iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** V **Month of publication:** May 2020

DOI: http://doi.org/10.22214/ijraset.2020.5281

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue V May 2020- Available at www.ijraset.com

A Review on Shear Strength of Fly Ash based Geopolymer Concrete

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Abstract: ***This Review aims to discuss the literature review on Shear Strength of Fly ash based Geopolymer Concrete with addition of GGBS .Concrete is the widely used material in the construction works in which cement is the main composite. The manufacturing of cement involves the emission of carbon dioxide and other greenhouse gases into the atmosphere which are responsible for global warming. Hence, the researchers are currently focused on various materials to replace and reducing the usage of cement. In this study Geopolymer concrete is prepared with Fly ash, Ground Granulated Blast furnace Slag (GGBS) with the addition of alkaline activator. Fly ash is the by-product from burning pulverized coal in electric power generating plant and GGBS is obtained by a product of iron and steel making. Both the material used as waste material from industry. Hence, it is carry out the research on Fly ash based Geopolymer concrete by using alkaline mixture of Sodium hydroxide and sodium silicate as alkaline activator. This paper includes the study of Fly ash and GGBS or any other waist based Geopolymer concrete research paper and to analyse the method which respected authors used.***
Keywords: Geopolymer concrete, Shear strength, Compressive strength, ambient curing.

I. INTRODUCTION

A. General

Research studies in the past had shown that fly ash–based geopolymer has emerged as a promising new cement alternative in the field of construction materials. The term geopolymer was first coined and investigated by Davidovits [1] which was obtained from fly ash as a result of geo-polymerisation reaction. This was produced by chemical reaction of aluminosilicate oxides with alkali polysilicates yielding polymeric Si-O-Al bonds. Hardjito and Rangan [2] demonstrated in their extensive studies that geopolymer concrete showed good mechanical properties as compared to conventional cement concrete.

Cement is one of the most energy intensive construction material and its production involves Very high temperature (1400°C to 1500°C) processing and leads to the uncontrolled quarrying of Natural resources and emission of CO_2 (greenhouse gas). Many efforts are being made to the use of Portland cement in construction. These efforts include the utilization of supplementary cementitious materials as well as use of alternate materials in place of Portland cement. Geopolymer concrete (GPC) is one of such alternatives to replace the Portland cement in concrete.

Geopolymer are formed by alkaline activation of an alumino-silicate material. Review of literature shows that Fly ash, metakaolin, rice husk ash, red mud etc. are the generally used alumino-silicate material and the alkali solutions include sodium hydroxide, potassium hydroxide, sodium silicate, calcium silicate etc.

Geopolymer concrete (GPC) is best suited for precast construction. However, the connective distress found in Precast construction is centred around the shear interfaces (Place where shear stress causes sliding type of failure along a well-defined plane) associated with corbels, bearing shoes, ledger beam bearing, coupled shear wall, wall to foundation, deep beams etc. Study of shear- slippage at the interface of both monolithic and precast construction is very important in such instances.

The literature survey related to the project shear strength of Fly ash and GGBS based Geopolymer Concrete was undertaken to get acquainted process adopted with the same. Technical articles published in the proceedings and other journals have been referred to determine the further scope of the work and to understand the status of each work undertaken. It has been also noted that many researches are work on fly ash based Geopolymer concrete development process.

B. Need for the Study

Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.

It is evident from current scenario that OPC is causing considerably environmental hazards such as increasing global warming by releasing greenhouse gases and enormous consumption of power and raw materials for production of OPC. Need for this study is to find the alternative of OPC to solve these problems.

1) To find an alternative for the OPC in concrete.
2) Produce a more durable infrastructure capable of design life measured in hundreds of year.
3) To reduce CO2 release and produce eco-friendly concrete mix.
4) Protect aquifers and surface bodies of fresh water via the elimination of fly ash disposal sites.
5) To produce a price efficient product.
6) To produce high strength concrete than ordinary Portland cement concrete.

C. Shear Strength of Geopolymer Concrete

In engineering, shear strength is the strength of material or component against the type of yield or a structural failure when the material or components fails in shear. A shear load is the force that tends to produce a sliding failure on a material along the plan that is parallel to the direction of the force. When paper is cut with scissors, the paper fails in shear.

In structural and mechanical engineering, the shear strength of component is important for designing the dimensions and materials to be used by the manufacture or construction of the component. In a reinforced concrete beam, the main purpose of reinforcing bar stirrups is to increase the shear strength.

