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A Review on Stabilization of Granular Subbase in Flexible Pavement by using Calcium Chloride

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Abstract: ***Highways plays a vital role in the development and progress of any nation, which provides them access to the resources and interconnection between countries, states and cities. India is known to have one of largest highway network in the world, which transports approximately 64.5% of goods all over the country and 90% traffic passengers of the country, who uses this network to commute. The total expenditure allocated by the Ministry of Road Transport and Highways for 2023-2024 is Rs. 2.7 lakh crores, which is 36% higher than 2022-2023(1.99 lakh crores). All we need now a day is the economical and engineering approach technique to enhance durability and life of the existing roads/ highways. This study is a review of application of stabilizers for Granular Sub Base of Flexible Pavements. The main objective of this study to determine Unconfined Compressive Strength, Elastic Modulus of stabilized material prepared with different dose of calcium chloride as a stabilizer for use in Cement Treated Sub Base (CTSB), determine optimum dose of $CaCl_2$ Stabilizers with or without cement to achieve desired strength of Cement Treated Sub Base (CTSB) and to determine the durability characteristics of the samples prepared at optimum dose. This paper deduces that many researchers used different stabilizers such as pumice, fly-ash, lime stabilized fly-ash, combined cement and bitumen emulsion, which were found suitable and effective to achieve required strength for the flexible pavements.***

Keywords: Calcium Chloride $CaCl_2$, Stabilizers, Cement Treated Sub Base (CTSB), Flexible Pavement.

I. INTRODUCTION

India is the second largest country in the world which has largest developing economy. Government has started many projects like Pradhan Mantri Gram Sadak Yojana (PMGSY) in the year 25 December 2000 and National Highway Development Project (NHDP) for the development of highway structures. Due to the increase in traffic, bituminous pavement life and quality of riding surface get deteriorated. Durability of roads also decreases if there are extreme changes in weather, high rainfall intensity, adverse terrain condition and poor subgrade of soil conditions. Attempts are therefore being made to make durable pavements. Therefore, for increasing the pavement life, different types of stabilizing additives like carbon black, fibers, rubbers, polymers, fly ash, artificial silica, and brick dust or a combination of these materials and modifiers such as polymers and fibers can be used. So, in present days, for enhancing the durability of roads, different types of fillers are using in bituminous mix at very fast rate. Currently, India has approximately 5,472,144 km of road network, most of which are bituminous roads. Generally, bituminous concrete is used to construct the expressway or NH roads carrying heavy traffic.

A. Types of Pavements

There are two types of pavements used in India. Following are mentioned below

1) Flexible Pavements.
2) Rigid Pavements.

The flexible pavements consist of bituminous surface over base course and sub-base course. The structural strength of flexible pavement can be attained by the combination of different layers of the pavement. These pavements have negligible flexural strength. The rigid pavements are named rigid because they have high flexural strength and rigidity and very less deflection due to high modulus of elasticity of their surface course, it is usually laid in cement concrete.

B. Stabilization of Flexible Pavements

Stabilization is an engineering approach by which flexible pavements can re-gain its lost strength by adding stabilizers such as different types of chemicals, fly-ash, lime, cement or a combination of cement and chemicals and emulsion etc. mixed and blended with soils to achieve desired strength. This concept was extended to sub base layers and base layers to strengthen these to meet the requirements of high strength for runway pavements.

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The technology has now got a place in roads for following reasons:

1) The existing granular layers can be strengthened by in-situ recycler with addition of Stabilizer and Cement thus, minimizing wastage and reducing period of construction.

2) There is less consumption of aggregate as the technology enables construction possible with less thickness, cost may even reduce.

II. REVIEW OF LITERATURE

The researchers can better comprehend the issues and knowledge gaps in their field of study with the use of a literature review. It provides the concept for future development as well as data and information about the issues being researched. There has been a lot of research done on Stabilization of Flexible Pavements and Compressive Strength separately utilizing different stabilizer, recycled materials, and chemicals. Here are several research projects that are presented.

Sagar T. Phatangare et al. [1] In this study the concept of CTB/CTSB is studied. The effect of CTB/CTSB rather than traditional sub-base/base materials are also studied. The virgin aggregate are required in large quantities and are not easily available in many regions. With the traditional materials used for the pavement construction problems are encountered under severe conditions of traffic or environment. The study explains the mechanism of Cement Treated Base/Sub-base and also the quantity of the cementitious material required to be added for stabilization process.

