iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** IV **Month of publication:** April 2022

DOI: https://doi.org/10.22214/ijraset.2022.40387

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue IV Apr 2022- Available at www.ijraset.com

Study on the Strength Characteristics and Mechanism of Weathered TUFF

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***Abstract:** Many countries in the world has a large number of tuff like cultural relics that have many historical history. These kinds of cultural relics tuff have experienced many natural weathering in the long historical years. Natural weathering like air pollution since industrialization, acid rain erosion and many different degrees of artificial damage, they are suffering from different degrees of surface degradation and decay, erosion and even destruction and a strong typhoon effect. Under consideration and effective protective measures are not taken, irreparable losses will be caused. People who are coming for tourism to look at the historical and cultural relics are in danger. Therefore, it is urgent to deeply study the weathering damage mechanism of stone cultural relics, and to develop stone cultural relics protection materials and construction technical measures. In this paper we will research by understanding the theoretical characteristics and relationship between tuff strength and weathering degree and weathering damage mechanism of stone, and characteristics of rock and mineral composition so that we can theoretically address by studying the weathering damage mechanism.*
***Keywords:** Natural stone decay; tuff materials, rock mechanics, weathering damage.*

I. INTRODUCTION

Tuff, is an glowing rock that forms from the products of an explosive volcanic eruption [1]. And in these eruptions, the volcano blasts rock, ash, magma and other materials from its vent. This eject travels through the air and falls back to Earth in the area surrounding the volcano. Tuff is usually thickest near the volcanic vent and decreases in thickness with distance from the volcano [2]. Many of the tuff has the characteristics of wide distribution, moderate and hardness there easy mining, processing and also strong weather resistance. It is a widely used ancient architectural stone and cultural relic material of tuff quarrying sites [3]. Many Buddha Temple are carved from tuff on the spot. The compressive strength, in particular, depends both on petrol physical features, tuff has a low values of bulk density which makes it weak, medium low compressive strength is in between 1.2 and 9 MPa, and somehow have high porosity of the average being variable between 35% and 60%. For many centuries, walls and giants budda temples were carve and made of solid tuff masonry [4][5]. Stone conservation is one of the key issues in preserving our cultural heritage. The modification of the properties is by consolidation, which is very important in influence the behaviour of the stone by slowing down the disintegration. So that people can come for touring to see the cultural relics of that country or state [6].
However, the safety for people touring the complete caverns is one of the most important things to discuss about because the issues need a pending adequate solutions. The caving would continue to collapse if they are not effectively protected and preserved soon [7][8]. But only when its not disturbed by human beings and strong earthquakes it can maintain it balance. Many people are concerned about stability and the long-term stability of the rock cavern [9][10]. Many incidents happened in different part of the world because of the collapsed of the cave people are injured [11]. It would be extremely sad and sorry if one of the roof collapse with people inside, We do not want to see such disasters to occur although partial failures have occurred to them. Therefore, addressing the issues is significant [12]. It is necessary to investigate the effective and efficient methods to protect and preserve the complete rock cavern.

Fig.1. New roof rock collapse with a plane area of 75 m2 of the originally partially failed

This image in fig 1 is an example of cave that partially fail, Now the government should paid more and more attention for the protection of the caves and cultural heritage [13]. historical heritage was not properly protected, and even accelerated the damage of some stone cultural relics [14]. Therefore, it is very important to study the weathering damage mechanism of stone cultural relics and also scientific and reasonable development and the system of restoration materials for the protection of stone cultural relics.