II. LITERATURE REVIEW

An attempt has been made in this chapter to make a review of the available relevant to the topic of study. Considerable amount of literature is available on the response characteristics of Fly ash based geopolymer concrete and GGBS with other waste products such as red mud, palm oil fuel ash, rice husk ash based geopolymer concrete but the literatures on the only Fly ash based geopolymer concrete are very limited. Among the study done in the field of Fly ash based geopolymer concrete, some of them are as follows:

A. Joseph Davidovits *et al.* (1994), stated on "Geo-polymers and geo-polymeric material" in geopolymer concrete Geo-polymerization is the main process involves a chemical reaction between alumina-silicate oxide present in source material and alkali silicates of alkaline activator solution yielding a three dimensional polymeric ring structure consisting of Si-O-Al bonds. For chemical designation, this alumina-silicate based geopolymer was named as isolated. Isolated is an abbreviation for silicon-Oxo-aluminates. The isolate network consists of SiO_4 and AlO_4 tetrahedral linked alternatively by sharing all the oxygen in 1978, Joseph Davidovits coined the term geopolymer to denote a wide range of materials characterized by networks or chains of inorganic molecules. He has suggested that an alkaline activator solution could be used to react with Silicon (Si) and Aluminium (Al) present in a source material of geological origin or in by-products of several industries such as ground granulated blast furnace slag, fly ash and rice husk ash to produce binders These are fundamentally inorganic alumino-silicate polymers synthesized from a fast chemical reaction called Polymerization. Due to geological origin of silicon and Aluminium and polymerization reaction it is termed as geopolymer.

B. Hardjito *et al.*(2005) claims that "Fly-ash based geo-polymer concrete development and properties of low calcium fly-ash based geo-polymer concrete" source materials like fly ash, slag (GGBS), claimed kaolin, and demonstrates a higher final compressive strength when compared to those made using non-calcined materials like kaolin clay, mine tailings, and naturally occurring minerals.

C. Benny Josef *et al.* (2013) [3] studied on "Interface shear strength of fly ash based geopolymer concrete." This paper present and experimental investigation conducted to study the influence of aggregate content on the interface shear strength of geopolymer concrete and to compare with that of ordinary Portland cement concrete. Further, it has been proposed to check the suitability of existing equation for OPC concrete for assessing the shear capacity of geopolymer concrete. Push-off specimen were used to study the interface shear strength. Both reinforced and unreinforced concrete were used for the study. It has been observed that the shear strength of geopolymer concrete is inferior to OPC concrete and that an aggregate content less than 65% in geopolymer concrete leads to drastic reduction in its shear capacity. A 50% reduction in the value has been suggested to predict the shear strength of geopolymer concrete.

D. B.H. Shinde *et al.* (2015) investigated "Properties of Fly ash based Geopolymer mortar" Laboratory investigation carried out to represent the effect of various parameters on the strength of geopolymer mortar was produce by using unprocessed fly ash, activated with sodium silicate and sodium hydroxide solution. Solution to fly ash ratio was 0.2,0.3,0.35,0.4,0.5,0.6,0.7,0.8 and Sodium hydroxide ratio 1,1.5,2,2.5,&3 were used. The specimen were cured at temperature 40, 60, 80, &100^{0}C. With rest period 1, 2, 3, 4, 5, &6 days. The ultimate compressive strength were obtained at the solution to fly ash ratio 0.5 with Sodium Silicate to Sodium Hydroxide ratio 1.5, the curing temperature 80^{0}C with rest period 4 days. As the result of which obtained

that the activation solution prepared before 1 day produce the same strength as solution prepared at the time of the mixing. The Sodium to fly ash ratio 0.5 with sodium Silicates to Sodium Hydroxide ratio 1.5 produces ultimate compressive strength at 7 days.

E. Shaik Usman *et al.* (2017) focused on the topic "Strength studies on Geo-polymer concrete by using fly ash and quarry dust". The alkaline liquids are used in this study for the polymerization are the solution of sodium hydroxide and Sodium Silicate. Different molarities of Sodium hydroxide solution are taken to prepare different mixes and Compressive strength is calculated for different mixes. The geopolymer concrete specimen are tested for their compressive strength at the age of 7 days. The result shows the strength of geopolymer concrete is increasing with the increase of molarity of sodium hydroxide.