Stephen Monlux et al. [2] The U.S. Department of Agriculture Forest Service has stabilized un-paved road surfacing materials with relatively high concentrations of calcium chloride salt. The percentage of calcium chloride is higher than that traditionally used for dust aggregate base stabilization. Up to 2% pure salt by weight of aggregate was mixed into the top (50 mm) of both aggregate and native road surfaces. The results were monitored for 2 to 4 years. The stabilized road surfaces resisted raveling for several, seasons and significantly reduced road blading and aggregate loss. As a result, calcium chloride stabilization may be a cost-effective treatment for roads with daily traffic volumes less than 200 PCU/hr. Other benefits include reduced surface erosion and sedimentation, improved safety from reduced dust, raveling, and less frost penetration. Encouraged by these results, the Forest Service is conducting additional evaluations to determine the cost-effectiveness of surface stabilization with both magnesium chloride and calcium chloride in different environments and with different aggregate materials.

Chang-Seon Shon et al. [3] Chemical stabilization with cementitious and chemical additives such as Portland cement, lime, fly ash, and calcium chloride ($CaCl_2$) is now being extensively used in road base or subgrade primarily to enhance mechanical strength and improve resistance to chemical attack, resulting in a more durable roadway. In recent years, there has been renewed interest in the combined use of these additives to induce effect on the strength, as well as to improve deficiencies of a single-chemical treatment process (e.g., slow early strength development of fly ash and susceptibility to leaching of $CaCl_2$ in wet environments). The effect of adding $CaCl_2$ to the fly ash-treated road bed during construction was investigated. The role of $CaCl_2$ in the system was studied, where determination was made as to how the soluble calcium species plays a role in bringing particles closer in the aggregate system and how it has an effect on the setting time, and ultimate strength. Laboratory test data revealed that the addition of $CaCl_2$ not only accelerated the setting rate but also increased the initial and long-term strength of the constructed road bed. Finally, field performance data showed that fly ashes can be effectively used in road construction if $CaCl_2$ is added to the system.

Pagar S.R. et al. [4] In India, due to massive infrastructure construction activities are taking place both in rural and urban area have caused scarcity of construction materials. The pavement industry looks for ways of improving lower quality materials that are readily available for use in road way construction. Cement /lime treatment has become an accepted method for increasing the strength and durability of soils and marginal aggregates, reducing quantity of aggregates. Indian roads congress (IRC) developed a special publication for mix design of base/subgrade. No pavement design guideline is presently available cement treated sub base. To overcome this problem, the objective of present research work is to develop a pavement design chart using cement and lime stabilized sub base for rural and urban roads with light and medium traffic (up to 50 MSA). It not only saves money but also helps to increase life cycle of roads.

Fabiano Emmert et al. [5] The study evaluated the chemical stabilization of soils with cement toward application in improving forest roads, as constructive alternative of low cost. The study was carried out with fine soils from the region of Niquelândia-GO Brazil, where the sand-clay-silt particle proportion was predominant, and Portland cement used as a stabilizing agent at 2% under dry soil weight. Geotechnical tests were conducted in different compaction energies (normal, intermediate and modified) and curing periods (1, 7 and 28 days), and the data were analyzed statistically by Analysis of Variance (ANOVA) and Tukey test. The soil-cement mixture presented higher unconfined compressive strength (UCS) than the compacted local soil, reaching a highest value of 650.52

kPa on modified compaction energy. Also, California bearing ratio (CBR) with values of 44.1% in the intermediate compaction energy and 41.7% in the modified compaction energy reached higher values compared to lateritic soil sampled.

Md. Mahmud Hasan Mamun et al. [6] Sand is the most available construction material in Bangladesh. Sand-cement stabilization is more cost effective and environment friendly for the construction of sub-base pavement layer in perspective of Bangladesh. The researchers conducted an investigation for the use of cement stabilized fine to medium sand in the construction of roads. Sands from various location such as — Mymensingh, Fajilpur Munshigonj and Sunamgonj are procured for this research work. Although Sunamgonj and Fajilpur sand are slightly expansive, those sand can be easily used as a substitute of unbounded material. According to the laboratory tests, all of the four types of sand have satisfied the criteria of sub-base layer strength on 14 days. The sand-cement material with 8 to 10% cement proved to be adequate for sub-base layers of heavily trafficked roads. It is observed that, sand sample with 8% cement mixes obtained from Fajilpur and Sunamgonj fulfill the specification requirements of sub-base layer for low traffic roads. On the basis of quantitative evaluation, appropriate sand-cement stabilization systems for roads need to be exercised and suggested.

