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Use of Waste Tyre in Concrete

Nupur Dewangan[1], Srijan Gopal[2], Faiz Ali[3], Anmol Bansal[4], Naveen Mahilang[5]
Civil-Engineering, Chhattisgarh Swami Vivekananda Technical University, Bhilai (C.G.), India

Abstract: Waste tyre rubber disposal has become a major environmental concern in all parts of the world, posing a serious threat to the environment. One potential application for scrap tyre rubber is to mix it into concrete to replace some of the natural material. Every year, an estimated 1000 million tyres reach the end of their useful lives, with another 5000 million predicted to be thrown on a regular basis by 2030. Currently, only a small portion is recycled, and millions of tyres are just stacked, landfilled, or buried. This not only reduces pollution caused by waste tyres, but it also reduces the usage of conventional aggregate, which is limited in supply.As per the mix design specifications, the rubber pieces (rubber aggregate) were sieved through a 25 mm sieve and held at a 20 mm sieve before being added to the concrete mix at 3.5,5.5,7.5 percent by weight of the aggregate.

This study investigates the beneficial impact of waste tyre rubber particles on several concrete characteristics. The used rubber scraps are obtained through the mechanical trituration of used tyres from automobiles and trucks. They have long been researched for resource reutilization as an aggregate in concrete, resulting in the 'Rubcrete mix,' which may be easily used in a variety of applications with promising results. Rubcrete produces a finished product with good mechanical qualities and also represents an efficient and cost-effective method of recycling waste tyres. The purpose of this paper is to report the findings of an experimental examination into the ideal types and quantities of aggregates in concrete mixtures for engineering purposes. The following parameters were investigated: density of rubber aggregates, workability, air entrapment, and compressive strength. In rubberized concrete mixtures, three types of rubber particles (ash rubber, crumb rubber, and tyre) were utilised to partially or totally replace natural aggregates.

Keywords: Concrete, aggregates, waste tyre, sand.

I. INTRODUCTION

Vehicle tyres disposed of in landfills are an important component of solid waste. Stockpiled tyres can pose several health, environmental, and economic problems due to pollution of the air, water, and soil. Because of their unique shape and impermeable nature, tyres store water for an extended period of time, creating a breeding home for mosquitoes and other pests. Tyre burning, which was the most convenient and cost- effective form of disposal, creates major fire concerns. Once ignited, it is extremely difficult to extinguish due to the 75% empty space that can retain a large amount of free oxygen. Furthermore, the residual powder left over from burning pollutes the land. The oil produced by the melting of tyres can potentially damage land and water. Every year, an estimated 1000 million tyres reach the end of their serviceable life. Currently, large amounts of tyres are stacked (whole tyre) or landfilled (shredded tyre), 3000 million within the EU and 1000 million in the US. The quantity of tyres from motor vehicles is expected to exceed 1200 million by 2030, meaning about 5000 million tyres to be disposed on a daily basis. Tyre landfilling poses a severe environmental risk. Waste tyre disposal locations primarily contribute to biodiversity loss; also, tyres contain hazardous and soluble components. Second, despite the fact that discarded tyres are difficult to ignite, this risk is always present.

When tyres begin to burn down owing to an unintentional reason, high temperatures occur and hazardous gases are produced; also, high temperatures lead tyres to melt, generating oil that contaminates land and water. According to preliminary research, tyre waste concrete is especially recommended for concrete constructions located in seismically active areas, as well as for applications subjected to strong dynamic motions, such as railway sleepers. This material is also suitable for non-load-bearing applications such as noise reduction barriers. Investigations on rubber waste concrete reveal that the performance of the concrete is highly dependent on the waste aggregates. Even if the compressive strength of the crumb tyres is lowered, it can meet the strength requirements of light weight concrete. The addition of crumb rubber to the mixture has only a little influence on the workability of the mixtures. Rubberized concrete mixtures have lower unit weights and better workability than ordinary concrete. The findings of compressive and flexural testing revealed a greater drop in mechanical characteristics of rubcrete when coarse aggregate was used instead of fine aggregate.

