



# IJRASET

International Journal For Research in  
Applied Science and Engineering Technology



---

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

---

**Volume:** 13    **Issue:** IV    **Month of publication:** April 2025

**DOI:** <https://doi.org/10.22214/ijraset.2025.68304>

[www.ijraset.com](http://www.ijraset.com)

Call:  08813907089

E-mail ID: [ijraset@gmail.com](mailto:ijraset@gmail.com)



# Study on Effect of Enzyme Induced Calcite Precipitation in Fine-grained soil

Devika M S<sup>1</sup>, Kannan K<sup>2</sup>

<sup>1</sup>MTech student, <sup>2</sup>Assistant professor, Department of Civil Engineering, Marian Engineering College, Trivandrum

**Abstract:** When the natural soil cannot satisfy engineering requirements, soil improvement is regarded as a substitute. One of the most common methods for improving the soil in the past was to add cement or lime. There are numerous customised soil improvement methods accessible today. While some treatments are difficult to apply, others are not ecologically friendly. The development of alternatives to mechanical and chemical stabilisation for soil has led to the emergence of bio-stabilization approaches. Enzymes are frequently involved in the bio-stabilization process, which promotes ureolysis and causes calcite to precipitate in the soil mass. Recent studies on sustainable ground improvement techniques suggest that Enzyme Induced Calcite Precipitation (EICP) is a good choice for soil development. Soil sample was silty clay with liquid limit 69%, plastic limit 28.3%, and plasticity index of 40.7%. Soil has an undrained shear strength of 25.4 kPa. By using 2.5 g/l urease enzyme concentration, the liquid limit and plasticity index of the sample decreased by 20.3% and 51.4% respectively and plastic limit of the sample increased by 24.4% after 7 days of curing. By using 5 g/l urease enzyme concentration, the liquid limit and plasticity index of the sample decreased by 21.7% and 62.2% respectively and plastic limit of the sample increased by 36.4% after 7 days of curing.

**Keywords:** Enzyme-induced calcite precipitation, Soil improvement, Calcite precipitation, Soil stabilization

## I. INTRODUCTION

Soil stabilisation is crucial when constructing infrastructure in underdeveloped countries or historic cities where site growth is constrained by topography. Construction projects require a solid foundation since it presents significant engineering challenges in addressing human demands (Gitanjali et al., 2024). The goal of soil stabilisation is to increase the soil's bearing capacity while decreasing settlement and deformation (Changizi et al., 2016). Traditional methods for stabilising soil include chemical and mechanical methods. Mechanical stabilisation entails removing air spaces from the soil mass and lowering the water content to the lowest practical level in order to improve performance. Conversely, chemical stabilisation uses chemicals to increase soil strength, decrease permeability, and achieve the desired density (Renjith et al., 2020). The soil is compacted and densified by mechanical techniques such as vibroflotation, rammering, rollers, blasting, and soil preloading. The field implementation of this method may result in significant energy release and high production and installation expenses. The chemical improvement procedure includes grouting and careful mixing of chemical admixtures including fly ash, cement, and lime (Gitanjali et al., 2024). Chemical stabilisation involves the use of silicates, asphalt, Portland cement, polymers, and lime. These changes improve the soil's geotechnical behaviour by changing its chemical composition (Calik et al., 2014). Chemical stabilisation has become popular due to the fact that it improves soil so well; in addition to traditional calcium-based binders such as fly ash, cement, and ash, it can also use novel stabilisers such as lignosulfonates, acids, salts, and enzymes; emulsions, resins, and petroleum-derived polymers can also be used (Tingle et al., 2020). Biologically mediated soil alteration is another new development in soil stability: the domestication of microorganisms to improve soil function; there are many engineering applications for natural mineralisation produced by microorganisms such as fungi, bacteria, and algae (Han et al., 2020). Microbial-induced calcite precipitation (MICP) is a bio-mediated ground improvement technique that uses bacterial invasion to improve the geotechnical properties of soil by binding soil particles together and causing calcium carbonate (CaCO<sub>3</sub>) to precipitate (Rahman et al., 2020). Among the geotechnical engineering problems that MICP treatment enhances are soil liquefaction, erosion control, carbon dioxide sequestration, shear strength, and contaminated soil rehabilitation. One of the drawbacks of the MICP is the unequal distribution of calcium carbonate (Gitanjali et al., 2024). An innovative and bioinspired method of improving ground is enzyme-induced calcite precipitation (EICP). EICP is a sustainable and ecologically responsible strategy with reduced carbon emissions. Instead of using microbes to precipitate CaCO<sub>3</sub>, enzyme-induced calcite precipitation (EICP) employs enzymes (Putra et al., 2020). Slope stabilisation, soil scouring reduction, wind and water erosion control, seepage monitoring beneath levees, soil bearing capacity enhancement, tunnelling, and seismic settlement management are just a few of the many engineering uses for this technology (Kavazanjan et al., 2017).