II. STRENGHT OF TUFF

The tuff rock has geotechnical properties for example (1.5) -(2.4) gr/cm3 of bulk density, (18)-(25) kN/m3 of unit weight, and also (2.29) - (2.64) gr/cm3 of particle density, with compressive strength depending on the degree of weathering, (0) - (1.45) MPA of cohesion, friction angle = (24°) - (45°) of friction angle, and (4%) - (42%) of porosity. This tuff soil properties depend on the location, Because Tuff soil materials have a high silt content in sandy soils which contains a few silty clay soil [15]. The tuff unit weight varies from (<10 kN/m3) to (30 kN/m3), while the compressive strength ranges from (0) - (0.2) MPa, cohesion from > (0) to (0.1) MPa, and the friction angle is from (10°) - (40°). All of this is based on the plasticity index data. Tuff is included in pyroclastic rock types. Because pyroclastic rocks it consists of reworked material in which erupted from an explosive volcanic and transported by cloud incandescent material and air, and then be on the ground in dry conditions or in the body of water. (Vide Carozi, 1975 & Fisher, 1961) [16][17]. According to the composition of stone cultural relics in China, the materials are mainly divided into marble, granite, limestone, sandstone and other types. The tuff rocky cultural relics are widely distributed in Zhejiang Province with unique cultural relics with local characteristics [18]. There are three type of tuff base on lithological variations according to Schmidt (1981) which are (1) vitrie tuff, (2) lithic tuff and (3) crystal tuff. In the research area, there are two types of tuffs that are lithic tuff and crystal tuff.

1) *Lithic:* Tuff is a pyroclastic rock which is dominated by rock fragments. Rock fragments which usually become tuff, The constituent are andesite, porphyry, diorite and others. This fragment determines the quality of the tuff as a building material because each type of fragment has a predominance or different mineral composition.
2) Crystal: Tuff is a pyroclastic rock that is dominated by crystal fragments. Fragments of crystal in the form of minerals such as of plagioclase, pyroxene, amphibole, biotite

III. CURRENT RESEARCH SITUATION AND DEVELOPMENT

In recent years, researchers have carried out research on the causes and mechanisms of stone cultural relics. For example, there is a lot of Classification and Illustration of Stone Cultural Relic Diseases that brought destruction, such as the biological diseases, mechanical damage and surface weathering [19].

Liu Qiang carried out investigation on the types of stone cultural relics, weathering damage mechanisms and restoration and protection measures in Stone Cultural Relics Protection. Explanation of the surface [20]. Chen Xiandan and others investigated the diseases of the Sichuan cliff tomb stone carving and carried out the experimental research on various weathering mechanisms. Huang Jizhong and others applied the principle of water and rock action to study the chemical effect of weathering failure of Yungang sand rock cave stone carving [21]. Shao Mingshen and others found that the weathering diseases on the sandstone cultural relics of Chengde Summer Resort. gold Hao believes that there is also contribution of the external environmental factors such as temperature and humidity, freeze-thaw, acid rain and so on is an important cause of stone cultural relics diseases [22]. Zhang Kexie and others believed that hydrology, climate, geological structure would cause environmental geological diseases of stone cultural relics.

With the development of modern science and technology, it is possible to use nondestructive testing technology to test and diagnose diseases of stone cultural relics [23].

The detection methods of stone cultural relics mainly include ultrasonic which is nondestructive detection Sun Jinzhong and others used Ruilei waves and ultrasonic transmission waves to carry out the nondestructive testing of the Hanbaiyu railings of the Forbidden City, Zhang Zhiguo and others used ultrasonic methods to detect the internal damage of Qianlong Royal Monument. electrical exploration and detection of cracks, etc. The analysis work includes mineral composition analysis, crystal phase analysis of rock ore and material mechanical state analysis, etc. For example, Yang Junyong and others used X-ray diffraction to detect the stone pagoda of Xinchang Giant Buddha Temple [25][26].

The properties of rock mineral composition, rock mass compactness, rock mass porosity and other materials were tested, Zhang Xinpeng carried out acoustic testing of Huashan rock paintings, Zhang Zhongjian et al. used three-dimensional scanning to detect the cracks of stone cultural relics in Chengde Summer Resort.

Fang Yun et al. used ground penetrating radar to detect the cracks of the Giant Buddha of Fengxian Temple; Sun Yali and others studied the weathering speed of the rocks of the ancient city wall of Quzhou; Huang Zhiyi and others believed that the combination of radar and infrared thermal imaging technology had a good effect on the detection and treatment of water seepage diseases in the tomb. Zhang Huihui Through indoor simulation of rock seepage, infrared thermal imaging is used to classify the disease levels of large stone cultural relics. Zhou Xiao used a temperature infrared detector to survey and study the post preface monument of Yongyou Temple [27].

