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Temperature Behavior of Mass Concrete in Stage Pre, during and Post: Review

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Abstract: ***The mass concrete is a high volume concrete. When there is a high volume of concrete one should need to think about heat created by the high volume concrete. As in mass concrete there is a high percentage of cement and cementitious material used and out of which heat is generated this is the most important parameter to be considered while designing, transporting, placing, compacting and curing. In this paper it is reviewed that how the changes happens to mass concrete while placing and after placing. For this review previously published other author paper reviewed.***
Keywords: Mass concrete, Heat, Temperature, Thermal cracks, °C & Temperature difference etc.

I. INTRODUCTION

This particular paper consist of review of 10 different research paper. In this it is aim to found out the temperature effect of mass concrete. As the high volume of cementitious and cement material used that creates the heat and excess heat always create thermal stress. Which are weakens the structure. In mass concreter thickness or cross dimensional are more so thermal cracking chances are more than the normal. As concrete core temperature increases it leads to a major cracking inside the mass concrete and difference between core temperature to surface also leads cracking of concrete, So to reach any conclusion reviewed the different published research paper.

II. RESEARCH PAPER REVIEW

A. Research paper 1: Actual Temperature Evolution of Thick Raft Concrete Foundations and Cracking Risk Analysis.

By Yuwen Ju and Honggang Lei.

1) In this research paper author is saying Temperature measured with temperature measuring sensors at different location. It is found that temperature increases at initially after pouring (because of hydration of large volume of concrete)but it gets slow down and coming to steady state.
2) The rate of heat generation is higher in the inner surface than the rate of heat dissipation from the member surface. Auther given example if maximum peak is approximately is 73°C 4days after pouring. Surface had peak temperature 67°C.It shows that heat accumulation is more at the core of the foundation. during the peakup stage temperature rise rate was about 18°C per day.(Detailed analysis shown in below graph.

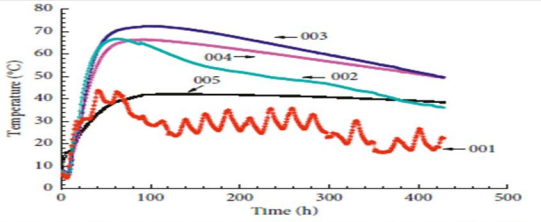

FIGURE 4: Measured temperature evolution of Points 001–005.

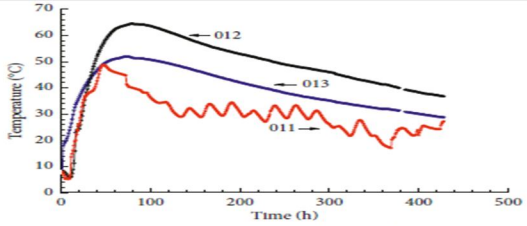

FIGURE 6: Measured temperature evolution of Points 011–013.

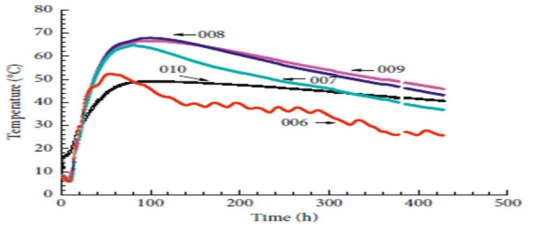

FIGURE 5: Measured temperature evolution of Points 006–010.

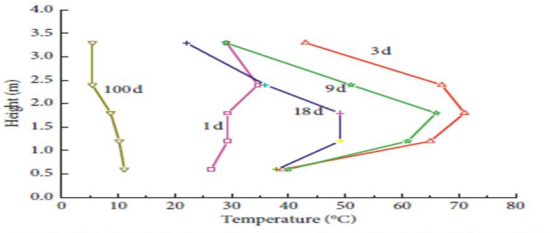

FIGURE 7: Temperature variation along the vertical direction of the foundation.

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3) As per the graph author is saying that Top of the foundation and bottom of foundation has the lowest temperature than the core of the foundation. top surface is becoming sinusoidal curve after 50 hrs. of pouring. Bottom one is declining in slow after peaking compared to top surface one. because Earth below the foundation relatively had low heat conductivity in that heat dissipation rate is slower than heat accumulation.

4) As per author it is found that high temperature zone is core of the foundation and compared to it surface of the foundation has lower temperature. The higher temperature dominates the compressive stress. it is happening because of the difference in temperature rise.at the same time low temperature zone dominated by tensile stress.There fore Elastic modulus of early age is low, So that mean in early stage compressive and Tensile stress values in phases are very small.