II. LITERATURE REVIEW

M.A. Aiello, F. Leuzzi Department of Innovation Engineering, University of Salento, via Monteroni, 73100 Lecce, Italy Accepted 3 February 2010, Available online 5 March 2010. The main objective of this paper is to investigate the properties of various concrete mixtures at fresh and hardened state, obtained bya partial substitution of coarse and fine aggregate with different volume percentages of waste tyres rubber particles, having the same dimensions of the replaced aggregate. Workability, unit weight, compressive and flexural strength and post-cracking behaviour were evaluated and a comparison of the results for the different rubcrete mixtures were proposed in order to define the better mix proportions in terms of mechanical properties of the rubberized concrete.

Results showed in this paper were also compared to data reported in literature. Moreover, a preliminary geometrical, physical and mechanical characterization on scrap tyre rubber shreds was made. The rubberized concrete mixtures showed lower unit weight compared to plain concrete and good workability. The results of compressive and flexural tests indicated a larger reduction of mechanical properties of rubcrete when replacing coarse aggregate rather than fine aggregate. On the other hand, the post-cracking behaviour of rubberized concrete was positively affected by the substitution of coarse aggregate with rubber shreds, showing a good energy absorption and ductility indexes in the range observed for fibrous concrete, as suggested by standard (ASTM C1018-97, 1997).

A. Sofi Department of Structural and Geotechnical Engineering, School of Civil and Chemical Engineering, VIT University, Vellore 632014, India Received 25 February 2016, Revised 29 September 2016, Accepted 30 August 2017, Available online 21 October 2017, Version of Record 28 December 2018.Disposal of waste tyre rubber has become a major environmental issue in all parts of the worldrepresenting a very serious threat to the ecology. One of the possible solutions for the use of scrap tyre rubber is to incorporate it into concrete, to replace some of the natural aggregate. An estimated 1000million tyres reach the end of their useful lives every year and 5000 millions more are expected to bediscarded in a regular basis by the year 2030. Up to now a small part is recycled and millions of tyres arejust stockpiled, landfilled or buried. The volume of polymeric wastes like tyre rubber and polyethyleneterephthalate bottles (PET) is increasing at a fast rate. This paper reviews the tests performed to determinethe compressive strength, flexural tensile strength, water absorption and water penetration of using rubbertyre waste concrete samples. Scanning Electron Microscopy (SEM) images were also presented in thispaper. It was observed that the compressive strength, flexural tensile strength and depth of waterpenetration of the rubberized concrete were less than that of the control mix, while the abrasion resistance and water absorption (up to 10% substitution) exhibited better results than that of the control mix concrete.

This paper also reviews the performance of concrete mixtures incorporating 5%, 7.5% and 10% of discarded tyre rubber as aggregate and cement replacements. Numerous projects have been conducted onreplacement of aggregates by crumb rubbers but scarce data are found on cementitious filler addition.Hence to examine characteristics of tyre crumb-containing concrete, two sets of concrete specimens weremade. In the first set, different percentages by weight of chipped rubber were replaced for coarse aggregates and in the second set scrap-tyre powder was replaced for cement. Selected standard durabilityand mechanical test were performed and the results were analysed.

Haolin Su, Jian Yang, Tung-Chai Ling , Gurmel S. Ghataora , Samir Dirar School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai 200240, PR China, School of Civil Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom Received 11 August 2014, Revised 29 November 2014, Accepted 4 December 2014, Available online 13 December 2014. Investigations and research into the recent use of rubber particles in concrete has been well documented. However, information on the rubber particle sizes or their distributions within concrete which may also influence the concrete properties is still limited. In this study, three groups of singly-sized rubber particle samples (3 mm, 0.5 mm and 0.3 mm) and one sample of continuous size grading (prepared by blending the three singly-sized samples to form the same particle distribution curve of sand) were used to replace 20% of the natural fine aggregate by volume. The reference concrete containing 100% sand was also prepared to compare its properties with those of the samples in terms of workability, fresh density, compressive strength, tensile splitting strength, flexural strength and water permeability. The experimental results demonstrated that the rubber particle size affects the concrete's workability and water permeability to a greater extent than the fresh density and strength. Concrete with rubber particles of larger size tends to have a higher workability and fresh density than that with smaller particle sizes. However, the rubber aggregates with smaller or continuously graded particle sizes are shown to have higher strengths and lowerwater permeability.