The development of modern industry and agriculture and environmental pollution are increasing day by day. The sedimentary disease of dirt on the surface of stone cultural relics poses a great threat to the lifespan of its own stone. At present, the cleaning methods of stone cultural relics mainly include physical and chemical cleaning and adsorption desalination technology. For example, Zhang Bingjian, Shi Meifeng, Qi Yang, Song Feng and others applied several commonly used surface cleaning methods of stone cultural relics, such as water cleaning, chemical cleaning, particle washing spraying and laser cleaning in addition, Ye Yayun studied the damage degree of sandstone under laser irradiation.

Stone cultural relics have special historical and cultural value and non renewable properties. Therefore, according to the characteristics of the protected stone, it is necessary to carefully select and use restoration and protection materials. At present, the inorganic materials used in the restoration of stone cultural relics mainly include Ba(OH)2, grout reinforcement materials such as lime water, and surface sealants such as oil and wax. The organic materials commonly used for the protection of stone cultural relics are mainly epoxy, acrylic resin, organosilicon resin, etc. With the attention paid to stone cultural relics in today's society, relevant research institutions have developed some new composite materials for stone cultural relics protection, such as Hong Kun and other Research believes that bionic inorganic materials have good water transmission, air permeability, environmental friendliness and other characteristics; Liu Yurong believes that Kong Jie materials have The higher specific surface area and regular pore structure are characterised by good permeability and hydrophobicity, strong resistance to acid rain when applied to the protection of stone cultural relics; Fan Min and others research believe that organosilicon has good adhesiveness, hydrophobic permeability, excellent weather resistance, light retention and other characteristics, etc. A nano-TiO2 modified stone cultural relic waterproof material has been developed. After experiments, it is believed that the salt resistance, air permeability and light resistance of this material have been significantly improved before modification.

The monitoring of stone cultural relics is mainly used to understand the preservation status of existing stone cultural relics, the weathering speed of stone cultural relics ontology materials and early warning of weathering damage, and track and inspect the use effect of some restoration materials and restoration technologies of stone cultural relics. At present, the monitoring of stone cultural relics mainly focus on the monitoring of the mechanical properties of stone cultural relics, ontological materials and environmental monitoring With the development of information science and technology, relevant experts and scholars have applied modern scientific and information technology to the rescue protection of stone cultural relics, and have achieved remarkable results. For example, Li Shukun and others used three dimensional laser scanning technology to carry out three dimensional measurement and virtual restoration of stone cultural relics and carried out permanent digital protection in the protection project of Yungang Grottoes [28]. Tao also established a three dimensional display system for Chongqing Dazu stone carving Qianshou Guanyin statue Ma Wen Wu extracted blurred invisible doll images in the original image of stone tablets by hyper spectral data. Ge Huaidong constructed a digital protection scheme for stone carvings of mausoleums in the Southern Dynasties using adaptive three-dimensional reconstruction system and three-dimensional panoramic spatial measurement technology. Many institute example Piero Bagl, University of Florence, Italy Ioni et al. They all put forward the idea of building a multimedia digital information system for the protection of cultural relics to provide basic data for the follow up protection of stone cultural relics.

IV. WEATHERING PROCESS

Weathering is the deterioration of rocks, soils and minerals as well as wood and artificial materials through contact with water, atmospheric gases, and biological organisms or breakdown of intact rock and rock masses due to physical and chemical processes under the influence of atmospheric and hydrospheric factors (Hack, 2006) and this implies decay and change in state from an original condition to a new one.the research on weathering damage of stone cultural relics mainly focuses on several universal rocks such as marble rocks, granite rocks, limestones, sandstones, etc. The factors affecting weathering mainly focus on factors in geological history, and the study of modern factors such as acid rain corrosion is not in depth enough. For tuff, such as local special rocks [29]. There is not much research. Therefore, the research on the weathering damage mechanism of tuff rock cultural relics proposed in this paper is of practical and historical significance, and can provide a scientific basis and theoretical basis for the subsequent development, restoration and protection materials for the protection of tuff rock cultural relics.