Marandi S.M et al. [7] The main objectives of this research was to analyze the use of combined cement and bitumen emulsion in base course stabilization in details and examine its replacement with conventional pavement in regions with low quality materials and limited construction period. To conduct the objectives, the research divided into three phases. Phase I involved the optimization of cement and bitumen emulsion. In this case, a series of Indirect Tensile Strength (ITS), Unconfined Compressive Strength (UCS) and Marshal Tests carried out. In the second phase, various alternative roadway sections examined for minimizing the pavement thickness and increasing the bearing capacity and finally in third phase, a Falling Weight Deflectometer (FWD) machine used to examine the pavement bearing capacity for three sections of the roadway. It was found that, the optimum values to eliminate the creation of shrinkage cracks in the whole project and minimize the execution period and construction costs were 3% for both binders in stabilization and its replacement with conventional pavement method i.e., stabilized layer with conventional sub-base and base layers.

Saket Prasad et al. [8] It is a case study to know feasibility of cement treated base roads in India for low-cost development of roads. Cement stabilized layers was used in service roads of NH 50. Service road of 22.6 Km was constructed using Cement treated base and sub-base layers. It not only saved money but also help to increase life cycle of road. Granular bases can carry less tonnage of loads but can withstand more tonnage of loads. As Design tonnage increases cost increases in Granular bases but not in the case of cement treated bases. When traffic is diverted from main Carriageway to Service Road due to maintenance, cement treated bases can withstand more traffic load as compared to granular bases. It resists cyclic freezing, rain, and spring-weather damage, when compared with granular base of service road. Cement-treated base continues to gain strength with age even under traffic, when compared.

G. W. K. Chai et al. [9] Cement stabilization is one of the most common techniques for stabilizing recycled road base material, and offers a longer pavement life. With the cement effect, the increase in stiffness of the stabilized layer would provide better load transfer to the pavement foundation. The recycling method provides an environmental friendly option as the existing road base materials will not be removed. This paper presents a case study at a trial section along the North-South Expressway in Malaysia, where the Falling Weight Deflectometer (FWD) was adopted to determine the in-situ stiffness of the cement stabilized road base material. The FWD would assess the compressive strength and the material stiffness of the cement stabilized layer. The improvement in the stiffness of the stabilized base layer was monitored, and samples were tested during the trial. FWD was found to be useful for the structural assessment of the cement stabilized base layer prior to the placement of asphalt layers. Results from the FWD were also used to verify the assumed design parameters for the pavement.

Hyung Jun Choi et al. [10] On-going research at Texas A&M University indicated that soil stabilization using calcium chloride filter cake along with Class F fly ash generates high strength. Mix design was fixed at 1.3% and 1.7% calcium chloride and 5% and 10% fly ash with crushed limestone base material. Throughout previous studies, recommended mix design was 1.7% calcium chloride filter cake with 10% Class F fly ash in crushed limestone base because Class F fly ash generates early high and durable strength. This research paper focused on the strength increase initiated by greater than 1.7% pure calcium chloride used with Class F fly ash in soil to verify the effectiveness and optimum ratio of calcium chloride and Class F fly ash in soil stabilization. Mix design was programmed at pure calcium chloride concentrations at 0% to 6% and Class F fly ash at 10 to 15%. Laboratory tests showed samples containing any calcium chloride concentration from 2% to 6% and Class F fly ash content from 10% to 15% obtained high early strength however, optimum moisture content, different mix design, and mineralogy deposit analysis are recommended to evaluate the role and the effectiveness of calcium chloride in soil stabilization because of the strength decreasing tendency of the samples containing calcium chloride after 56 days.

