the available literature concerning the characteristics and composition of Kota stone slurry powder and its influence on the engineering behavior of expansive soils. Particular attention is given to changes in compaction characteristics, strength properties, California Bearing Ratio (CBR), swelling behavior, and pavement subgrade performance resulting from the incorporation of KSSP. The environmental and sustainability benefits associated with the utilization of Kota stone waste are also discussed. The review further identifies existing research gaps and highlights areas requiring additional investigation to establish optimum KSSP content, long-term performance, field applicability, and suitable guidelines for its

implementation in sustainable pavement and geotechnical construction.

II. IMPORTANCE OF KOTA STONE

Kota stone is a naturally occurring limestone widely used as a building and decorative material because of its durability, attractive appearance, affordability, and favorable physical properties. It is primarily quarried from the Kota region of Rajasthan and is available in a variety of natural shades and textures. The combination of aesthetic and functional properties has made Kota stone a popular choice for both residential and commercial construction.

A. Aesthetic and Architectural Importance

One of the major advantages of Kota stone is its natural appearance. It is available in different shades, including variations of green, blue, brown, grey, and other natural tones. These colors and textures provide an attractive and distinctive appearance without requiring extensive artificial treatment. Consequently, Kota stone is extensively used for architectural and decorative purposes.

It is commonly used for flooring, wall cladding, staircases, pathways, corridors, driveways, balconies, terraces, entrance areas, and commercial buildings. Its natural finish can provide buildings with a durable and aesthetically pleasing appearance. The stone can also be cut, polished, and finished in different dimensions and shapes according to specific architectural requirements.

B. Physical and Functional Properties

Kota stone possesses several physical characteristics that contribute to its suitability as a construction material. It is relatively hard and durable and exhibits good resistance to abrasion and wear. Its low water absorption makes it suitable for applications where resistance to moisture is important. The relatively non-slippery surface characteristics of properly finished Kota stone also make it suitable for flooring and outdoor applications.

Another important characteristic is its resistance to oil and staining compared with some other flooring materials. These properties contribute to its use in areas exposed to regular traffic, moisture, and environmental conditions. Kota stone is generally supplied in the form of slabs and tiles, which can be processed according to the dimensions and requirements of the intended application.

C. Economic Importance

Kota stone is considered an economical alternative to several other natural stones used for flooring and architectural applications. Its relatively low cost, local availability, and ease of processing make it accessible for a wide range of construction projects. The availability of substantial deposits and an established stone-processing industry in the Kota region further supports its economic importance.

The Kota stone industry also contributes to local employment and supports various activities associated with quarrying, cutting, polishing, transportation, and construction. However, these processing activities simultaneously generate significant quantities of stone slurry waste, creating a need for appropriate waste-management and utilization strategies.

D. Suitability for Different Climatic Conditions

Kota stone is suitable for a wide range of climatic conditions because of its durability and relatively low water absorption. It can be used in both indoor and outdoor applications and is particularly suitable for areas where resistance to moisture and regular wear is required. Its substantial weight and strength require appropriate preparation of the supporting base when it is used as flooring or paving material.

E. Versatility in Application

Another important advantage of Kota stone is its versatility. The stone can be sawn, cut, ground, honed, and polished into different sizes, thicknesses, and shapes. This flexibility allows it to be used for both conventional and customized architectural designs. Depending on the desired appearance and functional requirements, different surface finishes can also be obtained.

Kota stone is therefore an important natural construction material due to its durability, aesthetic appeal, affordability, low water absorption, wear resistance, and versatility. At the same time, the extensive processing of Kota stone generates considerable quantities of fine slurry waste. The conversion of this waste into Kota Stone Slurry Powder (KSSP) provides an opportunity for its beneficial utilization in engineering applications, including the stabilization of problematic soils. Such utilization can help reduce the environmental burden associated with stone-slurry disposal while creating a potential low-cost material for sustainable geotechnical construction.

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III. PHYSICAL AND CHEMICAL PROPERTIES OF KOTA STONE

Kota Stone are quite impervious, Hard, Compact, fine to very fine grained calcareous rocks of sedimentary nature.

Table 1: Physical Properties of Kota Stone

Compressive Strength	21.75 kg/sq. Mm
Abrasion Resistance	18.12 (Abrasion value)
Oil Absorption	Nil
Water Absorption	0.31 %
Mohr Hardness No.	will scratch -3 Calcite will not Scratch- 2.1/2 Galena
Density	2.5 to 2.65 Kg/m3
Porosity	Quite Low
Weather Impact	Resistant

Chemically, Kota Stone are siliceous calcium carbonate rocks.