Cairns, R.A. and Kew, H.Y. and Kenny, M.J.; Limbachiya, Mukesh and Roberts, John, eds. (2004) Theuse of recycled rubber tyres in concrete construction. In: Sustainable Waste Management and Recycling. Thomas Telford Ltd., London, pp. 135-142. ISBN. The growing problem of waste tyre disposal in the UK can be alleviated if new recycling routes can be found for the surplus tyres. One of the largest potential routes is in construction, but usage of waste tyres in civil engineering is currently very low. This study investigates the potential of incorporating recycled rubber tyre chips into Ordinary Portland Cement (OPC) concrete. This report presents the workability, strength and durability properties of concrete incorporating rubber tyre chips as a partial replacement for the coarse aggregate in the concrete. Plain rubber aggregate and rubber aggregate coated with cement paste were used. The results showed that concrete incorporating rubber aggregate has lower workability and unit weight and exhibited a notable reduction in compressive strength. However, the rubberised concrete did not exhibit a typical failure mode of plain concrete and a beneficial effect on flexural strength was observed.

Kudzai Mushunje, Mike Otieno and Yunus Ballim 1. University of the Witwatersrand, School of Environmental and Civil Engineering, Johannesburg, South Africa 2. Sol Plaatjie University, Kimberly, South Africa The current global waste tyre generation far exceeds its consumption in terms of recycling and re-use. The traditional recycling and re-use methods like thermal incineration have proven ineffective, costly and in some cases environmentally unsustainable. Particularly, in developing countries where some of the sophisticated techniques required to process tyres to allow them to be utilised are either too costly orhave not yet been developed. The situation has resulted in accumulation of large waste tyre stockpiles that pose health and safety risks. To combat the problem, the use of waste tyre rubber in concrete construction has been proposed. Several studies have been conducted to assess the effects of the inclusion of waste tyre rubber in its different forms (fibres, particles), for concrete production and the results are promising. Although there are some apparent demerits to the inclusion of tyre rubber in concrete, the potential benefits seem to overshadow the negatives. This paper reviews published research on the scientific and technical viability of using waste tyre rubber in concrete production. It discusses the production and properties of waste tyre particles. It highlights advances made with regards to the incorporation of tyre rubber material in concrete, focusing on the engineering properties of the tyre rubber modified concrete. Inconclusion, recommendations for future research and possible application for the material will be discussed.

N. Oikonomou, S. Mavridou Aristotle University of Thessaloniki, Greece Available online 27 March 2014. Scrap tyres are being generated and accumulated in large volumes causing an increasing threat to the environment. In order to eliminate the negative effect of these depositions and in terms of sustainable development there is great interest in the recycling of these non-hazardous solid wastes.The potential of using rubber from worn tyres in many civil engineering works has been studied for more than 30 years. Applications where tyres can be used and where the addition of tyre rubber has proven to be effective in protecting the environment and conserving natural resources include the production of cement mixtures, road construction and geotechnical works. Recycling of tyres in the applications mentioned above represents a suitable means of disposal for both environmental and economic reasons.

Marijana Serdar Faculty of Civil Engineering, University of Zagreb. Paper presents the effect of products obtained during recycling of waste tyres on properties of concrete. Only by taking into account specific properties of each product obtained by recycling, it is possible to apply them in concrete industry for preparation of concrete products with special properties. Products incorporating waste tyres can then be ecologically, technically and economically competitive alternative to products traditionally used in engineering practice.

Dr. Manvendra Verma,Ashish Juneja, Deepanshu Saini Department of Civil Engineering, Dr. Akhilesh Das Gupta Institute of Technology and Management Delhi, India. This study determines the compressive strength performance of rubber concrete and disposal of waste tyre, which consists of 0%, 10%, 20% and 30% of the selected rubber content that is mixture of 60% crumbled and 40% powdered form. The rubber particles used in the experiments are made of the recycled tire. The rubber waste is not easy to decompose even after long period of treating in landfill. Partial replacement of rubber in fine aggregate can be a wayto utilize only where strength requirement is very low. Casting of cubes and beams with M30 design mix. The specimens were cured in water for required number of days before testing. Results were clear for reduction in strength with increase in rubber content.

III. MATERIALS USED

1) *Cement:* Cement is a fine, powdery substance that is used as a binding material in construction. It is usually made by heating limestone and other materials to a high temperature and then grinding them into a fine powder. When mixed with water, cement hardens and binds together to form a solid and durable material that is commonly used in the construction of buildings, bridges, roads, dams, and other structures. There are several types of cement, including Portland cement, which is the most commonly used type, as well as blended cements, masonry cements, and others.

