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Comparative Study of Earth Pressure Theories on Retaining Wall Considering Earthquake Forces

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Abstract: Retaining walls provide support for vertical Alignment and Prevents Erosion. Due to various properties and Phases of Soil, The Effect on Lateral Earth Pressure can be analyze and Calculated by various methods hence the comparison between Lateral earth pressure computed by Rankine's and Coulomb's theory for Dry, Fully Saturated and Partially saturated Backfill is done. Calculations are made which involve Rankine and Coulomb earth pressure theories as Static Methods and how stability of a retaining structure is influenced by these pressures. Computation of Maximum Base pressure is also done for complete analysis of the retaining wall. Seismic earth pressure has been calculated by using IS code method as Dynamic Approach. The results is obtained from analytical expressions for the active and passive Earth pressures for different backfill conditions including seismic Forces , and found to have a similar trend of variation for both the theories. The future work can be perform on comparison with more parametric studies such as the different height of the wall and various properties along with Shear Strength of Soil.

Keywords: Cohesive Backfill, Retaining Wall, lateral earth pressure, Static and Dynamic Approaches, Base pressure, Seismic Analysis.

I. INTRODUCTION

A retaining wall is a structure constructed to primarily hold back masses of soil known as backfill. They provide support for vertical or near vertical grade changes, while also preventing erosion or down slope movement. The backfill is usually associated with an amount of surface strip load, thereby creating lateral pressure which acts onto the non-yielding retaining wall. Typical surface strip loads may include highways, building infrastructure, or railroads. Surface strip loads will become in particular interest in the thesis, especially under circumstances where a rigid retaining wall is directly under its influence. The purpose of this thesis is to Analyze and to compare Retaining walls by static and dynamic methods to calculate the lateral earth pressures i.e. Active and Passive earth Pressure and hence, how stability of a retaining structure is influenced by these pressures. The selected retaining wall which will be focused upon in this thesis includes the cantilever type structure. Calculations are to be made which will involve Rankine earth pressure theory and Coulomb's wedge theory as Static Methods and I.S Code Method to find Dynamic Earth Pressure. It will also involve determining whether there are any correlations between these two cases.

A. Rankines Earth Pressure Theory

Rankine's theory involves the consideration of the stress levels in the soil when the plastic equilibrium has been reached. Rankine's method in distinguishing the stress levels at failure is represented by Mohr circle, this is achieved in a two dimensional plane, detailed in Figure 1.

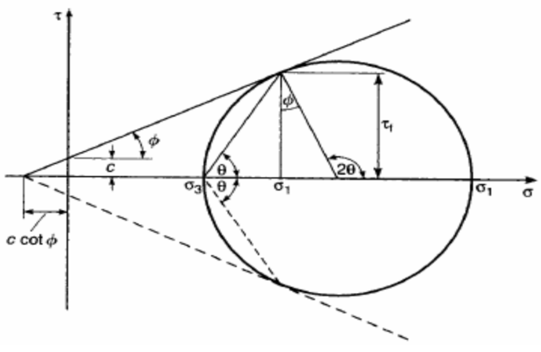

Fig 1. Mohr's Circle

Where, C and Φ are the relevant shear strength parameters.

Using the failure envelope given in the Mohr circle and substituting the horizontal and vertical stresses for the minor and major principle stresses, Rankine was able to determine equations which calculated the active and passive pressure coefficients.

1) *For Cohesive Soils:* For a frictionless retaining wall with cohesive soil backfill, at any depth the active soil pressure against the wall can be determined;

$$\sigma_a' = \gamma z K_a - 2\sqrt{K_a}c'$$

It is detailed in Figure 1.7a, the Comparison of $K_a\gamma H$ with depth, and detailed in
Figure 2(b), the Comparison of $2c'\sqrt{K_a}$ with depth.