Table 2: Chemical Properties of Kota Stone

Lime (CAO)	38-42%
silica(SiO_2)	20-25%
Alumina (Al_2O_3)	2-4%
Other Oxides like Na, Mg	1.5 to 2.5%
Loss On Ignition (LOI)	30-32%

IV. GENERATION OF WASTE

Indian calcareous stone industry currently produces around 17.8M.T of solid calcareous waste (12.2 M.T as rejects at the mine sites, 5.2 M.T in the form of cutting /trimming or undersize materials and 0.4 M.T. calcareous slurry at processing and polishing units). The polishing is applicable only to marble and flagstones. To accumulate calcareous waste is of the order of 250 M.T. it has become an environmental waste is of the order of 250 M.T. it has become an environmental hazard affecting the land and population over a large area.

The solid waste generated in the calcareous stone industry is directly related with the production and processing of various types of calcareous stones that have drastically increased over the years. It is about 16.5% of the total calcareous stone produced in the country. the waste generated varies from negligible in case of the calcareous stone used in cement

industry, 10-20% in case of lime burning industry 20-40% in case of building stone(block and slab) industry,40-45% in case of steel grade limestone and dolomite production and 65-85% in case of marble and flag stone (Kota stone , Cuddapaha Slab and Shahabad stone)used in dimensional and decorative industry . Presently out of 6773 mines of calcareous stone covering an area of about 0.2 million hectares of land. Only about 5400 mines are operating. The production of calcareous stone has gradually increased from 76 M.T. (1989-90) to 97 M.T. (1993-94) and 118.6 M.T. (1996-97). It is expected to touch 139 M.T. by 2000 AD and to 188.6 M.T. by 2005 A.D.

Quarrying of Kota stone and other dimensional stones is being carried out throughout the state and same is being processed at gangsaws, single and multi-blade cutters and similar processing units which are spread all across the state only insignificant quantities have been utilized and the rest has been dumped resulting in tremendous increase in generation of stone waste in the form of mine waste, cutting waste and processing/polishing waste which creates environmental problem and health hazards such as:

A. *Quarrying and Trimming Waste*

- The Cutting waste produced during trimming of edges of the slabs, broken pieces, unsawable blocks, irregular and odd shaped blocks are lying scattered here and there in the mine area as well as in processing units.
- The quarrying waste is just piled up in the areas nearer to quarries by the miners, creating huge mounds of stone waste, thereby destroying the natural vegetation and ecology of the area.
- The quarrying waste is even being dumped on seasonal river beds, thereby threatening the porosity of the aquifer zones.

Fig 1 : Huge Waste Dumps at Kota Stone Mines

B. *Slurry Waste*

The marble slurry generated during the processing of Kota stone causes the following environmental damage:

- The porosity and permeability of the top soil is reduced tremendously and in due course of time it results in water

logging problems at the surface and there by not allowed the water to percolate down. When & where it has happened the ground water level had adversely been affected and it has gone down to deeper levels

- The fine Kota stone dust reduces the fertility of the soil by increasing its alkalinity.
- Waste thus dumped dries out and the fine Kota stone dust suspends in the air and is slowly spread out through winds to the nearby area. It settles down on crops and vegetation, thus severely threatening the ecology of the Kota stone clusters.
- When dumped along the catchment area of natural rain water, it results in contamination of over ground water reservoirs and also causes drainage problem.
- It causes respiratory ailments in the nearby residential areas. Pneumoconiosis is the non – neoplastic (i.e. exclude cancer) reaction of the lungs to inhaled minerals dust and the resultant alteration in their structure. It also includes diseases mainly of the airways like asthma, bronchitis and emphysema (although destruction of alveoli as in emphysema can be caused by dusts) silicosis is a pneumoconiosis caused by inhalation of silica (or some other crystalline forms of silicon dioxide) which is lethal to macrophages that ingest it and releases their enzymes. It is a serious and progressive disease. The term mixed dust fibrosis describes the pulmonary disorder caused by the inhalation of silica dust simultaneously with another non-fibrogenic dust. Other mineral pneumoconiosis may be caused by beryllium, talc, kaolin and mica. Extrinsic allergic alveoli is can be Caused by sensitization to farmer's lung and malt worker's lung by Kota stone slurry dust. it tends to affect the respiratory units of the lung rather than the conducting airways and may have 'flu' like symptoms in addition . in some respects it is similar to humidifier fever which might be caused by sensitization. Asthma is a condition characterised by inflammation of the lining of the airways and intermittent spasm of the underlying smooth muscle. Comparatively more is known about the cause of asthma caused by work than about other forms of asthma. It is often the result of allergy to an inhaled dust in the workplace .Its symptoms include cough, wheeze, chest tightness and shortness of breath which improve on days off work or longer holidays

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.Some dusts e.g. lead of its salts can be absorbed into

- The body after inhalation or skin contact. They can then have harmful effects on other organs e.g. the nerves or the blood forming organs. Ultrafine particles might travel through the alveoli to produce harmful affects the fertility.
- It has become a safety hazards on the highways along which it is dumped, due to its slippery nature when wet.
- It also has an adverse effect on the landscape beauty of the area.