F. Tanveer Singh Bains, Khushpreet singh *et al.* (2019) studied on "Experimental study on Geopolymer concrete using Fly ash, Bagasse ash and Metakaolin with pet fibre". This experimental work is done to examine the fully replacement of cement in concrete to fly ash, bagasse ash and metakaolin. Total 4 mixes prepared for this study and strength parameters were explored. Cement was replaced fully with 70% fly ash, 20% metakaolin and 10% bagasse ash. PET fibers are also added to with the varying proportion. The obtained concrete mixes were tested for its compressive strength, split tensile strength and flexural strength at 7 days and 28 days. It can be concluded from the present investigation that the geopolymer containing 3% PET fiber is more effective in strength than the other mixes.

G. Ee Hui Chang *et al.* (2009) investigated on "Bond Behaviour of Reinforced Fly Ash-Based Geopolymer Concrete Beams" This paper describes the bond behaviour between geopolymer concrete and reinforcing bars in tensile splices in beams. Twelve full-scale beam specimens with lap- cast and tested in the laboratory to study the bond performance of geopolymer concrete. The effects of concrete compressive strength, bar diameter and splice length of the bars on bond strength of lap splices in geopolymer concrete were evaluated. Test results, including general behaviour of beams, failure modes and cracking patterns were gathered and analysed. Current analytical models and codes provision to predict bond strength for Ordinary Portland Cement (OPC) concrete were used to analyse the bond strength of test specimens. Good correlation between test and analytical results were found. This study also demonstrates the excellent potential of geopolymer concrete for use as a construction material.

H. Maria Rajesh *et al.* (2014) studied on "Behaviour of Low Calcium Fly ash Based Geopolymer Concrete Structural Elements with GGBS & Steel Fibre" Fibre reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibres. Steel fibres increases the durability of geopolymer concrete. To enhance the curing ground granulated blast furnace slag is added. It is proposed to determine and compare the differences in properties of geopolymerconcrete with GGBS and steel fiber. The investigation are to be carried out using several tests which include workability test, impact value test , sieve analysis, specific gravity test, compression test, split tensional strength and flexural strength.

I. M. Mustafa Al Bakri *et al.* (2015) focused on "Comparison of Geopolymer Fly Ash and OPC to the Strength of Concrete" The different ratio of FA 50%: AGG 50%, FA 40%: AGG 60%, FA 30%: AGG 70% and FA 20%: AGG 80% for geopolymer concrete was used in this study. The same designs also have been used for OPC concrete as a control reference. The strength was measured by compressive strength, and other tests also have been conducted such as density, water absorption and porosity test. The results show that fly ash-based geopolymer with FA 30%: AGG 70% give highest compressive strength compared to OPC concrete at 1, 7, and 28 days of testing. The density of geopolymer concrete is comparable with OPC concrete. The water absorption and porosity of geopolymer concrete was lower than OPC concrete. The test data indicates that a better quality of fly ash-based geopolymer concrete can be produced with proper content of mix design of material.

J. Ravikumar.V *et al.* (2016) focused on "Effect of Fly Ash in Concrete" India is a developing country and doing lot of research for building materials to find alternatives by using waste materials and easily available material. These materials are used as replacement and admixtures for getting good strength and durability of concrete. However we should find the proportion of the admixtures that gives good strength and durability of the concrete. Also note workability in different mix proportions by using slump test.

K. Ambily P.S *et al.* (2012) studied on "Experimental studies on Shear behaviour of reinforced Geopolymer concrete thin webbed T-beams with and without fibres" This paper presents the details of the mix proportion of geopolymer concrete (GPC) mixes, preparation of RGPC beams, testing and evaluation of structural behaviour with respect to cracking, service load, deflections at various stages and failure modes. Investigations on the shear behaviour of the reinforced concrete beams showed that the failure mechanism can be transformed from brittle to ductile mode by addition of steel fibres.

L. Jerrin Emmanuel *et al.* (2015) investigated on "Experimental Investigation of Alkali Activated Slag and Fly Ash based Geopolymer Concrete" This thesis report is about experimental investigation done on various strength and durability parameters of Alkali Activated Slag (AAS) And Fly ash (FA) Based Geopolymer Concrete and comparing it with nominal mix conventional concrete of grade M40. The investigation results shows that there is a increase in compressive and flexural strength with the increase in concentration of NaOH solution, and also noted that there is an increase in tensile strength with decrease in concentration of NaOH solution.as a result of surface cracking dominating these characteristics. When compared with control mix results with AAS-FA based geopolymer concrete mix it shows a greater improvement of strength parameters in Geopolymer concrete than in conventional concrete.