5) In the temperature decay phase it is found that elastic modulus of the concrete gradually increases as 90% of the eventual value.

6) As per author previous study a large temperature gradient in core and surface leads higher tensile stress inside the the foundation, concrete is highly susceptible to cracking when core and surface temperature difference is more than 25°C Author current report shows the temperature difference is 35°C.which is higher than the limit may cause more cracking.so it is suggested that control measure has to take to prevent the early stage crack.

7) In this research paper Author has given formula of Calculation of the Concrete Heat Generation Rate.

$$\frac{\partial T}{\partial t} = \alpha\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\frac{\partial^2 T}{\partial z^2}\right) + \frac{Q(t)}{c\rho} \quad \forall (x, y, z) \in R, \qquad (1)$$

where T is the temperature in °C; t is the physical time in h; a is the thermal conductivity of concrete in kJ/(m·h·°C); Q(t) is the heat generation rate of concrete in kJ/m3·h; c is the specific heat of concrete in kJ/(kg·°C); and ρ is the density of concrete in kg/m3.

8) Author had performed finite element analysis (FEA) on five various thickness raft i.e., 1.65 m, 3.30 m,4.95 m, 6.60 m, and 9.90 m. With the same material. The temperature peak increases as the thickness of raft increases but not in significant manner. Thicker the raft longer the high temperature. core temperature of the 1.65 m raft is dropped by 54% of the peak temperature. The core temperature of the 3.30m thick raft temperature is dropped to 80% of its peak temperature for 9.90m.thick raft temperature is dropped high 98% of its peak temperature. reason of the above said scenario is easy as the thinner foundation were fast in heat dissipation. It causing core temperature rapidly drop. Heat transfer direction also affect the rate of drop of temperature.

9) There are some method suggested for temperature control measures. Use the traditional insulation material at top surface, Pouring has to be done in the three layers and time between each layer has to be identified by the real time study. foundation has to cover with the straw-woven insulation material, Temperature difference has to be controlled within 25°C.

B. Research paper 2: Estimation of Early Age Thermal Behaviour of Mass Concrete

By N.V. Mahure, S.K.Jain, M. Raja & S.L.Gupta

1) As per author the delayed ettringite formation (DEF) creates when concrete internal temperature crosses the 70°C.thrmal cracking generally happens when unexpected volume changes in mass concrete. This creates tensile stress, due to tensile stress it exceeds tensile strength of concrete.

2) Thermal cracking happens due to internal and external tempearature difference. large temperature difference leads large thermal stresses. The temperature difference between interior and surface should be within 20°C.or leethan that to minimise the thermal cracking.

3) Author is bifurcated thermal gradient in two sub parts i)mass gradient:it is a difference between maximum interior temperature and ambient temperature. ii)Surface gradient: it is the surface concrete temperature, it is affected by daily and annualy cycled ambient temperature.

4) Minerals has the different thermal properties due to that fine and coarse aggregate which has more volume in concrete influence the thermal properties of concrete.

5) Author given thermal conductivity values of the raw materials for example basalt aggregate have very low thermal conductivity of the order of 1.20 to 1.35 J/m/s/oC

6) As per the author water reducer and retarders reduces the temperature rise at initial 12 to 16 hrs.but after 24hrs. concrete casting that also influence some heat.

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7) There are generally 2-4% of poures in concrete if pours filled partially or fully with water canhave the low thermal conductivity and heat capacity compared to the other phases.If poues filled with air the values could be zero for both the case.
8) Precooling process for raw material has to be initiate for the better results.
9) Post cooling can be done with embedded cooling pipes,sparaying cool water or ponding of water at top surface.
10) Two different mixdesign considered for the research M15 maximum aggregate size is 80mm and M20 maximum size of aggregate 40mm.
11) Author given relation between the thermal properties of concrete and quantities with fourier equation.

$$K = \frac{q \log_e(r_2 / r_1)}{2\pi l(t_1 - t_2)}$$

Where q = Rate of flow of heat
r2 = Outer radius or specimen radius
r1 = Inner radius or radius of hole
t1 = Inner temperature
t2 = Outer temperature
l = length of specimen

12) In this resraech with the machine assembly Specific Heat (C) Test on Concrete Specimen is also calculated.

$$\text{Specific Heat} = \frac{(\text{Heat to Specimen})}{(\text{Weight of specimen x Temperature rise})}$$

13) Diffusivity is shows the material will undergo temperature changes.as per author given formula

$$\text{Diffusivity} = \frac{K}{(C \times \rho)}$$

Where
K = Thermal conductivity of concrete.
C = Specific heat of concrete.
ṕ = Unit weight of saturated concrete.

