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Comparison of Effect of Hot Water Curing, Steam Curing & Normal Curing on Strength of M-20 Grade of Concrete

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Abstract*: Curing of concrete is the operation of maintaining humidity & temperature of freshly placed concrete during some definite period following placing, casting or finishing to assure satisfactory hydration of cement. When water is added to cement, sand & aggregate mix, the reaction between cement & water is exothermic. Hence lot of heat is evolved in reaction. This is known as heat of hydration. The heat of hydration results in evaporation of water from concrete that results in reduction of strength of concrete. Hence external application of water is required. This is 'curing'. Efficient uninterrupted curing is the key to quality concrete. Proper curing of concrete is crucial to obtain design strength. The curing period depends on the required properties of concrete. Curing is designed primarily to keep the concrete moist by preventing the loss of moisture from the concrete during the period in which it is gaining strength curing may be applied in the number of ways & the most appropriate means of curing may be dictated by the site or the construction method. Various methods of curing are available. The existing study suggests that immersion curing is best suited for concrete but it involves more water as compared to other methods. However, if a combination of two or more methods is tried, the consumption of water can be reduced.

The literature reviewed so far indicates that immersion method of curing concrete gives the best result as regards compressive strength. However, the basic limitation of immersion method is that it cannot be replicated on site. Hence the strength of concrete observed in laboratory is illusive & is not the real strength of concrete on site.

Keywords: Curing, immersion method, Heat of hydration.

I. INTRODUCTION

In present scenario most of the construction done by concrete so proportion of concrete is important factor for strength as well as durability. Concrete is a single most extensively used man-made material in the world. It has been used for the construction of buildings, bridges, dams, pavements, tunnels, waste containment system. In 1999, Lambert corporation attempted to introduce that concrete curing is the treatment of newly placed concrete during the period in which it is hardening so that it retain enough moisture to immunize shrinkage & resist cracking. It has long been recognized that adequate curing is essential to obtain the desired structural & durability properties of concrete. Two main categories of methods of curing concrete are: those that maintain availability of water & those that minimize the loss of mixing water from concrete by sealing its exposed surfaces. To determine which curing method(s) to adopt, it is necessary to consider factor such as the availability of curing material, the size & shape of structure, environmental condition etc. Traditionally, quality of concrete in construction work is calculated in terms of its 28 days compressive strength. If after 28 days, the quality of concrete is found to be dubious, it would have been buried by subsequent construction.

II. LITERATURE REVIEW

Many researchers have worked and published their work on comparison of different curing methods on the compressive strength of concrete. Some important papers relating to this are referred in this work. The methodology, observations, conclusions and further scope of work of these publications are used to finalize the objectives of present work. Summary of such reports is presented in further sections.

The available literature of review is classified as follows:

Gokul et al., 2016 Presented the research work is about determining the compressive strength for M20 grade of normal strength concrete & M40 grade of medium strength concrete as per 10262:1999 by using immersion curing, wet gunny bags & accelerated warm water curing as per IS 9013:1978. As we know quality of concrete can be estimated only after 28 days compressive strength test. This procedure required 28 days of moist curing, which is too long period with the assistance of reliable test methods employing accelerated curing techniques. It is now possible to test the strength of concrete within a short period by using

accelerated curing techniques. Result obtained from the investigation demonstrate that superior strength is achieved by immersion curing than other two types of curing & it also can be concluded that result obtained by accelerated curing within 24 hrs is nearly to immersion curing. Variation in the strength calculated by immersion curing, wet gunny bags curing & accelerated warm water curing with strength 24.6 N/mm2, 23.2 N/mm2 & 22.43 N/mm2 for M20 grade of concrete at the age of 28 days. At the same age for M40 grade of concrete compressive strength of 43.6 N/mm2, 41.3 N/mm2 & 40.7 N/mm2 respectively.