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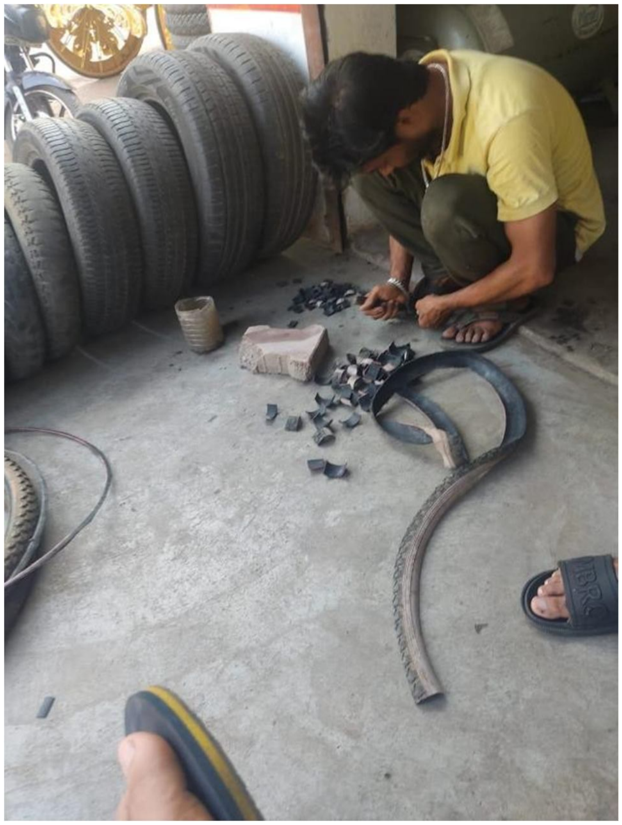
2) *Sand:* Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is a common material found in many parts of the world, typically on beaches, riverbeds, and deserts. Sand particles vary in size, ranging from 0.063 to 2 mm in diameter, and may be composed of different minerals such as quartz, feldspar, and mica. Sand is often used in construction as a key ingredientin concrete and mortar, as well as in landscaping and gardening for its ability to improve soil drainage andwater retention. It is also used for recreational purposes, such as building sandcastles, volleyball courts, and golf course bunkers.

3) *Coarse Aggregate:* Coarse aggregate is a term used in construction to describe a type of material that is typically larger than 4.75 mm (3/16 inches) in size. It is also sometimes referred to as "crushed rock" or "gravel". Coarse aggregate is made up of a variety of materials, including crushed stone, gravel, and recycled concrete. It is used in a variety of construction applications, such as in the production of concrete, asphalt, and road base, as well as in drainage systems and landscaping. In concrete production, coarse aggregate is mixed with cement and fine aggregate to create a strong and durable concrete mixture. The size and shape of the coarse aggregate can affect the strength and workability of the concrete mixture.

4) *Tyre:* A waste tyre is a discarded or used tyre that is no longer suitable for its original intended purpose, such as on a vehicle. Waste tyres are considered a type of waste or scrap material and can pose a significant environmental problem if not properly disposed of or recycled. Waste tyres can accumulate in landfills, where they can take up valuable space and also pose a potential fire hazard. They can also be illegally dumped in open spaces, causing pollution and creating health and safety hazards. However, wastetyres can also be recycled and repurposed for a variety of applications, such as fuel, road construction, civil engineering, and other industries. Recycling waste tyres can help reduce waste and conserve resources while also providing economic and environmental benefits.



IV. METHODOLOGY

A. *Sample Preparation*

Waste tyres that have been shredded into various sizes have been used as coarse aggregate alternatives. As previously stated, several trial mixes were undertaken to determine the variation in concrete qualities. In the sample, 3.5%, 5.5%, and 7.5% of the coarse aggregate was substituted by waste tyres. Steel moulds simplified the procedure of creating and removing the specimens. Concrete glueing was avoided by lubricating the interior surface of the moulds. After 24 hours, the specimens were removed from the moulds. Mould specimens were kept in normal air for 24 hours before curing, and then each specimen was immersed completely in water for 7 days and 28 days to cure.