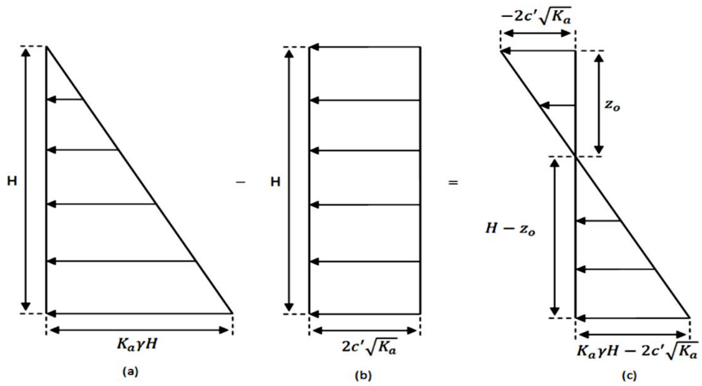

Fig 3. Earth Pressure Distribution for Cohesive Backfill

Therefore, overtime, tensile cracks will develop at the soil-wall interface up to a total depth. The area of the total pressure diagram in Figure 3(c) can be used to calculate the total active force per unit length of wall. For calculation of the total active force with a horizontal cohesive backfill,

$$P_a = 0.5K_a\gamma H_2^2 - 2\sqrt{K_a}c' \quad 1.5$$

It was detailed that for active earth pressures for clayey soils is equated differently to that of soft soils.

B. Coulombs Earth Pressure Theory

Figure 4.details a failure wedge ABC, with active forces on the wedge between the wall surface and the failure plane BC. Soil type contains cohesion parameter *c* equal to zero. For the failure condition, the soil wedge acting under its own weight (W) is in equilibrium. The reaction force (P) between the wall and soil and the reaction on the failure plane (R). Since the wedge moves down the failure plane BC, then the reaction force P is declined at an angle to the normal. At failure, the reaction force R along the failure plane is declined at an angle of to the normal. These three forces are then connected head-to-tail (triangle of forces) to determine the magnitude of P. This is detailed in Figure

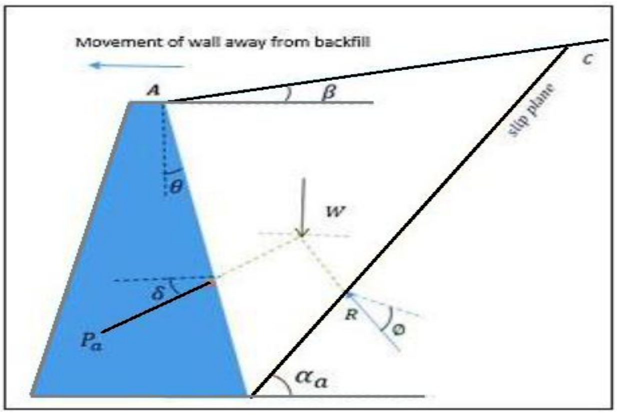

Fig 4. Coulomb's Active Theory

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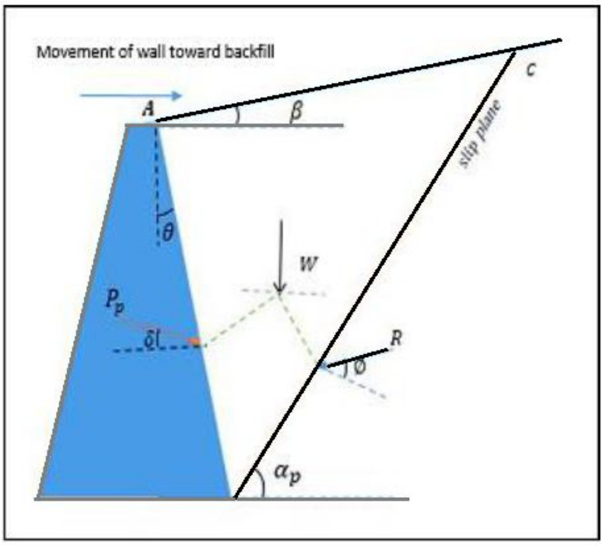

Fig 5. Coulomb's Passive Theory

In this procedure, multiple cases of failure planes will need to be selected to determine the maximum value of P, which would be defined as the maximum active thrust on the retaining wall.

$$P_a = \frac{1}{2} K_a \gamma H^2$$

$$K_a = \frac{\sin^2(\beta + \phi')}{\sin^2\beta \sin(\beta - \delta')\left[1 + \sqrt{\left(\frac{\sin(\phi' + \delta')\sin(\phi' - \alpha)}{\sin(\beta - \delta') \times \sin(\alpha + \beta)}\right)}\right]^2}$$

The calculated maximum active thrust is assumed to act at a total distance of H/3 above the base of the retaining wall.