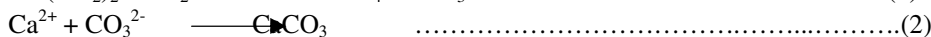
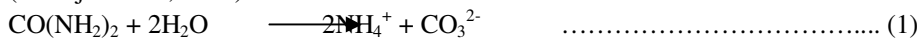
## II. CONCEPT OF EICP METHOD

### 1) Enzyme Induced Calcite Precipitation

By employing an aqueous chemical solution to precipitate calcite in cavities, the EICP approach enhances the geotechnical properties of soil. By filling the pores and binding and roughening the soil grains, the precipitation makes the soil stronger and more rigid. The EICP approach introduces urease enzymes straight into the soil, while the MICP method uses bacteria to produce urease enzymes. Because bacteria require laboratory equipment to sterilise their surroundings in order to form colonies, using them as living organisms in soil requires a certain environment for their survival. This discovery has the benefit of removing the difficulties associated with using microorganisms to create calcite precipitation (Yousefi et al., 2021). The EICP method employs free urease rather than microorganisms, in contrast to MICP. Microorganisms, plants, and agricultural resources can all create enzymes (Almajed et al., 2018). Based on biological principles, EICP is a new method of ground improvement. EICP is an environmentally beneficial, sustainable, and low-carbon method.

### 2) Urea Hydrolysis

Using urease enzymes produced by bacteria or derived from plants, EICP catalyses the hydrolysis of urea (Ahenkorah et al., 2021; Almajed et al., 2018). Urea can be changed into ammonium and carbonate anions by the urease enzyme (Eq. (1)). When carbonate anions and external calcium sources are present, the ammonium that is released helps to create an alkaline environment that is favourable for the precipitation of calcium carbonate ( $\text{CaCO}_3$ ) (Whiffin et al., 2007). EICP uses the  $\text{CaCO}_3$  precipitation that comes from the hydrolysis of urea as cementation materials to hold soil particles together and prevent soil erosion. Because the  $\text{CaCO}_3$  crystals that are principally created have less of an impact on the environmental conditions of the soil matrix, EICP procedures are more ecologically benign than traditional soil stabilisation technologies. High temperature settings, as those seen in arid and semi-arid locations, are more suited for the EICP approach. Purified urease enzyme is expensive for real-world EICP applications (Almajed et al., 2018).



The catalytic mechanism and, consequently, the rate of the reaction or precipitation are determined by the concentration and activity of the urease enzyme. The urease enzyme first hydrolyses urea ( $\text{CO}(\text{NH}_2)_2$ ) into ammonium ( $\text{NH}_4^+$ ) and carbonate ( $\text{CO}_3^{2-}$ ) ions as part of the EICP process. As a result, the solution's pH likewise increases. These ureolysis products can precipitate carbonate if there are enough divalent cations, such as calcium ions, present. Calcium chloride is one source of calcium ions. In the presence of calcium salt ( $\text{CaCl}_2$ ), the solution generates  $\text{Ca}^{2+}$ , which causes  $\text{CaCO}_3$  to form.

## III. MATERIALS AND TEST METHODS

### A. Test Materials

Soil sample was taken close to Neyyar Dam. Jack bean meal was utilised as a source of urease enzyme. The urease enzyme employed in jack bean meal was a firm, light brown powder that dissolves in water. Fig. 1 shows soil sample collected and Fig.2 shows jack bean meal urease enzyme.



Fig. 1 Collected soil sample Fig. 2 Urease enzyme



Various properties of soil sample are shown in Table 1.