Nuruddeen Usman et al., 2015 presented paper is about investigating the effects of different types of curing methods on the strength of concrete. A lot of research works were carried out to identify the suitable curing method for concretes and several methods were suggested by various researchers. For these investigation normal concretes were prepared using specified mix ratio of 1:2:4 and 1:3:6 and the cubes are tested for compressive strength at 3, 7, 21, and 28 days of curing respectively using four curing methods namely immersion, sprinkling, polythene sheeting and sharp sand coating. By testing it indicate that water immersion curing method as well as sprinkling methods of curing, provide better results than membrane method of curing while sharp sand gives least strength. The rate of drying was significant when the specimens were subjected to curing with polythene sheet method of curing. This thus hampered the hydration process and thus affected the compressive strength property of the hardened concrete. Results of the study from the laboratory analysis of various cubes cast shows that curing by immersion gives the best output in terms of compressive strength but in practical it could be seen to be expressive on a small scale production, therefore spraying in situ is the nearest available option so wastage of water is minimized. The overall findings of this study suggests that concrete should be cured by water immersion or spraying regularly to achieve a better compressive strength in concrete.

Akinwumi et al., 2014 presented a study on the effects of curing methods & curing ages on the compressive strength development of ordinary Portland cement concrete in tropical environment. The research effort is aimed at investigating and comparing, in a tropical climate such as that of Nigeria, the compressive strength development of concrete cubes were cured by immersion in potable water, immersion in lime water, covering with wet rug, covering with plastic sheets and air-drying. For each of these curing methods, the average compressive strength of concrete cubes was determined after 3, 7, 14, 28 and 90 days curing periods. They were suggested that special precaution needs to be taken if the environmental temperature for curing is higher than 30°C or less than 10°C and that curing water should not be more than about 11°C cooler than the concrete, to prevent thermal stresses that could result in cracking. Various research efforts have been made to investigate the influence of curing conditions or methods on the concrete, self-compacting concrete, concrete under hot weather conditions, ordinary concrete, and concrete containing supplementary cementations materials. Results obtained from the concrete cubes in water & those cured by plastic sheet covering was nearly equal & also relative strength development of concrete cured by air drying & those by covering with wet rug showed similarity. Various investigations discourage the use of curing by air-drying method and also suggest limiting the use of the other curing methods to 28-days period. Generally, the highest compressive strength was obtained for concrete cured by immersion in lime water. The result may be attributed to the outdoor (exposure) condition that this curing method was subjected to.

Chithra et al., 2014 presented a study of the effect of thermal curing on strength characteristics of GGBFS based concrete. Their main objectives are that a comparative study was done on strength parameter for different standards & proposed a strength predicting exemplar for GGBFS based concrete. Concrete with characteristics compressive strength of 20MPa was chosen for the present study. Concrete specimens were cast with 20%, 30% and 40% replacement of cement with GGBFS and were cured under different curing conditions like hot water and hot air oven. The specimens were exposed to three different temperatures, 40˚C, 50˚C and 60˚C for four hours in hot water curing. Compression test and split tensile test were conducted on concrete cubes and cylinders respectively. They concluded that compressive strength of control concrete has found to be higher when compared to GGBFS based concrete for all percentage replacement and ages. They also found that 40% replacement of GGBFS with cement attains more compressive strength when compared to 20% and 60% replacement of GGBFS. 60% replacement of GGBFS gives less strength when compared to 20% and 40% replacement. From the result it was inferred that higher percentage replacement of cement with GGBFS yielded considerable increase in both tensile and compressive strength of the resulting concrete& they also found that replacement of cement with 40% of GGBFS under hot water curing at 60˚C temperature has yielded maximum compressive and tensile strength of concrete. Variation in the percentage of cement replacement with GGBFS yielded better results on compressive strength and tensile strength to an extent of 16 % and 54% respectively.