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Alaka Sreedhar et al. [11] In the field of Construction expansive soils pose a great problem especially for foundations, & using the locally available in situ soils is a big issue since they are not suitable for Construction. The most problematic soil in the field of Construction is the Black Cotton soil especially in foundations, since Black Cotton soil has a tendency to shrink and swell excessively. When it comes in contact with water, it swells and when it becomes dry it shrinks. The alternate process of swelling and shrinking results in differential settlement which results in Cracks in the building. Hence the entire in – situ soil is to be replaced which is a very complicated process. This can be avoided by conducting soil stabilization by making use of RBI Grade 81 powder. RBI Grade 81 is a Cementitious powder stabilizer which can be mixed in proper proportions to achieve desired results. Here I have conducted Modified Proctor Test on Black Cotton soil in the following proportions 1%, 2%, 4%, 6% and obtained results for Optimum Moisture Content and Maximum Dry Density. Optimum moisture content increases as the percentage of stabilizer is increased and Maximum dry density decreases. By making use of RBI Grade 81 stabilizer, excellent load bearing capacity is obtained.

Anil Chhangani et al. [12] In this study, Index properties of a soil sample, taken from campus, were determined to comment on the nature of the soil, and then its strength is determined in terms of CBR value. The strength of this soil sample was compared with that of soil samples prepared with adding 2% and 4% of CaCl2 in the form of a flake. From the results of the study, samples of soil with 0 to 4% calcium chloride have reached optimum strength. Unacceptable levels of dust are generated on the unsealed road networks in most countries. In the past, dust has mostly been considered as a safety hazard and nuisance. However, research on unsealed roads has revealed that the loss of fines associated with road dust contributes to increased gravel loss and the need for more frequent maintenance. By controlling this dust, the rate of gravel loss and maintenance expenditure can be significantly reduced. Effective dust control can be achieved either with chemical dust suppressants or by upgrading the road to a sealed surface. Calcium chloride can be used as a dust suppressant and base stabilizer.

Henry Kirchner et al. [13] The use of liquid calcium chloride on unpaved roads as a dust control agent and as a base stabilization material is examined. In the first section a description is provided of how calcium chloride controls dust and the benefits it produces. The performance of calcium chloride is compared with that of other commonly used dust control agents. Recommended guidelines and application rates for controlling dust on unpaved roads with calcium chloride are then given. The second section provides a description of how calcium chloride stabilizes unpaved road bases provided. Calcium chloride ($CaCl_2$) is a simple material produced from natural brine deposits found underground. It is processed into a colorless, odorless liquid, which is the material primarily used for dust control and base stabilization on unpaved roads. Calcium chloride is also processed into white flakes and white pellets. These products are occasionally used for dust control and base stabilization.

Vivek Singh Pundir et al. [14] Poor sub grade soil conditions can result in inadequate pavement support and reduce pavement life. Soils may be improved through the addition of chemical or cementations additives. These chemical additives range from waste products to manufactured materials and include lime, Class C fly ash, Portland cement, cement kiln dust, RBI Grade 81. These additives can be used with a variety of soils to help improve their native engineering properties. The effectiveness of these additives depends on the soil treated and the amount of additive used. Design of the various pavement layers is very much dependent on the strength of the sub grade soil over which they are going to be laid. The sub grade strength is mostly expressed in terms of Indian Bearing Ratio (IBR). Weaker sub grade essentially requires thicker layers whereas stronger sub grade goes well with thinner pavement layers. The pavement and the sub grade mutually must sustain the traffic volume. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based upon the sub grade strength which is primarily dependent on IBR value for a laboratory or field sample soaked for four days. For an engineer, it's important to understand the change of sub grade strength. This project is an attempt to understand the strength of sub grade in terms of IBR values subjected to different types of stabilizers. Treatment with cement and lime was found to be an effective option for improvement of soil properties, based on the testing conducted as a part of this work. It was found that with the addition of stabilizers i.e., cement and lime, the I.B.R. increased upto a certain limit but after that the I.B.R. decreased even on the further addition of stabilizers.

K. Saravanakumar et al. [15] In this project an experimental study was conducted in the soil stabilization method by using the chemical admixtures like calcium Chloride (CaCl2) and Sodium chloride (NaCl). Stabilization is the process of physical and chemical alternation of soil to increase their engineering properties. And this process used to improve the load bearing capacity for the pavement works. In India expansive soil is popularly known as black Cotton soil. Compared to red soil the Black Cotton Soil is the problematic soil that has high potential for shrinking or swelling due to change of moisture content. Soils are stabilized with various proportion of chemicals (0%, 5%, 10%, and 15%) up to optimum percentage. And the properties are compared after done the following tests, Specific Gravity Test, Plastic Limit and Liquid Limit Test, California Bearing Ratio test. Unconfined compression test.