Table 1: Properties of soil

Property	Value
Natural water content	35%
Specific gravity	2.22
Percentage of clay	45
Percentage of silt	46
Percentage of sand	9
Soil classification	Silty clay
Liquid limit	69%
Plastic limit	28.3%
Plasticity index	40.7%
Undrained shear strength	25.4 kPa

Particle size distribution curve, plasticity chart and stress strain curve are shown in Fig. 3, Fig. 4, Fig. 5.

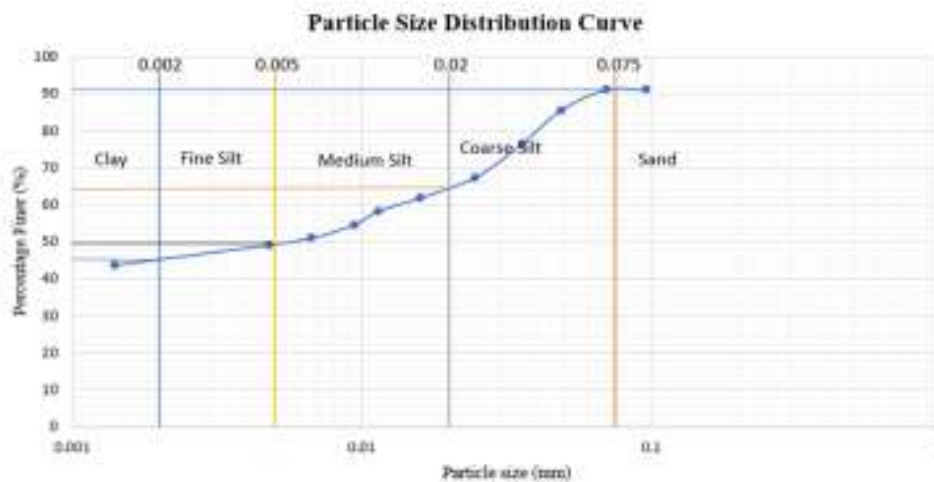


Fig. 3 Particle size distribution curve

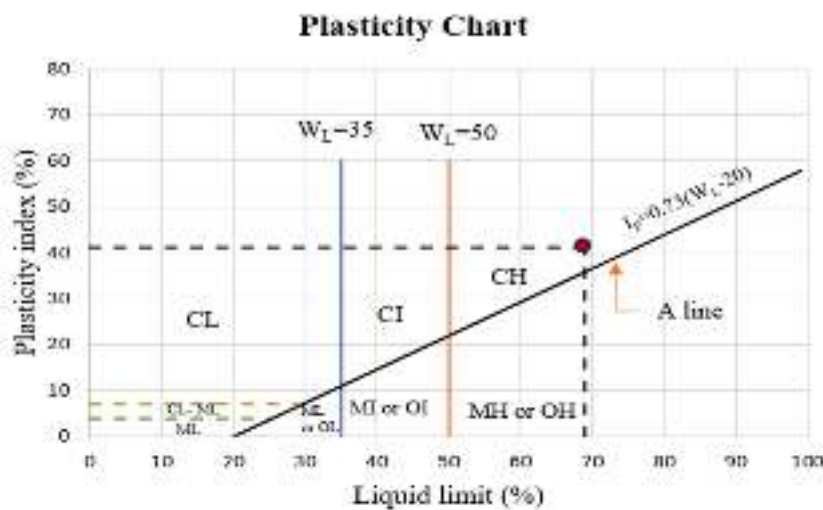


Fig. 4 Plasticity chart

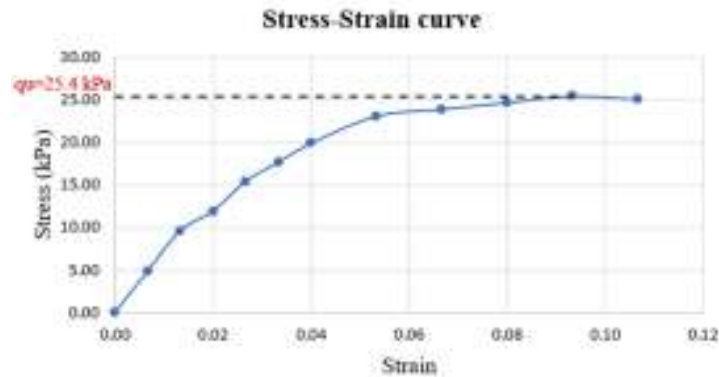


Fig. 5 Stress – strain curve

**B. Test Methods**

Laboratory tests including unconfined compressive strength (UCS) test and plasticity test were performed on untreated and treated samples to study the effects of Enzyme induced calcite precipitation in soil. Soil samples were oven dried.