Fig 2: Disposal of slurry waste at agriculture land

Fig 3: Disposal of slurry waste near road side

The agriculture land use in Kota district is reducing due to increasing in mining dumps of waste of polishing and cutting of Kota stone industries as well settlement of habitation. The cutting and polishing industries established in area causes a huge waste material dumps in the vicinity. This is causing serious problem, increasing danger both to mining industry as well as habitants. There is a minimum safe zone of 500 m which has to be vacated before conducting any blasting operation. Further movement of heavy earth movement machine expose danger of road side accidents to the families of such inhabitants besides causing environmental problem from dust and fines.

V. BLACK COTTON SOIL

Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and

ISSN 2277 – 8322

swelling properties. This Black cotton soils occurs mostly in the central and western parts and covers approximately 20% of the total area of India.

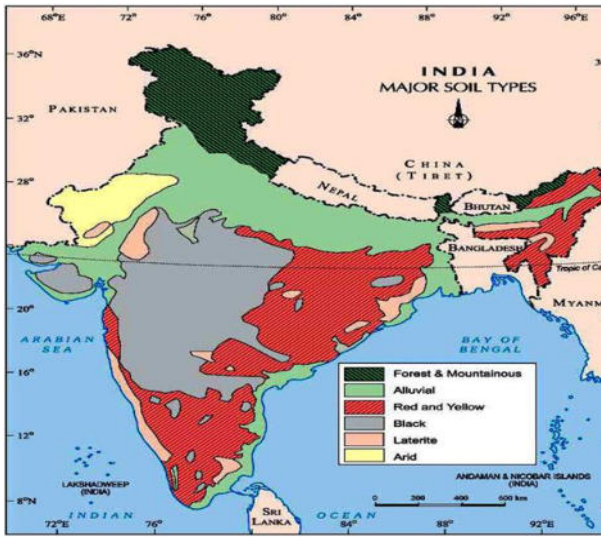

Fig 4: Soil map of India

Generally, lands with black cotton soils are fertile and very good for agriculture, horticulture, sericulture and aquaculture. Good irrigation systems exist, rainfall is high and people are affluent in these areas. Though black cotton soils are very good for agricultural purposes, they are not so good for laying durable roads. Good road network is a basic requirement for the all round development of an area. Unfortunately, poor road network is hampering the full fledged development of the otherwise prosperous areas. Black cotton soils absorb water heavily, swell, become soft and lose strength. Black cotton soils are easily compressible when wet and possesses a tendency to heave during wet condition. BC soils shrink in volume and develop cracks during summer. They are characterised by extreme hardness and cracks when dry. The stability and performance of the pavements are greatly influenced by the sub grade and embankment as they serve as foundations for pavements. On such soils suitable construction practices and sophisticated methods of design are to be adopted.

Because of its high swelling and shrinkage characteristics, the Black cotton soil (BC soils) has been a challenge to the highway engineers. It is observed that on drying, the black cotton soil develops cracks of varying depth. As a result of wetting and drying process, vertical movement takes place in the soil mass. All these movements lead to failure of pavement, in the form of settlement, heavy depression, cracking and unevenness.

VI. NATURE OF BLACK COTTON SOILS

Roads running in black cotton soils are known for bad condition and unpredictable behavior for which the nature of the soil contributes to some extent. Nature of black cotton soils is discussed here.

- BC soils absorb water heavily, swell, become soft, lose strength, easily

compressible and have a tendency to heave during wet condition.

- BC soils shrink in volume and develop cracks during summer. They are characterised by extreme hardness and cracks when dry.
- Soils are called highly expansive when Free Swell Index exceeds 50%. Such soils undergo volumetric changes leading to pavement distortion, cracking and general unevenness due to seasonal wetting and drying.
- BC soils produce a CBR value of 2 to 5% if compacted efficiently.

VII. CONCLUSION

In this Paper give an overview of the Kota stone slurry powder is used as a stabilizing material for soil stabilization. The stone slurry waste taken from the stone cutting plant, stone slurry rich in calcium oxide. The study describes the effectiveness of stone slurry waste to stabilize the black cotton soils. The stone slurry waste was mixed with black cotton soils in different proportion and investigates the effect of stone slurry waste on strength, compaction and CBR properties of black cotton soils.

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