V. PHYSICAL OR MECHANICAL WEATHERING

Physical or mechanical weathering is the disintegration of a rock material into smaller pieces without any change in the original property of the rock. The main causes of this results is from temperature and the pressure changes. The main mechanisms for this type of weathering are wedging, exfoliation and abrasion. Exfoliation occurs when rock layers break apart due to the removal of confining pressure such as when the slopes are excavated or eroded (Gamon, 1983). Abrasion is the physical grinding of rock fragments either by action of water or air. Several mechanical weathering processes, such as salt weathering involve the growth of a solid substance along the confining space of a pore exerting tensile stress along the pore walls and which exceeds the tensile strength of the pore leading to splitting and eventual disintegration of the rocks

VI. CHARACTERISTICS OF ROCK AND MINERAL COMPOSITION

Most minerals can be characterized and classified by their unique physical properties. Properties that help the geologists to identify a mineral in a rock which are the color, hardness, luster, crystal forms, density, and cleavage [30]. Crystal form, cleavage, and hardness are determined primarily by the crystal structure at the atomic level. Color and density are determined primarily by the chemical composition. Most rocks are composed of minerals. Minerals are defined by geologists as naturally occurring inorganic solids that have a crystalline structure and a distinct chemical composition. Of course, the minerals found in the Earth's rocks are produced by a variety of different arrangements of chemical elements.

VII. MATERIAL AND METHODS

A number of methods have been used to quantify the changes in mineralogical, chemical and engineering properties of rocks (Ramana and Gogte 1982; Hodder 1984; Martin 1986; Guolin and Yushan 1990; Hodder and Hetherington 1991; Esaki and Jiang 1999; Irfan 1999; Ng and others 2001). The methods include chemical analysis, X-ray diffraction (XRD) analysis, optical microscopy, scanning and transmission electron microscopy (SEM, TEM), electron diffraction (ED), infrared spectroscopy (IS), differential scanning calorimetry (DSC) and tests for assessing the index properties of rocks. The research methods that have been used from several previous studies and research are by conducting field investigations and laboratory tests. And this field investigation aims to obtain geological and topographic data of the research location and also obtain samples of material to be tested in the laboratory. The laboratory test aims to determine the characteristics of the material samples according to the purpose of the study.

A. Geotechnical and Geomechanical Laboratory Test of Rock and Soil Materials

Tuff, a relatively soft, porous rock that is usually formed by the compaction and cementation of volcanic ash or dust. (The Italian term tufa is sometimes restricted to the soft, porous, sedimentary rock formed by the chemical deposition of calcite, or calcium carbonate, or silica from water as sinter.) Index properties tests include moisture content, volume weight, specific gravity, Atterberg Limits (liquid limit, plastic limit and shrinkage limit), and soil particle size distribution. Consolidation and shear strength tests include consolidation test with a consolidometer or odometer, shear strength test with Direct Shear Test, Triaxial Test, and Unconfined Compression Strength Test.

B. Weathering Effects on the Geotechnical Properties of Intact rock

Various rock types respond to weathering in various ways. For volcanic rocks, the reaction of water itself converts the volcanic glass into clay and this causes volumetric changes that would further promote physical and mechanical changes in the inter granular structures (Yokota & Iwamatsu, 1999). Volcaniclastic rocks may generally behave like conglomerates with the matrix materials sometimes it will behaving as sand stones. Chigira and Sone (1991) studied the weathering profile of young sand stones and conglomerates and identified weathering zones of oxidation to dissolution through depth. The mechanical properties of the rock mass vary systematically with the change of the weathering zone. Gupta & Rao (2000) presented studies showing that in granites, the loss of strength from fresh to moderately weathered rocks reach about 80%. For claystones, the tensile strength observed in fresh rocks is decreased by 75% in slightly weathered rocks because of the increase in micro fractures. Results of petrographic analyses suggest that microfractures, pores and voids are the dominant factors that govern the strength of fresh rocks and not the mineralogy itself. Gurocak & Kilic (2005) studied the weathering effects on the properties of Miocene basalts in Turkey classified using ISRM weathering classification. Their results showed that UCS derived from Schmidt hammer tests, the compressive wave velocity and unit weight decrease while porosity and water absorption increase with increasing degree of weathering.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue IV Apr 2022- Available at www.ijraset.com