14) As per research author found the result thermal conductivity of M15A80 and M20A40 was found to be 2.2515 Joule/m/sec/oC and 2.2758 Joule/m/sec/oC respectively and at 28 days were found to be 2.2277 Joule/m/sec/oC and 2.2395 Joule/m/sec/oC respectively.
15) Specific Heat found for M15 A80 M15A80 and M20A40 at 7 days was found to be 1263.46 Joule/kg/oC and 1221.06 Joule/kg/oC respectively. Specific heats at 28 days for M15A80 and M20A40 were found to be 1233.30 Joule/kg/oC and 1207.11 Joule/kg/oC respectively.
16) Diffusivity result of thermal conductivity is given for M15A80 and M20A40 grades at 7 days the diffusivity was calculated to be 0.00269 m2/hr and 0.00288 m2/hr respectively. Diffusivity at 28 days for M15A80 and M20A40 were calculated to be 0.00273 m2/hr and 0.00287 m2/hr respectively.
17) Thermal conductivity is depend on the aggregate type,volume and density.

C. Research paper 3: Experimental Study on Early-Age Crack of Mass Concrete under the Controlled Temperature History.

By Nannan Shi,1 Jianshu Ouyang,1 Runxiao Zhang,2 and Dahai Huang1

1) As mentioned in the research paper after pouring concrete maximum temperature reaches in 48hrs, and then it started to cool down subsequently.
2) As per the research done on concrete and reinforced concrete early age cracking author conducted 4 case studies on the same.
3) As per case 1 Low temperature can reduce the cracking or postponed cracking of concrete at initial stage.
4) Case 2 shows that if concrete placing temperature is less then probability of cracking concrete is less.
5) In case 3 RC concrete reinforcement concrete postpone the crack formation. The crack formation delayed by 108 hrs.
6) Reinforcement increase the tensile strength of concrete by 30%.
7) In case 4 it is seen that reinforcement can enhance ultimate tensile strain of the structure. Compare to plain concrete ultimate tensile strain value is more than the reinforced concrete.

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D. Research paper 4: Experimental Study on Hydration Heat Control of Mass Concrete by Vertical Pipe Cooling Method

By Tae-Seok Seo, Sam-Soo Kim & Chang-Keun Lim

1) As in general in every mass concrete heat generation is high with compare to normal concrete.high temperature develops cracks and it affrect to structure to cater with this suggested method is insert cooling Horizontal and vertical pipes.
2) Maximum Heat of hydration generated after 1 day of casting after reaching at maximum temperature it start gets down slowly it take about 8days to reach as ambient temperature.
3) With the help of cooling vertical pipes poured concrete temperature of can be reduced by 8°C. to 14°C.
4) The effective young modulus is predicted was approximately 50 to 60%.
5) Comparison done between Cooling pipe and non cooling pipe.In non cooling pipe width of crack is 0.40mm and length is 1250mm and observed at middle of the specimen.In cooling pipe crack only observed at bottom the maximum width of crack found is 0.15mm and length 220mm.
6) With the above all statement it is observed cooling pipes are most efficient methodology to control/reduce heat from mass concrete.

E. Research paper 5: Performance of Stage and Direct Method of Mass Concrete Construction in Controlling Temperature Gradient.

By MASYKUR KIMSAN,MORGAN L. SETIADY,CHANDRA YUDI KUSUMA, KURNIATI ORNAM,EDI CAHYONO

1) To prevent thermal cracking temperature difference of surface and core of concrete should have to limit within 20°C.
2) As per author In mass concreting there are 2 method one is direct concreting method and another is layer wise casting.
3) In layer wise casting there should have to provide shear connector longitudinal reinforcement provide to make as a monolithic structure.
4) As discussed in research paper in direct method of raft casting shown upward trend in core temperature, Where as in layer wise raft casting it is observed that temperature is still low.
5) Core temperature seen increment until 70hrs after casting but then it gets slightly stable and decreasing.
6) Direct raft casting method has more advantage as it save casting time, but quality control and quality assurance is very important. As if core temperature crossed limit then repairing cost is extra and involves additional time.