C. Is Code Method

Following are Provision of IS 1893:1984 for Calculation of Dynamic Lateral Pressure.

The active earth pressure exerted against the wall is given by

$$P_a = \frac{1}{2} wh^2 C_a$$

$$C_a = \frac{(1 \pm \alpha_v)\cos^2(\phi - \lambda - \alpha)}{\cos\lambda \cos^2\alpha \cos(\delta + \alpha + \lambda)} \times \left[\frac{1}{1 + \left\{\frac{\sin(\phi + \delta)\sin(\phi - \iota - \lambda)}{\cos(\alpha - \iota)\cos(\delta + \alpha + \lambda)}\right\}^{\frac{1}{2}}}\right]^2$$

Similarly The passive pressure against the wall shall be given by

$$P_p = \frac{1}{2} wh^2 C_p$$

$$\text{where, } C_p = \frac{(1 \pm \alpha_v)\cos^2(\phi + \alpha - \lambda)}{\cos\lambda \cos^2\alpha \cos(\delta - \alpha + \lambda)} \times \left[\frac{1}{1 - \left\{\frac{\sin(\phi + \delta)\sin(\phi + \iota - \lambda)}{\cos(\alpha - \iota)\cos(\delta - \alpha + \lambda)}\right\}^{\frac{1}{2}}}\right]^2$$

II. RESULTS AND DISCUSSION

We have assumed following parameters For Static and Dynamic Approaches :

A. Angle of wall shearing (δ) = 20°
B. Height of Retaining wall (H) = 6m

Also We have Performed Direct shear Test and Standard Proctor Test and Following Results were obtained Respectively for the collected soil sample that can that we are supposed to be as a backfill behind retaining wall,

1) Angle of Shearing Resistance of soil (ϕ) = 24°
2) Cohesion (C) = 9.5 Kpa
3) Unit Weight of soil Sample (γ) = 13.71 Kpa

TABLE I : Active earth pressure by Rankine's earth pressure theory

Sr. no.	Types of Backfill	Active earth pressure (Pa) in Kpa
1	Dry soil	36.55
2	Fully Saturated soil	33.669
3	Partially saturated soil	45

TABLE II : Passive earth pressure by Rankine's earth pressure theory

Sr. no.	Types of Backfill	Passive earth pressure (Pa) in Kpa
1	Dry soil	760.62
2	Fully Saturated soil	513.75
3	Partially saturated soil	378.84

TABLE III : Active earth pressure by Coulomb's Wedge theory.

Sr. no.	Types of Backfill	Active earth pressure (Pa) in Kpa
1	Dry soil	36.55
2	Fully Saturated soil	33.669
3	Partially saturated soil	45

TABLE IV : Passive earth pressure by Coulomb's Wedge theory.

Sr. no.	Types of Backfill	Passive earth pressure (Pa) in Kpa
1	Dry soil	36.55
2	Fully Saturated soil	33.669
3	Partially saturated soil	45

TABLE V: Dynamic earth pressure for dry soil.

Sr. no.	Cases	Dynamic earth pressure in Kpa
1	Active earth pressure	103.77
2	Passive earth pressure	1053.75

TABLE VI: Dynamic earth pressure for fully Saturated soil.

Sr. no.	Cases	Dynamic earth pressure in Kpa
1	Active earth pressure	28.08
2	Passive earth pressure	286.48

TABLE VII : Rankine's Base pressure

Sr. no.	Types of Backfill	Maximum Base pressure in Kpa	Minimum Base pressure in Kpa
1	Dry backfill	115.44	103.75
2	Fully saturated backfill	124.21	94.98
3	Partially saturated backfill	115.44	103.75

TABLE VIII: Coulomb's Base pressure

Sr. no.	Types of Backfill	Maximum Base pressure in Kpa	Minimum Base pressure in Kpa
1	Dry backfill	122.9	37.4
2	Fully saturated backfill	83.71	75.43
3	Partially saturated backfill	125.09	38.07

TABLE IX : Dynamic Base pressure

Sr. no.	Types of Backfill	Maximum Base pressure in KN/m length of wall	Minimum Base pressure in KN/m length of wall
1	Dry backfill	141.74	77.45
2	Fully saturated backfill	93.52	125.67

III. ANALYSIS AND COMPARISON

Active Earth Pressure for Dry Backfill.