B. *Strength of Concrete.*

Mixing Concrete - In order to prevent the loss of water or other components, the concrete should be mixed by hand or in a laboratory batch mixer. To ensure there is enough concrete, each batch should have around 10% excess after moulding the necessary test specimens. The mixing process should take place on a watertight and non-absorbent platform using equipment like a trowel or shovel. Firstly, the cement and fine aggregate must be blended together until they are thoroughly mixed and uniform in color. Upon completion of the mixture of cement and fine aggregate, the coarse aggregate will be incorporated and blended until uniformly distributed throughout the batch. After this, water will be added to the mixture, and a thorough mixing will commence until a homogeneous concrete with desired consistency is achieved. In cases where additional mixing is required due to gradual addition of water in order to modify its consistency, discontinuing midway for trial consistency tests is not advised.

1) *Size of Test Specimens:* Test specimens to be used in the study must have a cube mould of dimension exactly 15 x 15 x 15 cm. Alternatively, if the size of the aggregate does not exceed 2cm, cylindrical test specimens with a length twice its diameter can be used. Tyres of size and dimension similar to the coarse aggregate and should be passed by 25mm and retained on 20mm, with coarse sand passing from 1.18 mm sieve.

a) *Cube Moulds:* This passage describes the requirements and specifications for constructing a cube mould and a tamping bar for use in the preparation of concrete cubes. The cube mould is made of metal, preferably steel or cast iron, and is designed to be sturdy and prevent distortion. The mould is also constructed in a way that allows for the easy removal of the moulded specimen without causing any damage. When assembling the mould, care is taken to ensure that the dimensions and internal faces are accurate within specific limits. The mould is designed with a metal base plate that is attached to the mould with springs or screws to prevent leakage during filling. Suitable methods are provided to ensure that the parts of the mould are positively and rigidly held together during the filling process and subsequent handling of the filled mould. To prevent adhesion of the concrete, the interior surfaces of the mould are thinly coated with mould oil. Similarly, the joints between the sections of mould and the contact surfaces of the bottom of the mould and the base plate are coated with mould oil to ensure that no water escapes during filling.

b) *Tamping Bar:* The tamping bar, on the other hand, is a steel bar that is 16 mm in diameter and 0.6 m long. It is bullet pointed at the lower end and is used to compact the concrete in the mould to remove any air pockets and ensure that the concrete is evenly distributed.

2) *Compaction:* To ensure accurate results, the test specimens need to be fully compacted without any segregation or excessive laitance. The concrete is filled into the mould in layers of about 5 cm deep, and each layer is evenly distributed within the mould. The concrete is then compacted either by hand or by vibration. When compacting by hand, a standard tamping bar is used, and the number of strokes per layer required to produce specified conditions will vary depending on the type of concrete. For cubical specimens, the concrete should not be subjected to less than 35 strokes per layer for 15 cm cubes or 25 strokes per layer for 10 cm cubes. The strokes need to penetrate into the underlying layer, and the bottom layer shall be rodded throughout its depth. If any voids are left by the tamping bar, the sides of the mould shall be tapped to close them.

3) *Compacting by Vibration:* This method is best for the compaction of the concrete. When compacting by vibration, each layer is vibrated by means of an electric or pneumatic hammer or vibrator or by means of a suitable vibrating table until the specified condition is attained. After the top layer has been compacted,the surface of the concrete shall be finished level with the top of the mould, using a trowel, and covered with a glass or metal plate to prevent evaporation.

4) *Curing:* To cure the test specimen, it needs to be kept in a place that is free from vibrations. It should be stored in moist air that has a relative humidity of at least 90% and at a temperature of 27° ± 2°C for 24 hours ± l hour after adding water to the dry ingredients. Once the 24-hour period is over, the specimens should be marked and removed from the moulds. If they are not required for testing within the next 24 hours, they should be immediately submerged in clean, fresh water or saturated lime solution and kept there until just prior to testing. The water or solution in which the specimens are submerged should be renewed every seven days and maintained at a temperature of 27° ± 2°C. It's important to make sure that the specimens never become dry until they are tested. The cubes made should be of 2 quantity for each required test because of the different proportions of mixing, In this case, coarse aggregate by waste tyre rubber (3.5, 5.5 & 7.5).