Nirav R Kholia et al., 2013 presented the working comparison & the effectiveness of curing methods on several hardened properties of concrete such as compressive strength, flexural strength, initial surface absorption, ultrasonic pulse velocity and dynamic modulus of elasticity. The “Curing techniques and curing duration significantly affects curing efficiency” Various degree of efficiency can be achieved by various in situ-curing methods. The effectiveness of the concrete curing method depends on the

material used, method of construction and the intended use of the hardened concrete. Techniques used in concrete curing are mainly divided into two groups namely," Water adding techniques and Water- retraining techniques". With the advancements in the construction and chemical industry have paved way for the development of the new curing techniques and construction chemicals such as Membrane curing compounds, Self-curing agents, Wrapped curing, Accelerators, Water proofing compounds etc. study revealed that for a given dosage of accelerator and for a given age of concrete all the water cured specimens acquired the stipulated design strength where as none of the specimens cured by curing compound could attain the same. The average efficiency of the curing compound was found to increase in the early stage of curing but reduced at the later stage. With the growing scale of the project conventional curing methods have proven to be a costly affair as there are many practical issues and they have been replaced by Membrane curing compounds and Self-curing agents up to some extent as they can be used in inaccessible areas, Vertical structures, Water scarce areas etc .It is most practical and widely used curing method. In this review paper effort has been made to understand the working and efficiency of curing methods which are generally adopted in the construction industry and compared with the conventional water curing method. Using Membrane curing and Self-Curing methods one can achieve 90% of efficiency as compared to Conventional Curing method.

Dr K. V Krishna Reddy 2013 presented a study to evaluate effectiveness of different curing methods & study the influence of climate on the strength properties of concrete. An attempt is made in this work to highlight the affect of different curing methods & that of climate on the quality of the concrete. Different curing methods namely ponding, jute bag curing, single layered membrane curing, double layered membrane curing and air curing are considered to study the affect of different methods of curing and climate on the quality of concrete. Concrete samples were tested after curing of 3 days, 7 days & 28 days. Curing compound was sprayed immediately after removal from moulds & in case of the double coat the second coat was applied after 5 min of application of first coat. Ordinary Portland cement of 53 grade satisfying the requirements of IS: 12269-1987 with 28-days compressive strength of 58.5 Mpa is used. Mix design was done aiming at M60 grade concrete as per ACI regulations. Curing may be applied in a number of ways and the most appropriate means of curing may be dictated by the site or the construction method. Result obtained the increase in strength up to 85 to 90 % of ponding.

Ajay goel et al., 2013 presented a study to demonstrate that the method and duration of curing greatly affects the strength characteristics of concrete. The parameters of the study include the curing period [3, 7, 28 and 56 day], curing method [Air curing, plastic films, immersion under water] and the type of cement [Portland pozzolona Cement (PPC) 43 grade,]. In this study the specimens used are: cube, cylinders. Beams were cast and cured under different conditions before testing. The test curing by air, nearly the same results as that of Plastic film but by immersion under water curing strength increase by age. From the test results, they were observed that there was an increase of 41.7 percent, 31.7 percent and 42.1 percent in compressive strength at 7 days when compared to its strength at 3 days for specimens air cured, cured with plastic film and immersion under water curing respectively. On further curing a decrease as compressive strength at 28 days compared to its strength at 7 days was observed for air curing and plastic film curing & the percentage decrease was higher for air cured specimens than plastic film cured specimens. For water curing an increase of 61 percent of compressive strength at 28 days over its strength at 7 days was observed. They found that there was also increase of 40.2 percent, 52.61 percent and 30.72 percent in compressive strength at 56 days when compared to its strength at 3 days for all specimens.

Akeem Ayinde Raheem et al., 2013 presented a study considered the effect of different methods of curing on density and compressive strength of concrete. Concrete cube specimens of mix 1:2:4 were prepared with water-cement ratio of 0.65. The cubes were cured using six methods (air curing, water-submerged curing, spray curing, polythene curing, moist sand curing and burlap curing) until testing ages of 3, 7, 14, 21 and 28 days when their densities and compressive strengths were determined. If concrete is cured for only three days, it will reach about 60% of the strength of continuously cured concrete; if it is cured for seven days, it will reach 80% of the strength of continuously cured concrete. If curing stops for some time and then resumes again, the strength gain will also stop and reactivate (Mamlouk and Zaniewski, 2006) the results showed that densities of the specimens ranged from 2432.59 to 2502.72 Kg/m3. Also, moist sand curing method produced concrete specimens with the highest 28-day compressive strength of 30.5N/mm2 followed by the burlap curing method with a value of 24.4N/mm2. Air curing method showed a 15% reduction in strength after 21-days thereby resulting in the lowest 28-day compressive strength of 17.8 N/mm2. It was also concluded that there exists a weak positive correlation between density and compressive strength of concrete specimens. This study seeks to assess the effect of different curing methods on the density and compressive strength of concrete and to determine method(s) that is unsuitable which may impair the quality of the concrete.