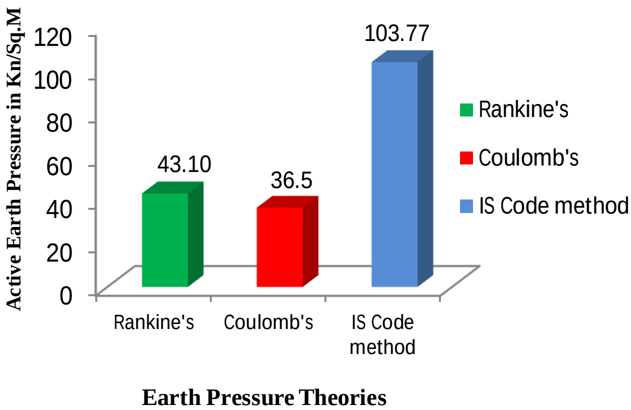

Fig 6. Comparison of Active Earth Pressure for Dry Backfill.

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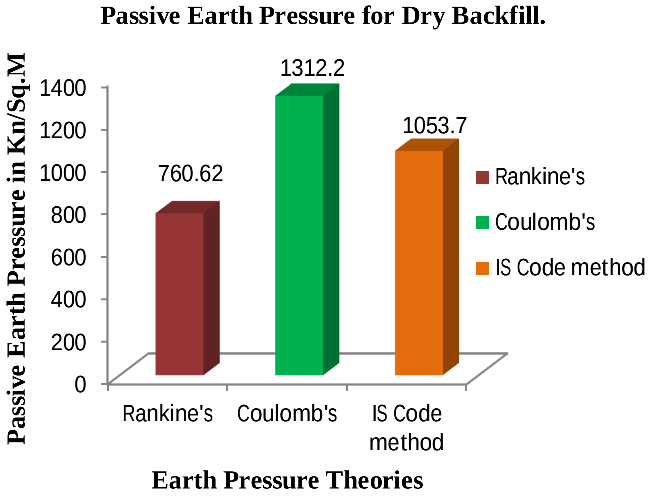

Fig 7. Comparison of Passive Earth Pressure for Dry Backfill.

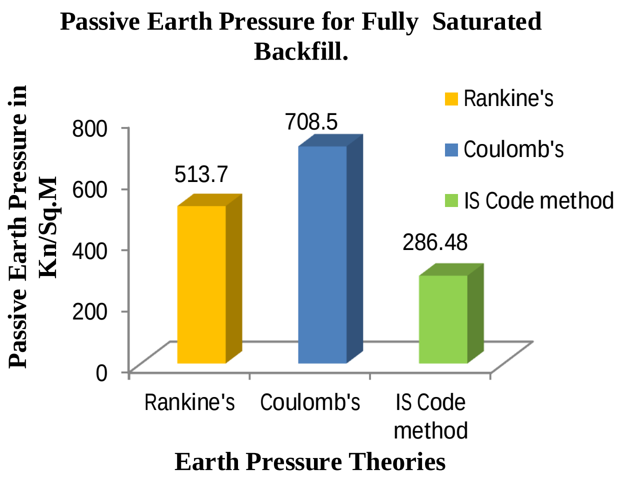

Fig 8. Comparison of Passive Earth Pressure for Fully Saturated Backfill

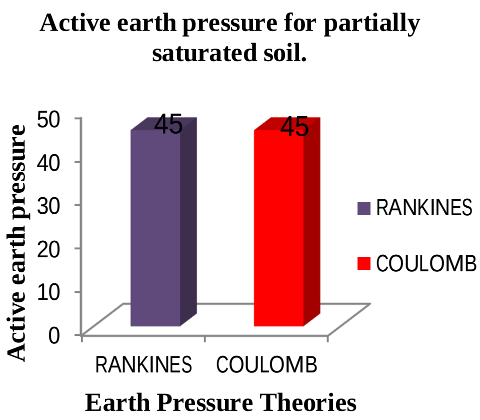

Fig 9. Comparison of Active Earth Pressure for Partially Saturated Backfill

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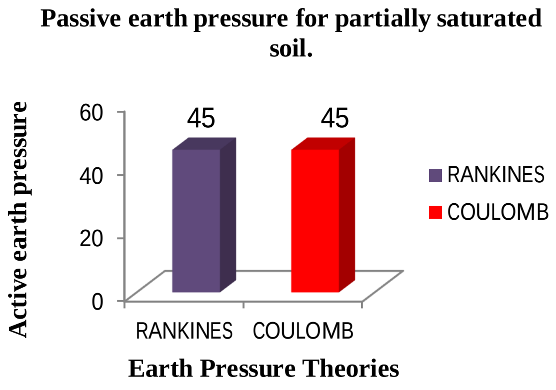

Fig 10. Comparison of Passive Earth Pressure for Partially Saturated Backfill.