C. Testing

1) *Compressive Strength Test:* To conduct the compressive test, the concrete specimen was carefully taken out of the water after a set amount of time, and any excess water on its surface was wiped off. The weight of each concrete block was recorded before the test began. To ensure accurate results, the machine's bearing surface was cleaned before the test started. The specimen was placed at the center of the base plateof the testing apparatus, and the opposite sides of the cube were loaded. The upper section of the machine was then turned until it made contact only with the top surface of the specimen. Following the ASTM guidelines, the load was applied at a rate of 8 to 21 mega Pascals per minute. The load was gradually increased until the specimen failed. The failed load was noted, and the failure pattern was thoroughly examined to understand the characteristics of the concrete under compression. Overall, the compressive test provided valuable insights into the strength and durability of the concrete specimen being tested.

The procedure for compressive strength test of concrete involves the following steps:

a) *Preparation of Specimen:* The concrete sample is prepared by filling a cube-shaped mould with freshlymixed concrete, which is then compacted and cured for a specific period of time.
b) *Removal from Mould:* After the curing period, the specimen is removed from the mould and anyexcess water on the surface is wiped away.
c) *Weighing the Specimen:* The weight of the specimen is measured before the test.
d) *Cleaning the Bearing Surface:* The bearing surface of the compression testing machine is cleanedbefore inserting the specimen.
e) *Placing the Specimen:* The specimen is placed on the centre of the base plate of the compressiontesting machine.
f) *Loading the Specimen:* The opposite sides of the cube are loaded, and the moveable upper section ofthe machine is turned to make contact with the top surface of the specimen.
g) *Applying the Load:* The load application rate is set according to the ASTM guidelines, typically 8- 21MPa/min, and the load is gradually increased until the specimen fails.
h) *Recording the Results:* The failed load is noted, and the failure pattern is examined thoroughly.

The result of the compressive strength test of concrete is expressed in terms of the maximum load the specimen can bear per unit area, typically in MPa or psi.

Fig. 1 Compressive Strength Test of Cube

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2) *Tensile Strength Test:* The tensile strength test is crucial for understanding how concrete performs under tension as it is brittle in nature and prone to cracking. To perform this test, it is important to ensure that the tensile limit of the concrete is well understood. To ensure accuracy, diametrical lines were drawn to guarantee that the specimen was on the same axial axis. One steel rod was placed on the lower plate of the testing device, and the cube specimen was placed on it. The diametrical lines were aligned vertically to ensure the accurate positioning of the concrete specimen. The cube was then placed in the centre of the bottom plate, and another steel rod was placed on top of it. The load was then applied repeatedly and gradually until the specimen failed. The point at which the specimen failed was considered the breaking point of the load. Overall, the tensile strength test provided valuable information on how concrete behaves under tension and helped to identify potential weaknesses in the material.

Fig. 2 Compressive Strength of Cylinder

Fig. 3 A split Tensile Test

Fig.4 Partial Replacement of aggregates with tyre

Fig.5 Rubberized Concrete cube cast

D. References

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V. CONCLUSIONS

1) Even if rubber tyre aggregate was utilised at low percentages in concrete, the amount of waste tyre rubber could be considerably decreased due to the extremely huge global market for concrete products. It is still possible to employ tyre rubber in concrete since, while there is a drop in strength, our environment will be protected due to waste rubber utilisation.
2) When compared to the same concrete without rubber particles, rubber tyre particles lowered the slump values. Such concretes are extremely beneficial in applications requiring minimal workability, such as roads and dams.
3) When specimens were loaded in compression, tyre rubber concrete did not fail brittle. Rubber tyre particles act as particle bridges in concrete, increasing ductility. Because of their ability to withstand severe tensile deformations, rubber particles act as springs, delaying fracture widening and avoiding complete disintegration of the concrete mass. Rubberized concrete outperforms normal concrete in applications requiring vibration dampening, such as earthquake shock-wave absorbers, foundation pads for machinery, and railway stations.
4) By replacing aggregates with rubber tyre particles, the density of concrete has been lowered. The general density reduction was expected because to the lower specific gravity of the rubber aggregates compared to natural aggregates. Density reduction can be a desirable quality in a variety of applications, including architectural applications such as nailing concrete, false facades, stone backing, and interior construction, as well as precast concrete, light weight hollow and solid blocks, slabs, and so on. Density is reduced by 3.75 percent with 5% replacement.
5) When compared to ordinary concrete, the use of rubber tyre particles reduces compressive strength at an early stage.
6) Non-load bearing applications for tyre rubber concrete include noise reduction barriers.
7) The addition of scrap tyres to rubber aggregate changes the surface layer's elasticity.
8) In the hot temperature range, permanent deformation and thermal cracking are reduced.
9) Certain quantities of conventional stone aggregate can be conserved.