**3.2.1 Preparation of Test solution**

In preparation for the EICP treatment, the urease enzyme solution and the urea-CaCl<sub>2</sub> solution also referred to as the cementation solution were made. CaCl<sub>2</sub> solution served as the study's Ca<sup>2+</sup> source. Urea and CaCl<sub>2</sub> were combined to create an equimolar cementation solution, with a concentration of 1M (Meng et al. 2021). Since less urea-CaCl<sub>2</sub> may result in the presence of excess urea and less mass of calcium carbonate precipitation, and because too much urea-CaCl<sub>2</sub> may reduce the efficiency of calcium carbonate precipitation by inhibiting the catalysing capacity of the urease enzyme, equimolar concentration, or 1M, was fixed for the study (Chandra et al. 2021). The components' molecular weights 110.9 g of CaCl<sub>2</sub> and 60 g of urea, respectively were dissolved in one litre of deionised water to produce 1M concentrated urea and CaCl<sub>2</sub> solutions. The "Jack bean meal Urease extra pure" enzyme can be utilised for the study because urease from jack bean seeds has been shown to be the most efficient of all plant-derived urease enzymes (Tirkolai et al. 2020).

**C. Effect of EICP in plasticity characteristics**

Variation in properties of Sample treated at 1M cementation solution and 2.5g/l urease concentration after EICP treatment for 3 and 7 days of curing is shown in Table 2.

Table 2: Change in plasticity characters after EICP treatment

No. of days of curing	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
Untreated	69	28.3	40.7
Day 3	65	30.5	34.5
Day 7	55	35.2	19.8

Variation in consistency limits of soil after EICP treatment of 2.5g/l urease concentration with a curing of 3 and 7 days is shown in Fig.6

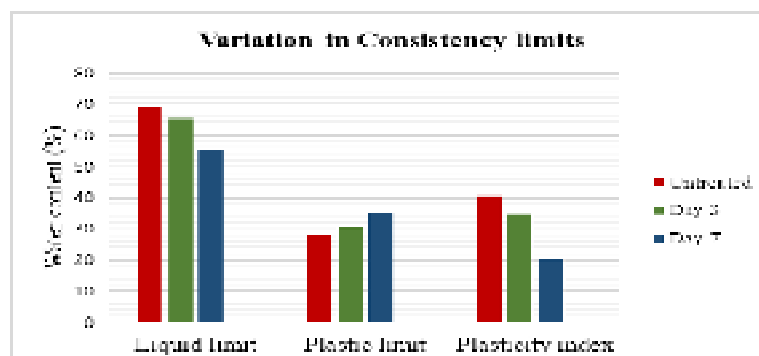


Fig. 6 Variation in consistency limits of 2.5 g/l urease concentration



- Liquid limit and plasticity index of the sample decreased by 20.3% and 51.4% respectively with increasing curing time from 0 to 7 days.
- Plastic limit of the sample increased by 24.4% with increasing curing time from 0 to 7 days.

Variation in properties of Sample treated at 1M cementation solution and 5g/l urease concentration after EICP treatment for 3 and 7 days of curing is shown in Table 3.

Table 3: Change in plasticity characters after EICP treatment

No. of days of curing	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
Untreated	69	28.3	40.7
Day 3	63	31.2	31.8
Day 7	54	38.6	15.4

Variation in consistency limits of soil after EICP treatment of 5g/l urease concentration with a curing of 3 and 7 days is shown in Fig. 7