S.S. Kolo et al., 2013 presented a study on the effect of different curing methods on the compressive strength of concrete using

Portland cement & finally identify the most effective curing process for normal concrete. Normal concrete was prepared with a water-cement ratio of 0.50. cube specimens were cast for testing the compressive strength at 7 and 28 days of curing, using three curing methods namely immersion, sprinkling and Plastic sheeting, curing to cure the cube specimens until the day of testing. The test specimens were cured under three types of curing until the day of testing. These were water curing (WAC), sprinkling of water (SWC) and wrapping with plastic sheeting (PSC). In water curing, the specimens were weighed and immersed in water. In sprinkling method, the specimens were also weighed and kept moist by sprinkling water on the specimens 2 times daily (morning and evening) until the date of testing. In plastic sheeting, the specimens were weighed and wrapped in flexible plastic sheets until the testing date. At least 2 layers of wrapping were used to prevent moisture movement from concrete surface. The curing temperature was maintained at 27 + 20c in all the curing methods. Results obtained indicates that water curing (WAC) as well as sprinkling (spraying) curing provided much better results than membrane (Plastic Sheeting) method of curing. The rate of drying was significant when the specimens were subjected to membrane (Plastic sheeting) method of curing. This thus hampered the hydration process and thus affected the compressive strength property of the hardened concrete & the overall finding of this study suggests that concrete should be cured by water curing to achieve a better compressive strength.

T. James et al., presented a study of the effect of curing methods on the compressive strength as well as the density of concrete. Their main objective was to study the effect of different curing methods on the compressive strength of concrete cured for 7, 14, 21 & 28 days. The di□erent curing methods are usually adopted to evaluate the compressive strength of concrete. As they reported, a proper curing maintains a suitable warm & moist environment for the development of hydration products & thus reduces the porosity in hydrated cement paste & the density of microstructure in concrete. The studies reported that the hydration products of cement extend from the surfaces of cement grains, and the volume of pores decreases due to proper curing under appropriate temperature and moisture. They went further to report that for any concrete, curing acts just like feeding to a newborn baby, if a concrete is not fed with water at the early age, it cannot gain the properties and durability for its long service life. They therefore suggests that a suitable curing method such as water ponding, spraying of water, or covering with wet burlap and plastic sheet is essential in order to produce strong and durable concrete. A total of 72 cubes of mix ratio 1:2:4 were investigated after subjecting them to various curing conditions, with the aim of finding which of the curing method is best. The cubes were cured in the laboratory at an average temperature of 28◦C (82.4◦F). The results obtained showed that the average compressive strength values for 7, 14, 21 and 28 days, vary with curing methods. The results show that ponding had the highest compressive strength and density, followed by wet covering, sprinkling, then uncured for two days, with the totally uncured cubes having the least compressive strength and density as well as highest shrinkage limit. Ponding method of curing was recommended to be the best of all the curing methods.

Suresh B Piplewar et al., presented a study with the effect of intermittent curing methods on the strength of M20 concrete. Intermittent curing of concrete means the curing process should be done intermittently to concrete. Studies of the effects upon strength of the various curing periods of alternate dry and wet curing at different air temperatures were done. The data appear to indicate that the amount of mixing water retained in the concrete during the curing period is an important factor in curing, and that satisfactory curing may be obtain in humid areas with a comparatively short initial wet curing period. Concrete specimens were evaluated at temperatures < 25° C. The water curing in the concrete specimens for test included 3,7,9,12,15,18,21,24 and 28 days. The comprehensive and comparative study of intermittent curing and the wet curing of M20 was sought. On the basis of interpretation of the results the following outcomes were made:

1) Full time curing longer than 7 days was seldom justified
2) If adequate intermittent curing was assured, a 7 days intermittent curing seemed adequate,
3) 3 days intermittent curing for 3 times a day produced a strength 98.95 percent of the 3 days full time curing and
4) 7 days intermittent curing for 3 times a day produced a strength 95.67 percent of 7 days full time curing
5) 21 days intermittent curing for 3 times a day produced a strength 94.65 percent of 21 days full time curing.