M. Rohit Kumar *et al.* (2017) studied on "Alternate Cementitious Material: Geopolymer Concrete" Widely used source materials are industrial waste like fly ash, granulated blast furnance slag, red mud; and alkaline solutions which are sodium/potassium hydroxide with sodium/potassium silicate of different molarity. This review focuses on till date information on geopolymer concrete like application of industrial waste in construction, proceeding reactions of alkaline activators with aluminosilicate source which has a similar or enhanced property over cement, factors governing production of commercial application of GPC by reduction of the high temperature needed for polymerization, to ambient temperature.

N. B. Vijaya Rangan et al. (2014) investigated on "Geopolymer concrete for environmental protection" Extensive studies conducted on fly ash-based geopolymer concrete are presented. Salient factors that influence the properties of the geopolymer concrete in the fresh and hardened states are identified. Test data of various short-term and long-term properties of the geopolymer concrete are then presented. The paper describes the results of the tests conducted on large-scale reinforced geopolymer concrete members and illustrates the application of the geopolymer concrete in the construction industry. Some recent applications of geopolymer concrete in the precast construction and the economic merits of the geopolymer concrete are also included.

O. K. P. Chandran *et al.* (2016) studied on "Impact resistance of fly ash based geo polymer concrete using coconut shell aggregate" In this context, use of Geo polymer concrete, where no cement is consumed, has to be encouraged. Geopolymer concrete is formed by the reaction of a source material which is rich in silica and alumina with alkaline liquids. Low calcium Fly Ash is source material used in this study. Sodium hydroxide and Sodium silicate are the alkaline activators. The coarse aggregate which is broken granite stone is partially replaced with coconut shell aggregates which is lighter than granite stone and is an agricultural waste product from coconut industries which is disposed as waste material. This study reveals that partial replacement of coarse aggregate with coconut shell can be used for making light weight geo polymer concrete which is having better Impact Resistance properties making it ideal for Prefabricated Structures and Precast Structural elements. Addition of Steel fibre enhances the impact resisting capacity.

P. B.Laxman Raju *et al.* (2019) investigated on "Interface Shear of Fly ash and GGBS Based Geopolymer Concrete" This article presents an experimental study conducted to find the shear strength of geopolymer concrete. In addition, it was proposed to check the suitability existing equations like Birkeland and Birkeland, Mattock and Design code ACI 318, which are developed for ordinary Portland cement concrete for estimating the shear capacity of geopolymer concrete. Push off Samples were used to study the shear strength at the interface. Both reinforced concrete and non-reinforced concrete samples were used for investigation. It was observed that the shear strength of geopolymer concrete is superior to OPC concrete. The existence of reinforcement transversely shear plane produced a rise of about 29% of the shear resistance against slip.

Q. N. A. Lloyd *et al*. (2010) investigated on "Geopolymer Concrete with Fly Ash" A summary of the extensive studies conducted on fly ash-based geopolymer concrete is presented. Test data are used to identify the effects of salient factors that influence the properties of the geopolymer concrete and to propose a simple method for the design of geopolymer concrete mixtures. Test data of various short-term and long-term properties of the geopolymer concrete and the results of the tests conducted on large-scale reinforced geopolymer concrete member's show that geo-polymer concrete is well-suited to manufacture precast concrete products that can be used in infrastructure developments. The paper also includes brief details of some recent applications of geopolymer concrete

R. Prof. Ruchira S. Ingole *et al*. (2018) investigated on "Geopolymer Concrete: A Concrete of Next Decade" This paper presents the progress of the research on making Geopolymer Concrete using fly ash. This aims at studying the different properties of Geopolymer Concrete using fly ash and the other ingredients locally available. The actual compressive strength of the concrete depends on various parameters such as the ratio of the activator solution to fly ash, morality of the alkaline solution, ratio of the activator chemicals, curing temperature etc. In recent years, Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The amount of the carbon dioxide

released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one tonne for every tonne of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminium. Attempts to reduce the use of Portland cement in concrete are receiving much attention due to environment-related. Fly ash-based Geopolymer Concrete is a 'new' material that does not need the presence of Portland cement as a binder.