VIII. MICROSCOPIC STRUCTURE AND MINERAL CONTENT TEST

X-Ray Diffraction Method (XRD), Scanning Electron Microscope and Energy-Dispersive X-Ray Spectroscopy (SEM EDS), Mass Spectrometry (MS) or Inductively coupled plasma Mass spectrometry (ICP-MS), X-Ray Fluorescence (XRF). However, not all laboratory testing methods can be use in this research. The selection of these methods is adjusted to the need to obtain the required material data. Therefore, in order to obtain the basic physicomechanical characteristics of tuff rock ultrasonic testing, X-ray diffraction (XRD), microscopic observation, uniaxial compression test, and scanning electron microscope tests would be carried out. The specific testing flow is depicted in Figure 2

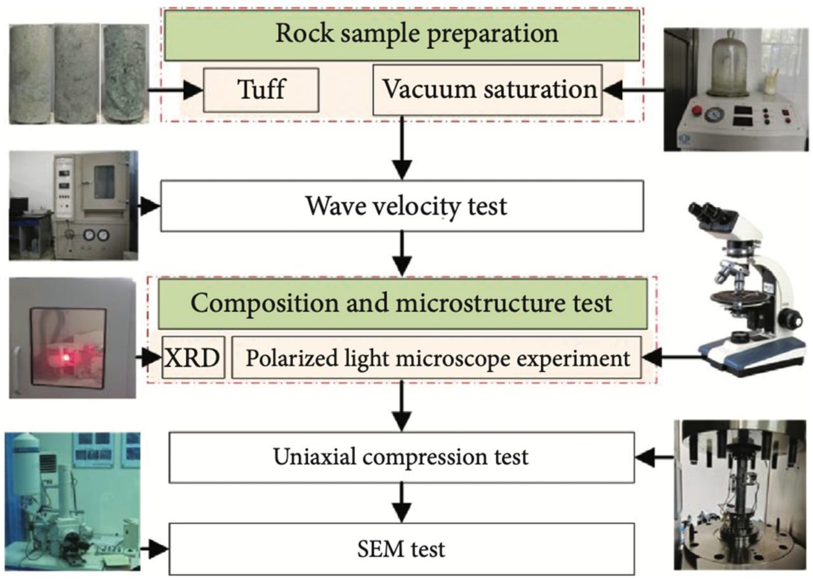

Figure 2: Experimental flowchart.

IX. METHODS OF ANALYSES USED BY SIETRONICS

Four suites of samples received were examined using ×-ray diffraction, thin section microscopy and x-ray fluorescence spectroscopy. X-ray diffraction scans were collected using the following instrumental conditions: (1) Cu K alpha radiation (2) 45 kV 35mA tube power 1% minute scan speed. X-ray fluorescence analyses were carried out on a Siemens SRS 300 x-ray spectrometer using an Rh anode x-ray tube, with other parameters set to optimize the particular element being measured. Major silicate element analyses were carried out on fused discs. The method used closely followed that of Nourish and Hutton where the fusion mix contains lanthanum oxide as a heavy absorb. Water was measured gravi metrically and carbon dioxide was analyse using a CO, analyser (LECO).

X. SAMPLE PREPARATION

A. Crushing

Samples were dried at air temperature. Crushing was carried out using Rock labs swing mill. All sample were crushed under similar conditions in order to ensure grain size etc.

B. X-Ray Diffraction.

X-ray Powder Diffraction (XRPD) is a versatile technique that can be used to identify any crystalline substances, such as most minerals. It can also be used to quantify the proportions of different minerals or indeed many other substances when they are present in a mixture. Unoriented powder mounts of the total sample were prepared for bulk mineralogy. Oriented sedimented mounts were made for examination of clay minerals (<2 micron fraction). These were obtained by suspension methods and air drying of the solution onto a glass slide. Scans were run of the clay untreated, and after heating to 15°C for 30 mins several scans. were made after glycolation to check for the presence of smectities (negative result in all cases)

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue IV Apr 2022- Available at www.ijraset.com

XI. SUGGESTIONS AND MEASURES

A. Improving Policy and Disaster Prevention Technology

There should be an emergency plans for the prevention and mitigation of cultural relic buildings affected by wind disasters throw scientific development, at the same time in the other hand, a law should be introduce on the prevention and mitigation of cultural relic buildings, cave affected by wind disasters. expanding the research and update of the disaster prevention and mitigation technology of cultural relics buildings and cave under the influence of wind disasters, so as to ensure that methods aren't out of step.