Following fact was disclosed: the intermittent curing of concrete is sufficient and it does not reduce the compressive strength considerably, which is an important conclusion for saving the water and thereby electricity.

Rakesh A. More et al., 2014 presented the study on the effect of different qualities of water on concrete compressive strength. The objective of the present work is to compare the compressive strength of concrete for M20 grade by using the different qualities of water such a tap water, bore well water, well water, waste water etc. which are available on different construction sites and are directly being used for making concrete, also identification of civil works where these water can be used without compromising structural strength parameters. In the present work, the mix proportion is designed as per IS 10262 for M20 grade of concrete. As

there are so many types of quality of water are available namely tap water, well water, bore well water, waste water etc. all these types of water were used for making the concrete cubes, specimen of size 150mm × 150mm × 150mm as per Indian standard were tested at 7 days and 28 days to find out compressive strength. The results obtained that the compressive strength of the concrete cubes made with mineral water, tap water, well water, waste water increased with days & not having much variation in their compressive strength & also shows that concrete made with different qualities of water samples such as ground water, packed drinking water, waste water etc. have 7- and 28 – day compressive strength equal to or at least 90 percent of the strength of reference specimens made with clean water for M20 grade of concrete. (Except Waste water specimen for 7- day).

M.V. Krishna Rao et al., The present work is aimed at influence of the type of cement, age & type of curing on M40 grade of concrete. This work encompasses all the aspects of curing and sets a guideline for effective concrete making in this range of concrete which has applications in rigid pavement and concreting applications. There is a limited work on the effect of curing period and curing techniques on the strength and performance aspects of concrete. The parameters of the study include the curing period [1, 3, 7, 14 and 28 day], curing method [conventional wet curing, membrane forming compound curing and accelerated curing] and the type of cement [Ordinary Portland Cement(OPC) 43 grade, Portland Pozzolana Cement(PPC) 43 grade and Ordinary Portland Cement(OPC) 43 grade +10% Silica Fume(SF) replacement for cement]. In all a total of 99 cube specimens were cast and cured under different conditions before testing. These studies were conducted with or without supplementary material. Test results indicate a drop in strength at all ages for concretes with PPC and the one in which 10% OPC is replaced by silica Fume(SF) in comparison with the concrete with OPC. Curing by membrane forming curing compound yielded nearly the same results as that of conventional wet curing for concrete with OPC and there was a marginal decrement in concrete with PPC. Predicted 28-day strength of concrete from the accelerated curing test was found to be on a conservative side compared to control concrete.

Maria west et al., 2010 presented a study to evaluate the effect of mix proportioning parameters and curing on concrete shrinkage with the goal of providing recommendations that will reduce concrete shrinkage in bridge decks Specimens are dried up to 365 days at 23 ± 20 C (73 ± 30 F) and 50 ± 4 percent relative humidity. Parameters include aggregate content; cement fineness; water-cement ratio; curing The results indicate that increasing the aggregate content (decreasing the paste content) of a concrete mix decreases shrinkage and that water-cement ratio has little effect in and of itself. For a given aggregate content and water-cement ratio concretes made with Type I/II cement shrink more than concretes made with Type II coarse-ground cement. Concrete containing a 30 percent cement replacement of either Class C fly ash or granulated ground blast-furnace slag exhibit higher shrinkage than concrete with only Type I/II cement when cured for three days. Limestone coarse aggregate produces concrete with higher shrinkage than concrete made with quartzite coarse aggregate. Increased curing periods lead to a decrease in shrinkage for concretes made with Type I/II or Type II coarse-ground cement. No consistent effect of dosage rate on shrinkage was observed for concretes made with the superplasticizers tested. The use of a shrinkage reducing admixture at a dosage rate of 2 percent by weight of cement reduced the shrinkage of concrete nearly 32 percent after 365 days. The shrinkage reducing admixture, however, produced concrete that at times exhibited unstable air content.