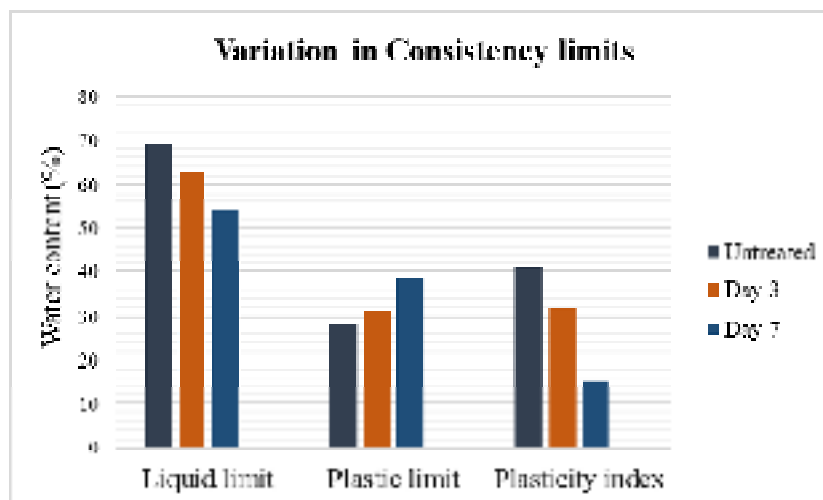


Fig. 7 Variation in consistency limits of 5 g/l urease enzyme concentration

- Liquid limit and plasticity index of the sample decreased by 21.7% and 62.2% respectively with increasing curing time from 0 to 7 days.
- Plastic limit of the sample increased by 36.4% with increasing curing time from 0 to 7 days.

#### IV. CONCLUSION

- 1) By using 2.5 g/l urease enzyme concentration, the liquid limit and plasticity index of the sample decreased by 20.3% and 51.4% respectively and plastic limit of the sample increased by 24.4%.
- 2) By using 5 g/l urease enzyme concentration, the liquid limit and plasticity index of the sample decreased by 21.7% and 62.2% respectively and plastic limit of the sample increased by 36.4%.
- 3) The increasing concentration of urease enzyme had a positive effect on improvement of plasticity properties of the soil.
- 4) EICP can be used as an excellent method for the improvement of plasticity characteristic of fine-grained soils.

#### REFERENCES

- [1] Ahenkorah, I., Rahman, M.M., Karim, M.R., Beecham, S. (2021). Enzyme induced calcium carbonate precipitation and its engineering application: a systematic review and meta-analysis. Construct. Build Mater. 308, 125000