P. Durga Bhavani et al. [16] In India, expansive soils popularly known as black cotton soils are highly problematic, as they swell on absorption of water and shrink on evaporation thereof. Because of this alternate swell and shrinkage, distress is caused to the foundations of structures laid on such soils. Understanding the behavior of expansive soil and adopting the appropriate control measures have been great task for the geotechnical engineers. Hence, in the present work, experimentation is carried-out to investigate the influence of electrolyte viz. potassium chloride, calcium chloride and ferric chloride on the properties of expansive soil. A methodical process, involving experimentation on Atterberg limit (liquid limit, plastic limit), sieve Analysis, specific gravity, proctor compaction test, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) test, Triaxial test were conducted by adding 0.5%, 1%, 1.5% of Potassium Chloride, Calcium Chloride and Ferric Chloride to the expansive soil by dry weight under controlled conditions in the laboratory. It is observed form the laboratory studies that maximum reduction in properties is observed for Ferric Chloride treatment compared to other electrolytes tried in this investigation.

Andrae Anthony Francois et al. [17] This study was initiated with the aim of evaluating the impact of stabilized and untreated base layers on the performance (i.e., fatigue and rutting) of flexible pavements. Four field sections constructed using stabilized base layers (i.e., bituminous (asphalt emulsion), calcium chloride ($CaCl_2$), Portland cement, and geogrid stabilized base layers) and a control section constructed using untreated RAP aggregates were analyzed in this study. Falling Weight Deflectometer (FWD) tests were conducted on all the field sections and the collected data was used to back calculate the elastic moduli for all layers. The influence of the stabilized bases and the untreated RAP base on the mechanical responses (stresses and strains) of the overall pavement structure was also evaluated by conducting layered elastic analyses. Pavement simulations were also conducted to determine which of the four stabilized bases enhanced the predicted performance of flexible pavements the most. Based on the results of the study, it was concluded that the Portland cement stabilized base seemed to be more effective than the other stabilized bases at improving the resistance of the pavement sections to fatigue cracking. It was also determined that base layer stabilization appeared to have little effect on the rutting resistance of the pavement sections.

III. FINDINGS DRAWN FROM LITERATURE REVIEW

1) Stabilization by different material gives better strength and performance also better as compare to the traditional materials. The result shows the saving in the construction cost for CTB/CTSB method is more as compared to the traditional materials.
2) Techniques of stabilization are not limited only up-to embankment or subgrade but also done in pavement layers like sub-base and base course.
3) Stabilization using calcium chloride along with Class F fly ash generates high strength, calcium chloride is beneficial to reduce surface erosion and sedimentation, ravelling and less frost penetration. Liquid calcium chloride on unpaved roads act as a dust control agent.
4) Chemical additives such as Portland cement, lime, fly ash, and calcium chloride (CaCl2), sodium chloride (NaCl) and even industrial waste such as copper slag, silica fumes are now being extensively used in road base or subgrade primarily to enhance mechanical strength and improve resistance to chemical attack, resulting in a more durable roadway.

IV. GAPS IN LITERATURE REVIEW

After going through the study carried out by different authors, the followings gaps have been identified:

1) It has been observed that the detailed study has not been carried out with calcium chloride (CaCl2) with different percentage for evaluating engineering properties of soil and financial aspects.
2) Most of the studies done by researcher on calcium chloride (CaCl2) not use it independently as a stabilizer in subbase and base for stabilization of soil.
3) Chemical stabilizer used in stabilization of CTSB/CTB shows different behaviour in various climatic conditions, but calcium chloride has properties to reduce maintenance cost, dust control etc.
4) It is necessary that further studies to be conducted on various types of materials to determine their suitability. Changes may be feasible in the current practices of bituminous mix design for improvement in the performance of mixes.

V. PROPOSED STUDY

Further research in this field involves the the effect of using calcium chloride (CaCl2) to increase the load bearing capacity of the weak soil and increasing the engineering properties of soil. The soil often is weak and has no enough stability in heavy loading. The aim of this study is to review on the stabilization of the soil using low-cost material. Based on literature, calcium chloride CaCl2 is a low-cost and effective to soil stabilization.

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The study will aim to improve engineering properties for CTSB/CTB by using calcium chloride. The study shall include detailed laboratory investigation of determining UCS values with (a) Cement + $CaCl_2$ (b) $CaCl_2$ alone and (c) Cement at various suitable percentages and combination. The results shall help to determine optimum dosage for various combination. It shall also help to make an economic analysis.