Gnana Venkatesh et al., presented experimental work was carried out to investigate the effect of concrete strength in terms of compressive and split tensile strength of normal strength M20and medium strength M40 grade concrete by adopting Immersion curing, Wet gunny bags curing and Accelerated warm water curing as per 10262:1999, IS 9031:1978. In this study a total of 42 cubes and 30 cylinders were cast and tested. Out of those, 18 cubes and 12 cylinders were tested for each Immersion curing and wet gunny bags curing. Remaining 6 cubes and 6 cylinders were tested for Accelerated warm water curing method. For Immersion curing and wet gunny bag curing methods 9 cubes and 6 cylinders each were tested for M20 as well as M40 grade of concrete. The variation in Result obtained from the experimental work is: The Immersion curing and wet gunny bag curing attained an average compressive strength of 24.14 N/mm2 and 22.51 N/mm2 respectively for M20 grade of concrete at the age of 28 days. At same age, the Immersion curing and Wet gunny bag curing attained an average compressive strength of 43.25 N/mm2 and 41.55 N/mm2 respectively for M40 grade of concrete The average compressive strength of concrete cubes with Accelerated warm water curing method equivalent to 28 days was found to be 20.88 N/mm by Wet gunny bags curing respectively.& also from the test result it is recommended that the accelerated curing can be adopted as a time consuming curing method in construction industry though it has around 1% of lesser compressive strength than the wet gunny bags curing system.

Tae-Kyun Kim et al., 2015 presented this study aims to evaluate the effects of temperature, relative humidity, wind velocity, and sunlight exposure time on the concrete material strength to identify counter measures to deal with curing condition variations due to climate change. In order to obtain necessary data for the analysis, 3, 7 and 28-day compressive and split tensile strength tests were performed on the concrete mix proportion most commonly used by ready-mix concrete companies in Korea. They use 100 mm ×

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200 mm concrete cylinder specimens were cured under various curing conditions including temperature, relative humidity, wind speed, and sunlight exposure time until the testing was performed. Using the test results, a performance based evaluation (PBE) procedure using a satisfaction curve is proposed. PBE is a statistical method of analyzing the satisfaction of a required performance in unpredictable conditions such as climate change and earthquakes, making it possible to evaluate the level of satisfaction of the required performance according to experimental and empirical outcomes. PBE has been utilized by many researchers. For the specimens cured under standard curing conditions, the 3 and 7day design target compressive strengths were 50% and 80% of a 28-day design compressive strength of 27 MPa, respectively. From the test, a 28-day compressive strength of 31.1MPa was obtained. The three-day strengths for the specimens cured at 35, 40, and 45 °C showed slightly higher strengths than those cured at 8 and 12 °C. The compressive strength obtained under various temperature and relative humidity curing conditions showed that a higher temperature increased the three- and seven-day early age strengths, which was similar to steam-cured concrete. However, the largest 28-day strength was obtained at curing temperatures of 8, 12, and 35 °C and a relative humidity of 95%. The optimal curing temperature and relative humidity condition for the largest 28-day strength was nearly equivalent to the standard temperature and highest relative humidity. The comparisons of concrete strength development histories based on the curing temperature and relative humidity variations between the current and past works showed that the results from the current work are valid. Also, the results showed that curing condition variations of wind speed and sunlight exposure time can have significant effects on the concrete strength at the construction site.

III. CONCLUSION

After going through the existing literature on Comparison of effect of Hot water curing, steam curing & Normal curing on strength of M-20 grade of concrete there is some short coming of immersion method & to overcome this shortcomings the present research effort aims at studying the combination of immersion method & other methods of curing like jute bag covering method & plastic membrane method. The effort shall be made to replicate the field condition in laboratory. The study seeks to assess the effect of different curing methods on compressive strength of concrete & concrete should be cured by best curing method to achieve a better compressive strength. The present study aims at combining immersion method with wet covering, with use of curing compound & plastic sheeting water requirement for 7 days, i.e. immersion curing combined with these is proposed to be calculated.