B. Establishing Disaster Preventive Protection Mechanism

They need to be sorting out and analyzing the disaster information by monitoring identifying and recognizing the causes and mechanisms of disasters, assessing disaster risks, They need to create a regional wind disaster map to protect damage assessment and disposal measures. By monitoring and by deepened the research on the cultural relics disaster prevention and mitigation technology. The special emergency and disaster relief team should be established to deal with damage in different levels , and rescue protection and temporary reinforcement maintenance measures should be formulated to reduce the damage degree of cultural relics after the disaster, as well as to reduce the risk of subsequent disaster of cultural relics (Fig.3).

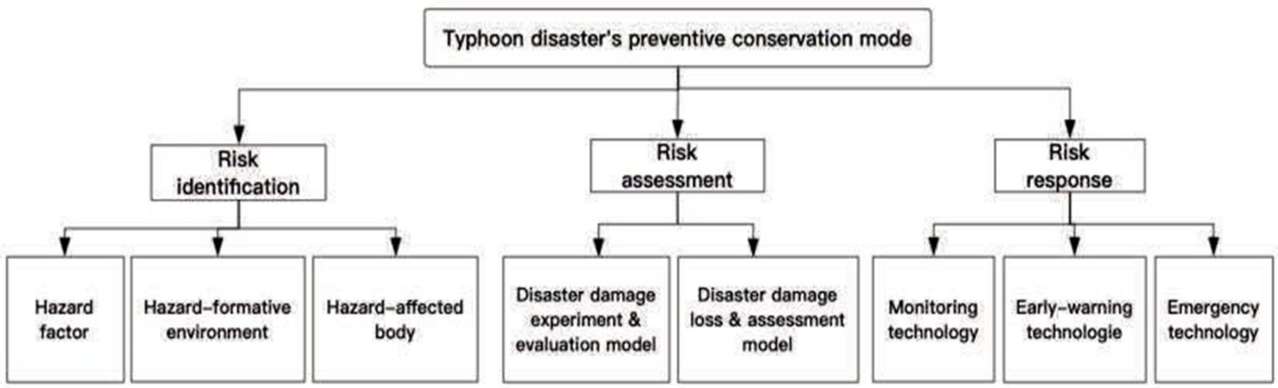

Fig.3 Preventive Protection Mechanism Map

C. Protection Management and Public Participation

Carrying out plans for their renovation and protection. Through the establishment of a daily inspection mechanism, monitoring the renovation and protection of cultural relics in real time. Carrying out daily maintenance training, and coordinating the management of cultural relics and their surrounding environment.

XII. CONCLUDING

In the above, a comprehensive summary of the data, analyses and findings has been presented on the mechanics of the relics of the rock caverns. These information that we gathered, analyses and findings have demonstrated that this relics are very important and valuable to our culture, engineering and science. They have expand and enriched our experience and knowledge on the long term stability and integrity of man made underground rock cavern engineering projects. Long term protection and preservation of the large rock cavern relics are of the national and international interests because is very significant. However,Many large and elegant rock caverns are in danger of entire collapse in the near future. It would be a tragedy if such entire collapse happens to the relics. We urge here to investigate with effective measures to preserve the relics from cracking and collapsing.