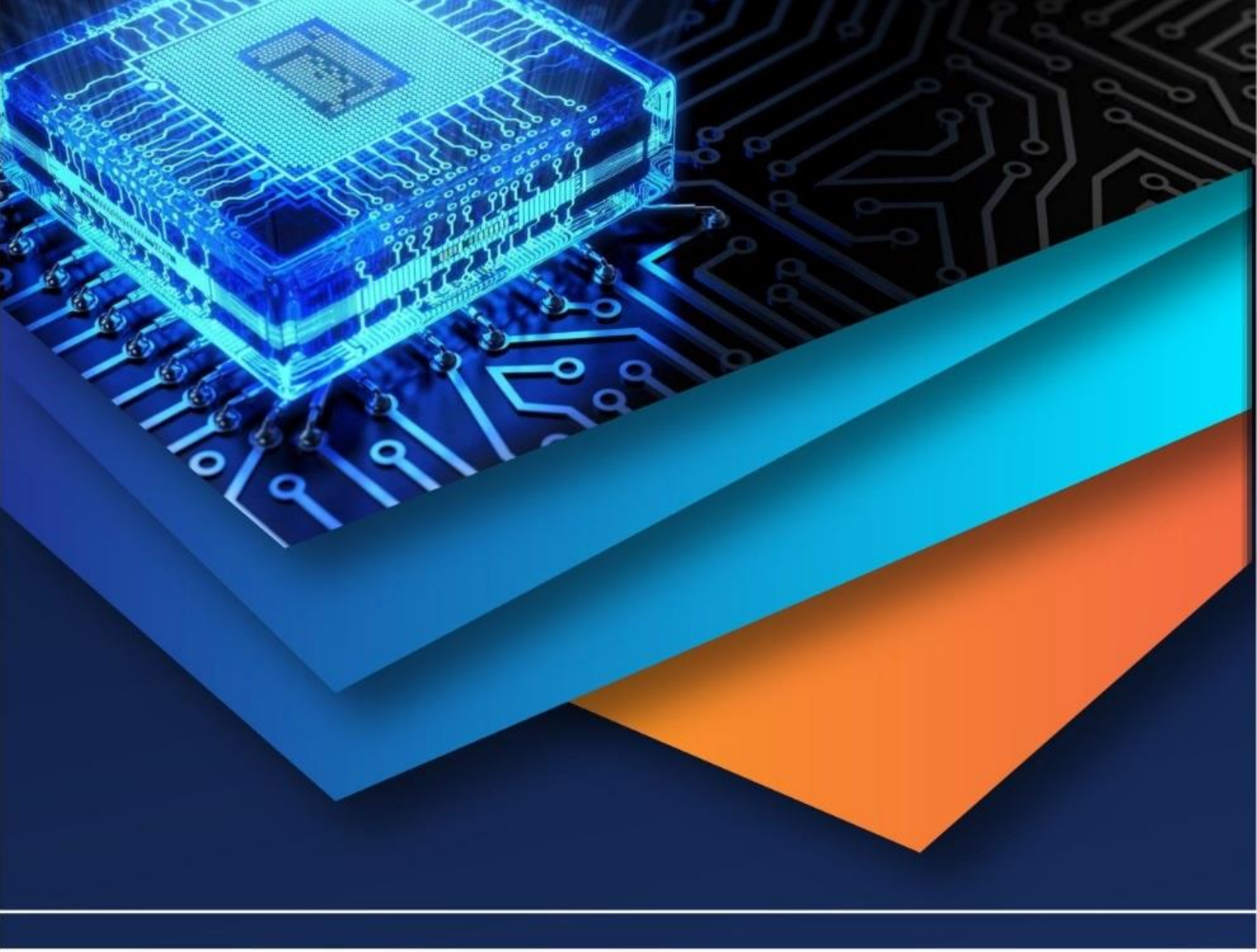
VI. CONCLUSION

A review of prior studies is based on that many researchers established different stabilizers such as, pumice, fly-ash, lime stabilized fly-ash, combined cement and bitumen emulsion are found suitable and effective to achieve required strength to flexible pavements. There is need to carry out more experimental studies using stabilizers available in Indian market to have a broad data base for ease of adoption of these. More studies may be made with other chemicals available.

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