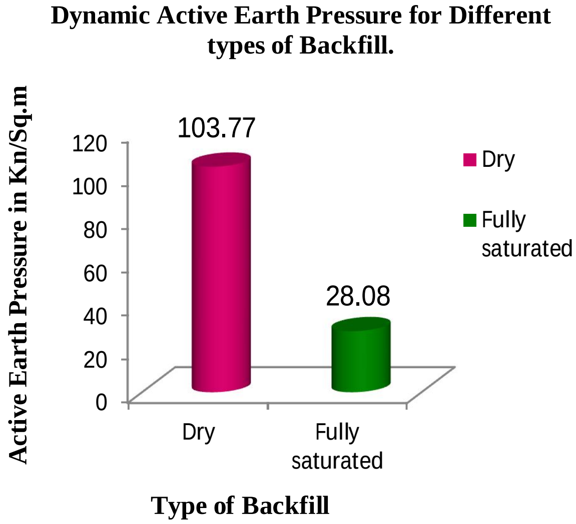

Fig 11. Comparison of Dynamic Active Earth Pressure for Different types of Backfill.

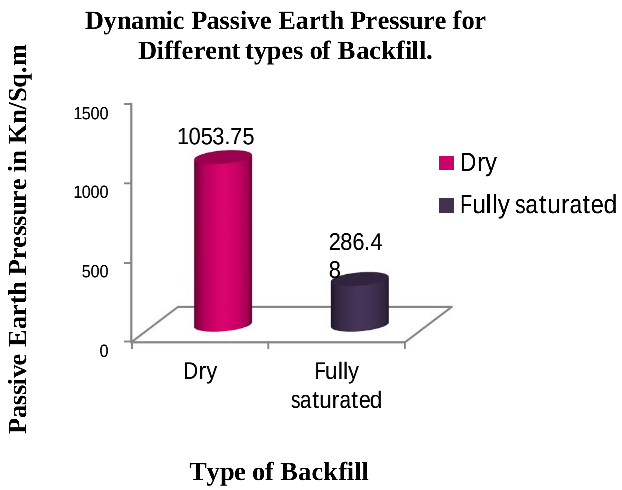

Fig 12. Comparison of Dynamic Passive Earth Pressure for Different types of Backfill.

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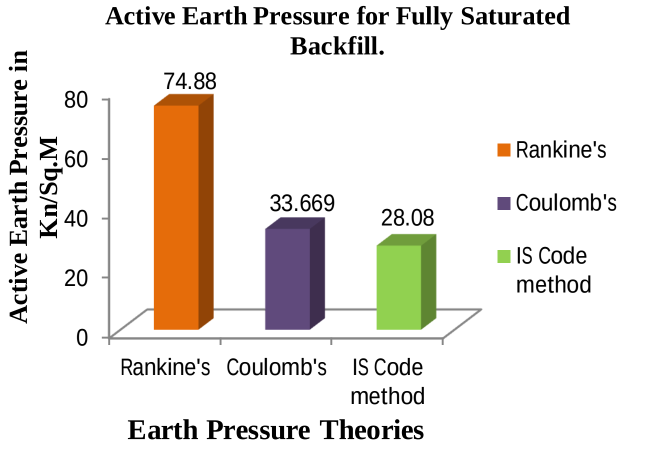

Fig 13. Comparison of Active Earth Pressure for Fully Saturated Backfill.