III. SUMMERY

It is understood from the earlier studies that good scientific information available on the evaluation of chemical and physical properties of geo-polymer concrete. Also, very few work has been reported on the shear strength of geo-polymer concrete. Further study has been reported on the effect of percentage of fly ash and GGBS on shear strength of geo-polymer concrete. The concentration and type of alkali needs to be investigated extensively to choose the combination and dosage of alkali for fly ash and GGBS. The effect of alkali activator on the rate of hardening of geo-polymer at different curing regime needs to be well documented. Generally, geo-polymer concrete cured at elevated temperature but at site it is not actually possible to cure at elevated temperature hence, it is decided to work on ambient curing on geo-polymer concrete for calculating compressive and shear strength of geo-polymer concrete. It was clear that as the NaOH concentration increases the compressive strength also increases.

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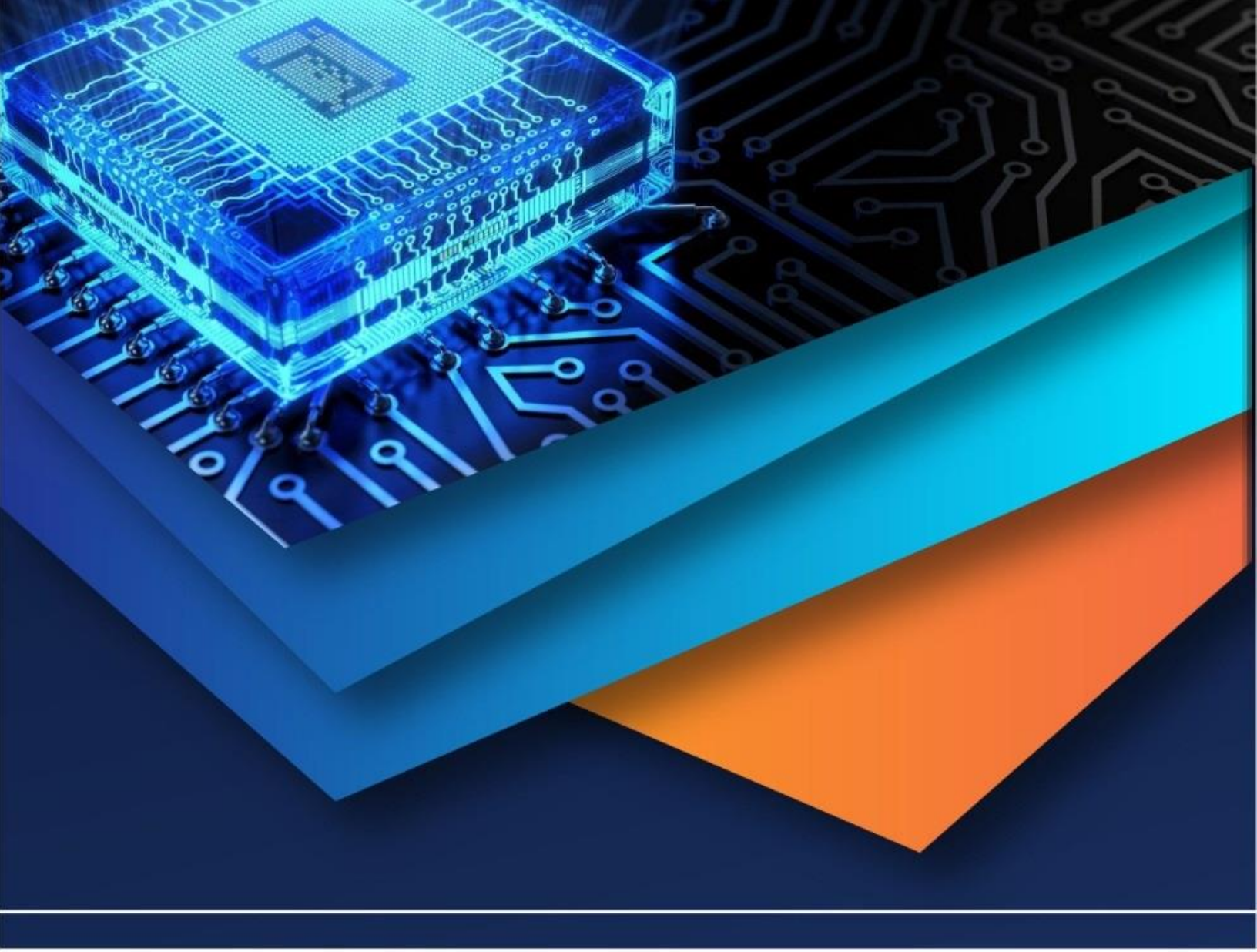

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