Non renew ability and frangibility are two remarkable characteristics of cultural relic buildings. From the case of caves which response to typhoon disaster, we believe that the national administration departments should firstly formulate a specific legal system of cultural relics disaster prevention and mitigation, and strengthen the research and update of cultural relics disaster prevention and mitigation technology under the influence of wind, Natural weathering like air pollution since industrialization, acid rain erosion and many different degrees of artificial damager, disasters, all departments should also actively establish the preventive protection mechanism of cultural relic buildings, starting from the three stages of pre disaster, in-disaster and post-disaster, so as to reduce the damage degree of cultural relics after the disaster and the subsequent risk of disaster.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
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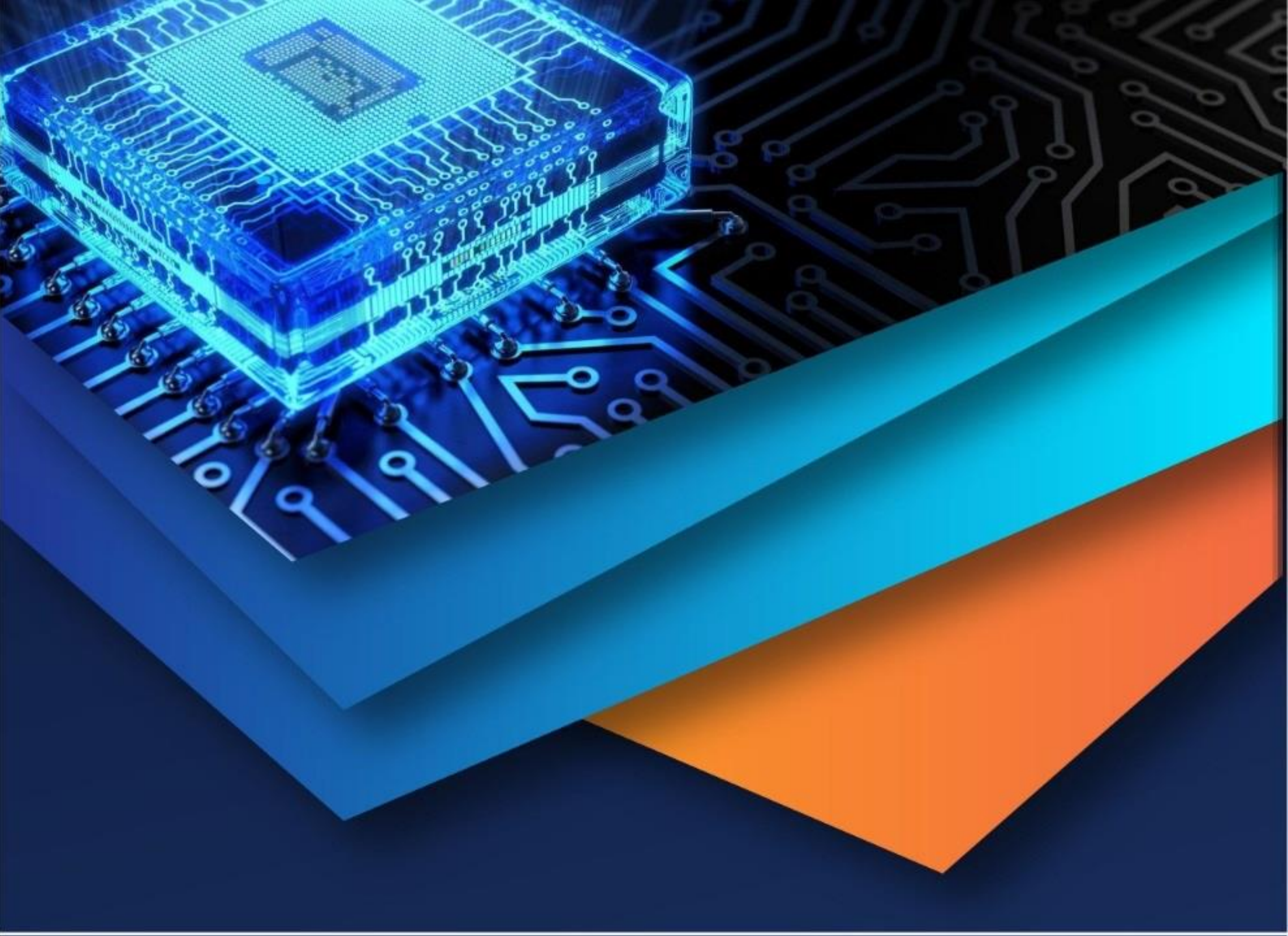

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