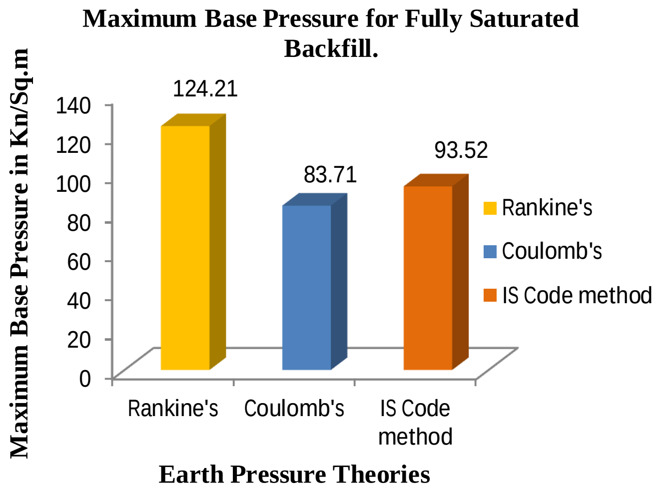

Fig 14. Comparison of Maximum Base Pressure for Fully Saturated Backfill.

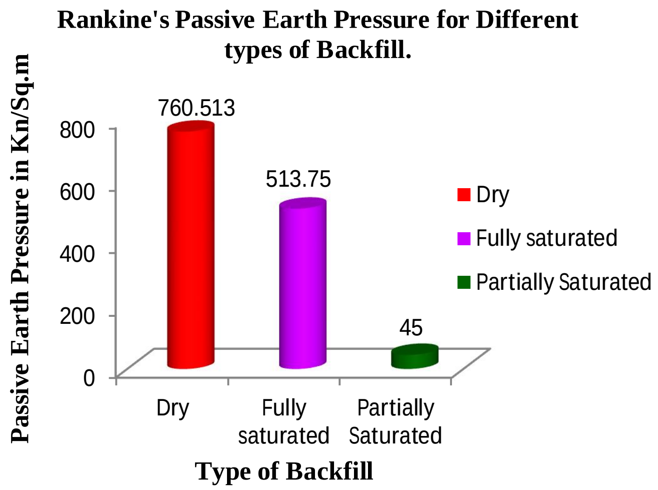

Fig 15. Comparison of Rankine's Passive Earth Pressure for Different types of Backfill

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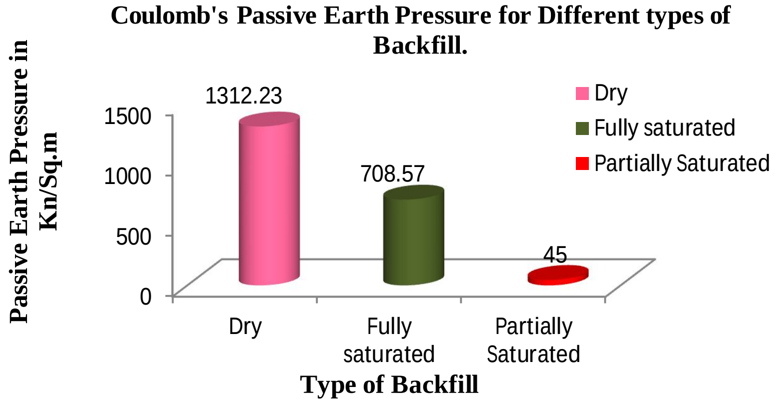

Fig 16. Comparison of Coulomb's Passive Earth Pressure for Different types of Backfill

IV. CONCLUSION

A. It is observed that Provision of Earthquake Forces (I.S. Code Method) in Dry Backfill may Increase active earth pressure and Base pressure compared to Coulomb's and Rankin's Earth pressure Theories.

B. Significant co relationship is observed for Dry backfill and fully saturated backfill as Passive Earth pressure is maximum in case of Coulomb's Earth pressure Theory as compared to I.S. Code Method and Rankine's Theory.

C. The Intensity of Active and Passive earth pressure for partially saturated soil for both Rankine's and Coulomb's Earth Pressure theories Remains constant and does not change.

D. Provision of Dry Backfill may Increase Active and Passive Earth Pressure by 73 % as compared to Fully Saturated soil in case of Dynamic Study.

E. It is also observed that active earth pressure and Base pressure is increased by Rankine's Earth Pressure theory as compare to compared Coulomb's and IS Code Method.

F. In the present work, Provision of Dry Backfill gives highest values of Passive Earth Pressure Compared to Fully and Partially saturated backfill for Rankine's and Coulomb's Theories.