F. Research paper 6: Study on Hydration Heat Coefficient of Mass Concrete Construction.

By Hongli Wang

1) In normal section concrete core temperature and surface has no much difference because of that chances to development of crack is less, But in high volume section heat dissipation cannot be rapidly.
2) If temperature difference between surface and core exceeds then there is a chances of developing major cracks.
3) To control the core heat horizontal and vertical cooling pipes can be provided.
4) To monitor temperature of mass concrete temperature sensor could install in side mass concrete. All sensor connected to data logger and can see the actual temperature reading.
5) Graph could be plotted with the help of Collected Numerous data from data logger.
6) As per research mentioned in paper maximum temperature measured at 63hrs.
7) After the peak temperature it is seen that there is a trend of consistently falling temperature.

G. Research Paper 7: Study On The Hydration Heat Of Mass Concrete Mixed With Urea By Fem Analysis

By Park Chang Gun, Lee Han Seung, Mohamed Ismail and Choi Hyun Kuk

1) Considering the authors research they have used Urea to see the effect of urea on temperature of concrete along with strength.comparision study mentioned in particular research paper.
2) As percentage of urea is increased it is found that maximum temperature is decreased.
3) Also it is found that urea mix delayed to get maximum temperature.
4) Initial temperature of concrete is very important as it contribute to rise core temperature.
5) Early Strength reduction seen in urea mixed mixture,But after 28 days strength loss is reduced.

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H. Research paper 8: Temperature Control Measures and Temperature Stress of Mass Concrete during Construction Period in High-Altitude Regions

By Zhenhong Wang , Li Tao,Yi Liu, and Jiang Yunhui

1) Considering the high altitude it is challenge to control the heat of hydration with the atmospheric condition.
2) Author mentioned the simulation formula and same simulation applied on actual structure.
3) Difficulties to control the heat climatic characteristics of the region which may adversely affect the core temperature of placed mass concrete.
4) Material properties also impact on the temperature of the concrete for example of the coefficient of expansion of material impact on concrete.
5) As it is very difficult to do the concrete at high altitude the temperature control measures has to follow to restrict the core temperature at it is seen that the lower layer temperature is always lower than the middle layer of the concrete.
6) Considering the research author is saying that the concrete temperature should restrict up to 27.5 °C Allowable temperature difference should be 17.5°C.
7) intelligent cooling water supply is recommended for dam construction.

I. Research paper 9: Temperature Control on Mass Concrete in Building Foundation

By ZheChristino Boyke S.P, Mudji Irmawan, Afif Navir R & Andreas Bambang S.A

1) As per author temperature generated by chemical reaction of mass concrete will be very high compare to normal concrete.
2) As per author there are method to reduce the temperature like reducing raw material temperature. Pre during and post concreting temperature could control with different methods.
3) Stresses developed in concrete due to increase in initial temperature of concrete
4) At the early stage modulus of elasticity of concrete is low so pressure created by temperature rise is not significant.
5) Author used some pre and post cooling methods to control heat.
6) In post cooling surface insulation done with the help of layer of plastic, 2cm Styrofoam&20cm thick wet sand.After removing surface insulation water and wet curing done to surface.
7) In post concreting temperature controlled or reduced by cooling pipes.This is used untill concrete temperature gets reduced by 16°C.
8) Installation of closed tent is also help to cover concrete surface from direct sunlight,so it directly helps to reduce concrete surface temperature.
9) As per research author is successfully controlled core temperature within 70°C. and temperature difference surface to core is within 20°C.

J. Research Paper 10: Thermal effect of mass concrete structures in the tropics: Experimental, modelling and parametric studies

By Herbert Abeka, Stephen Agyeman & Mark Adom-Asamoah

1) As per author the temperature of concrete is reduces from core to surface as you see the surface temperature is less than the core temperature.
2) As per Author experience Maturity of concrete and strengths are function of temperature.
3) As mentioned in research 1.1X1.1X1.1meter crosssectional concrete mould casted with the 4 nos of thermocouple to understand the behaviour of temperature.
4) Experiment mould is fully insulated with the polystyrene sheet.
5) In experiment it is seen that the temperature rise in 24hrs after placing concrete and gradually declined in 144hrs,after placing of concrete.
6) Maximum thermal stresses increases as peak concrete temperature raise.
7) It is seen that as dimension of mass concrete increases the temperature differential also increases for example 22.9°C. in 1,1meter block to 70.1°C.for 5meter block.
8) Peak temperature increase as size of mass concrete increases.
9) If the surface area to volume ratio (SVR) is less than 0.36 then it is not sufficient to stop crack occurrence.