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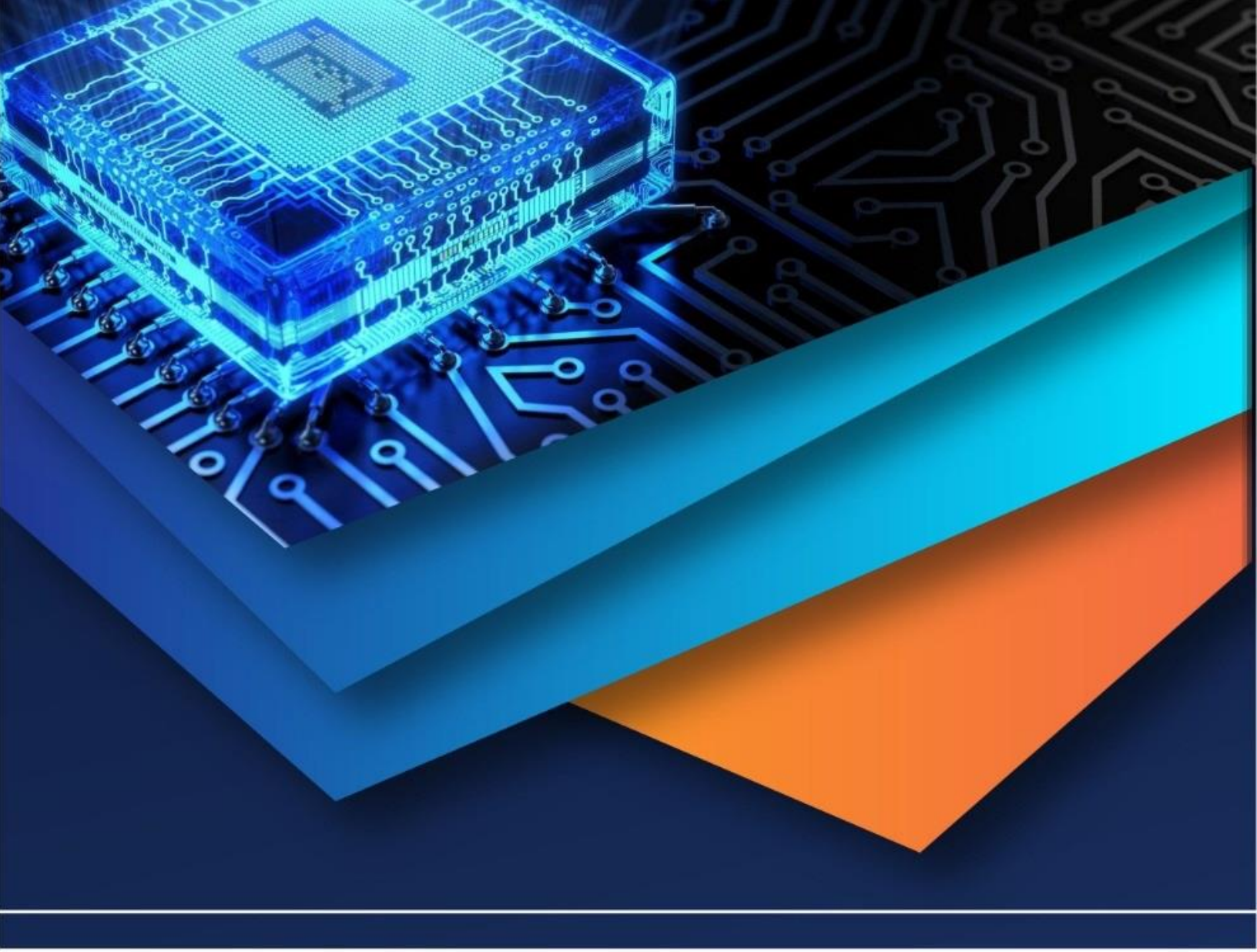

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