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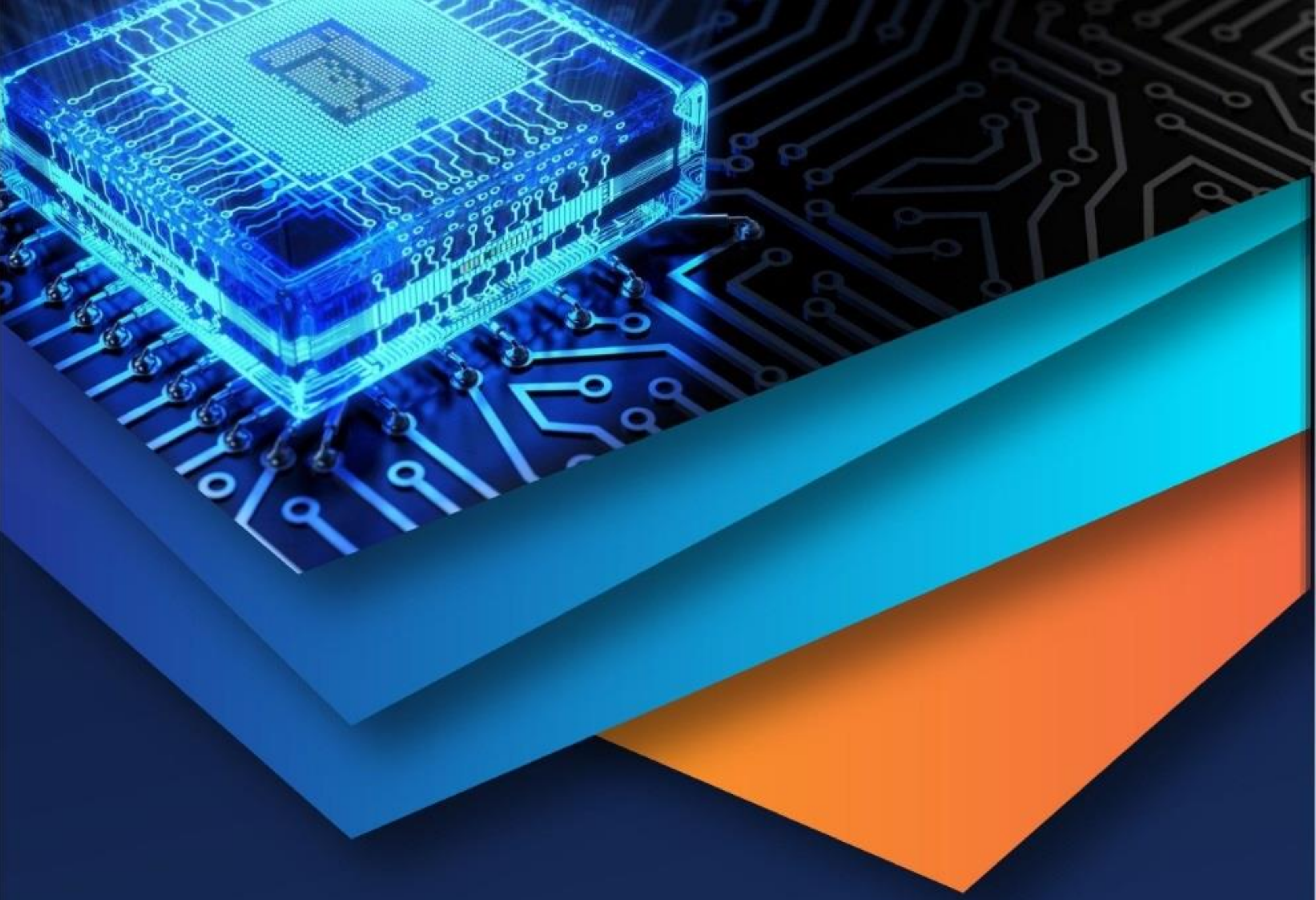

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