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III. DISCUSSION

Reviewing these all research paper it is seen that the fresh concrete temperature is also impact to the core temperature and surface temperature of concrete. There are all mutually saying core temperature increase and it should be limit to 70°C.and surface to core temperature difference should be 20°C..If the core and differential temperature is increase than limit then there are chances to develop Cracks. It weakens to structure and lead many impact on structure.To limit the temperature there are some perduring and post methods suggested by some authors, Mentioned method would help to reduce core temperature.

IV. CONCLUSION

Temerature of mass concrete exceeds then that adversely effect and create cracks in structure which is harmful considering structural design.

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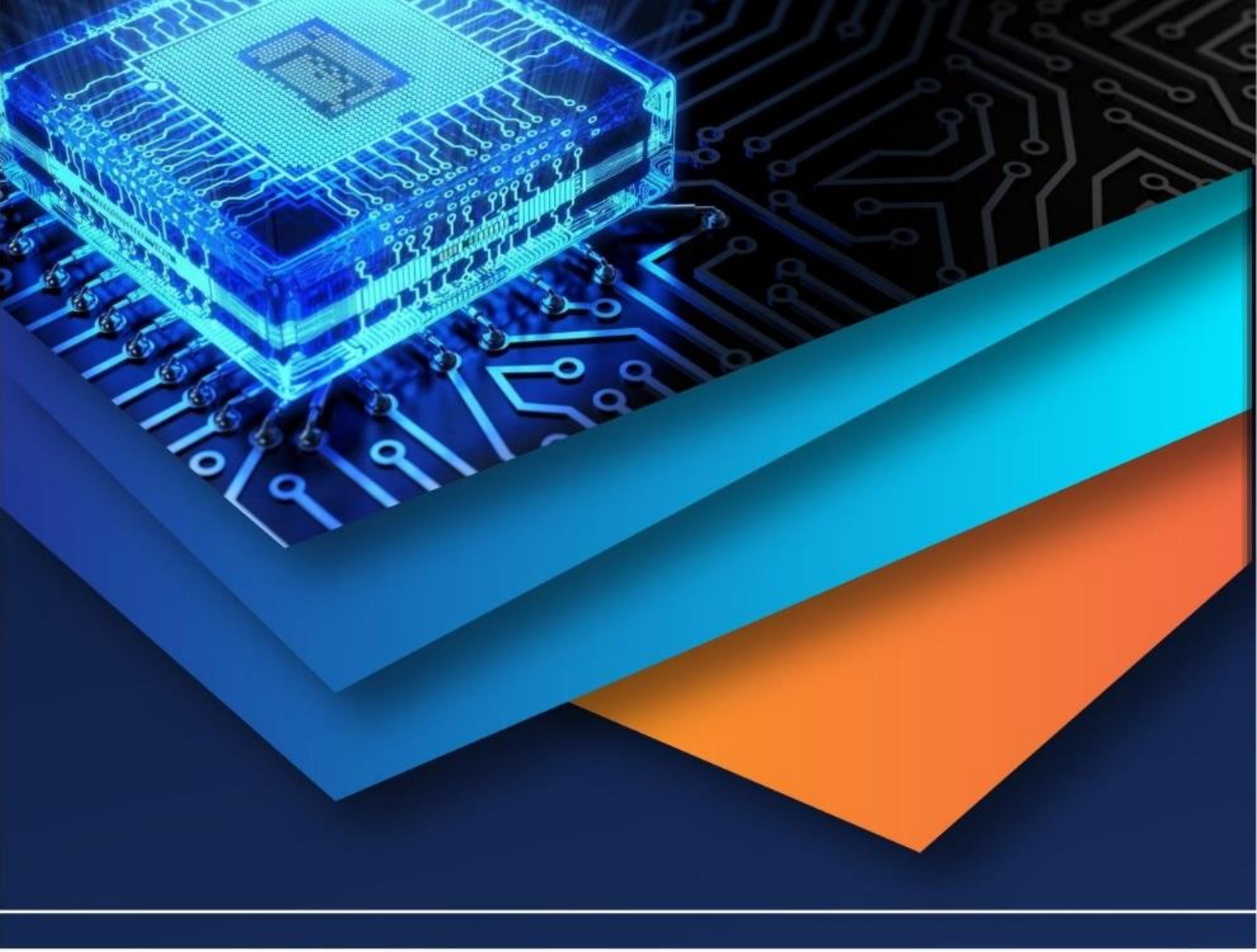

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