V. FUTURE SCOPE

A. Earth pressure in static method over dynamic method is one of the areas for further study.

B. Vertical load distribution due to earthquake can be study.

C. In respect to various properties of soil, the effects on lateral earth pressure can be study.

D. The effect of water table at different locations on lateral earth pressure can be studied.

E. The data generated in this project can very well be used for developing relationship with various parameters involved. This relationship developed can very well be used in predicting some of the parameters if some parameters are known.

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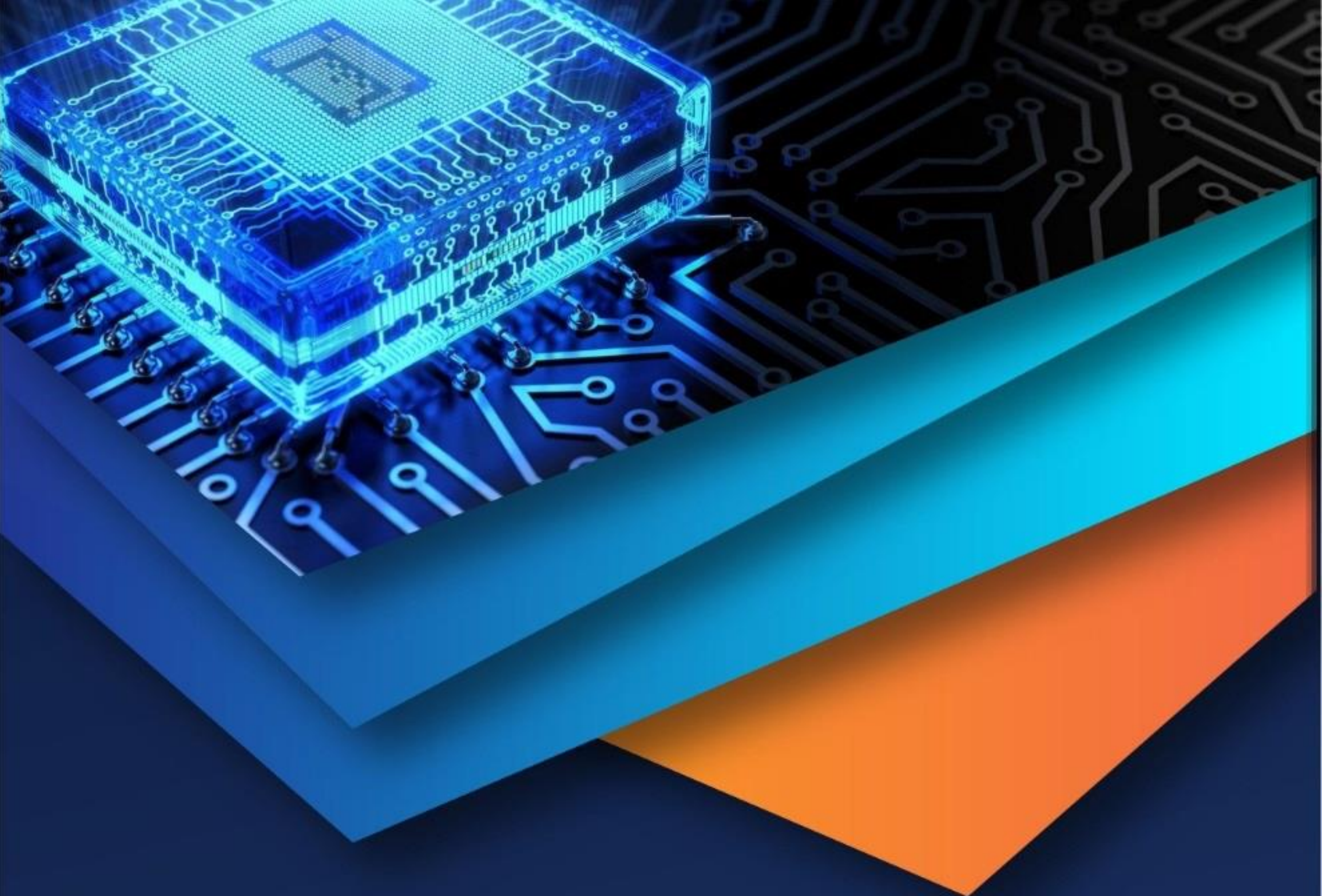

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