- [2] Almajed, A.; Khodadadi Tirkolaei, H.; Kavazanjian, E. (2018). Baseline Investigation on Enzyme Induced Calcium Carbonate Precipitation. *J. Geotech. Geoenviron. Eng.*, 144.
- [3] Anie, G. and K, Kannan (2020). "Investigation on the Geotechnical Properties of Nanoclay Treated Clayey Soil", *International Journal of Research in Engineering, Science and Management*, 03(02), pp. 453-455.
- [4] Baiq, H., Yasuhara, H., Kinoshita, N., Putra, H., Johan, E. (2020). "Examination of calcite precipitation using plant derived urease enzyme for soil improvement", *International Journal of GEOMATE*, 19(72), pp. 231-237.
- [5] Calik, U., andSadoglu, E. (2014). Engineering Properties of Expansive Clayey Soil Stabilized with Lime and Perlite. *Geomech. Eng.*, 6,403-418.
- [6] Changizi, F.; Haddad, A. Effect of Nano-SiO<sub>2</sub> on the Geotechnical Properties of Cohesive Soil. *Geotech. Geol. Eng.* 2016, 34, 725-733.
- [7] Choi, S.G., Chang, I., Lee, M., Lee, J.H., Han, J.T., Kwon, T.H. (2020). "Review on geotechnical engineering properties of sands treated by microbially induced calcium carbonate precipitation (MICP) biopolymers". *Construct. Build Mater.* 246, 118415
- [8] Dilrukshi, R., Nakashima, K., Kawasaki, S. (2018). "Soil improvement using plantderived urease-induced calcium carbonate precipitation", *Soils and Foundations*, 58, pp. 894-910.
- [9] Gao, Y., He, J., Tang, X., Chu, J. (2019). "Calcium carbonate precipitation catalyzed by soybean urease as an improvement method for fine-grained soil", *Soils and foundations*, 59(05), pp. 1631-1637.
- [10] Gitanjali, A., Jhuo, Y.S., Yeh, F.H., Ge, L. (2024). " Bio-cementation of sand using enzyme-induced calcite precipitation: Mechanical behavior and microstructural analysis", *Construction and Building Materials* Volume 417, 135360.
- [11] Han, L., Li, J., Xue, Q., Chen, Z., Zhou, Y., Poon, C.S. (2020). Bacterial-Induced Mineralization (BIM) for Soil Solidification and Heavy Metal Stabilization: A Critical Review. *Sci. Total Environ.*, 746, 140967.
- [12] Javadi, N., Krishnan, V., Hamdan, N., Kavazanjian, E. (2018). "EICP Treatment of Soil by Using Urease Enzyme Extracted from Watermelon Seeds", *Proceedings of International Foundations Conference and Equipment Expo, Orlando, Florida*, 296, pp. 115-124.
- [13] Kavazanjian, E.; Almajed, A.; Hamdan, N. (2017). Bio-Inspired Soil Improvement Using EICP Soil Columns and Soil Nails. *Grouting*, 13-22.
- [14] Kavazanjian, E.; Hamdan, N. (March, 2015). "Enzyme Induced Carbonate Precipitation (EICP) Columns for Ground Improvement", *IFCEE*. <https://www.researchgate.net/publication/280445959>.
- [15] Oliveira, P. J. V., L. D. Freitas, and J. P. Carmona. (2016). "Effect of soil type on the enzymatic calcium carbonate precipitation process used for soil improvement." *Journal of Materials in Civil Engineering*, 29(04), pp. 01-07.
- [16] Park, S.S., Choi, S.G. and Nam, I.H. (2014). "Effect of plant-induced calcite precipitation on the strength of sand", *Journal of Materials in Civil Engineering* 26(08), pp. 01-05.
- [17] Putra, H., Yasuhara, H., Erizal, Sutoyo, and Fauzan, M. (2020). "Review of Enzyme Induced Calcite Precipitation as a Ground-Improvement Technique", *Infrastructures*, 5, 66.
- [18] Rahman, M.M., Hora, R.N., Ahenkorah, I., Beecham, S., Karim, M.R., and Iqbal, A. (2020). State-of-the Art Review of Microbial-Induced Calcite Precipitation and Its Sustainability in Engineering Applications. *Sustainability*, 12, 6281.
- [19] Renjith, R.; Robert, D.J.; Gunasekara, C.; Setunge, S.; O'Donnell, B. Optimization of Enzyme Based Soil Stabilization. *J. Mater. Civ. Eng.* 2020, 32.
- [20] Roksanaa, K., Hewagea, S.A., Lomboyb, M.M., Tangc, C., Xued, W., Zhua, C. (2023). "Desiccation cracking remediation through enzyme induced calcite precipitation in fine-grained soils under wetting drying cycles", *Biogeotechnics*, 100049.
- [21] Shu, S., Yan, B., Meng, H., Bian, X. (2022). "Comparative study of EICP treatment methods on themechanical properties of sandy soil", *Soils and Foundations* Volume 62, Issue 6, 101246.
- [22] Tingle, J.S., and Santoni, R.L. (2003). Stabilization of Clay Soils with Nontraditional Additives. *Transp. Res. Rec.*, 1819, 72-84.
- [23] Tirkolaei, H., Javadi, N., Krishnan, V., Hamdan, N., Kavazanjian, E. (2020). "Crude Urease Extract for Biocementation", *Journal of Materials in Civil Engineering*, 32(12), pp. 01-12.
- [24] Whiffin, V.S., Van Paassen, L.A., Harkes, M.P. (2007). Microbial carbonate precipitation as a soil improvement technique. *Geomicrobiol J.* 24 (5), 417-423.
- [25] Yousefi, R., Amooei, A.A., Sakhi, M.A., Karimi, A. (2021). "Experimental Study on Influence of Using Urease Enzyme on Stabilized Sandy Soil's Engineering Property by Zeolite and Sawdust". *IJMT Vol.15/ Winter (17-27)*.
- [26] Yuan, H., Liu, K., Zhang, C., Zhao, Z. (2021). "Mechanical properties of Namontmorillonite-modified EICP-treated silty sand", *Environmental Science and Pollution Research*, Volume 29, pages 10332-10344.
- [27] Yuan, H., Ren, G., Liu, K., Zheng, W., Zhao, Z. (2020). "Experimental Study of EICP Combined with Organic Materials for Silt Improvement in the Yellow River Flood Area", *Applied Science*, pp. 01-19.



10.22214/IJRASET



45.98



IMPACT FACTOR:  
7.129



IMPACT FACTOR:  
7.429



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24\*7 Support on Whatsapp)