
RAMIFICATION OF MECHANICAL PROPERTIES IN REJOINDER OF CRUMB RUBBER WITH FINE AGGREGATE

Fayaz Khan A.^a, Dr. V. Johnpaul^b, Saranya K.^c, Dr. N. Balasundaram.^d

a. Student, Civil engineering, Karpagam Academy of Higher Education Coimbatore, Tamilnadu, India

b. Assistant professor, Civil engineering, Karpagam Academy of Higher Education Coimbatore, Tamilnadu, India

c. Assistant professor, Civil engineering, Sri Ramakrishna Engineering College, Tamilnadu, India

d. Head of Department, Civil engineering, Karpagam Academy of Higher Education Coimbatore, Tamilnadu, India

Abstract: environmental problem of discarded waste tires. Using recycled rubber as a partial replacement for fine aggregate in self-compacting concrete is an innovative approach to both reduce waste and improve material properties. Interesting to note that the addition of crumb rubber has different effects on compressive strength and flexural strength. The decrease in compressive strength may be due to the fact that rubber is less dense than concrete, and may not provide as much structural support. However, the increase in flexural strength suggests that the rubber particles can help to reinforce the concrete and prevent cracking under bending stresses. Further research could explore the long-term durability and performance of self-compacting concrete with crumb rubber, as well as the potential economic and environmental benefits of using this material in construction applications. This is a promising avenue for sustainable engineering and could contribute to a more circular economy.

Keywords: *Self-Compacting Concrete; Recycled/Crumb rubber; Compressive Strength; Flexural Strength*

I. INTRODUCTION

The objective of this experiment is to investigate the feasibility of incorporating waste rubber tires into concrete by substituting varying amounts of fine aggregates with waste tire rubber. The incorporation of waste rubber tires in concrete not only contributes to environmental conservation but also aids in the conservation of natural aggregates. The disposal of waste materials is a prevalent global issue, and waste tires pose a significant challenge due to their non-biodegradable nature. Typically, waste rubber is utilized as a fuel source or a raw material for rubber-based products. Concrete is the most commonly used material in construction, and its widespread use has led to a reduction in natural aggregates. Various techniques have been proposed for the utilization of waste tires, including using waste tire crumbs in concrete as a partial or full replacement for fine or coarse aggregates. However, limited research has been done on the use of waste rubber tires in concrete. The disposal of worn out automobile tires is a major environmental challenge faced by municipalities around the world. To address this global problem, several studies have been conducted to examine various applications of tire rubber (crumb rubber). Civil engineers are searching for new alternative materials that are both cost-effective and conserve scarce natural resources such as sand and aggregate.

The construction industry is increasingly focusing on researching and developing alternative materials for the production of concrete. The depletion of conventional aggregates, along with the requirement for lightweight materials, has led researchers to explore the use of various new materials such as blast furnace slag, fly ash, silica fumes, waste glasses, plastic strips, scrap tyre, among others. These materials can substitute aggregates, reduce costs, and also provide specific properties that are advantageous for concrete.

In India, the large-scale use of these materials is not yet widespread due to the lack of conclusive evidence and information. However, recent studies have shown that if scrap tyres are reused as a construction material instead of being burnt as fuel for cement kilns, the unique properties of tyres can be exploited in a beneficial manner.

One such study investigated the use of crumb rubber as a replacement for fine aggregates in M25 grade concrete. The study found that as the percentage of rubber content increased, there was a decrease in compressive strength compared to the nominal mix. The percentage replacement of fine aggregate with crumb rubber was 50% and 70%.

The use of alternative materials in concrete manufacturing has the potential to save costs, reduce waste, and improve the properties of concrete. However, more research is needed to fully understand the effects of these materials on the mechanical properties of concrete and to develop guidelines for their use in construction.

Ground Rubber Ground rubber is produced by using granulators, hammer mills, or other types of mechanical grinders. The rubber is typically ground to a particle size of 10 mesh or smaller, which is equivalent to a particle size of 2 mm or less.

Crumb Rubber Crumb rubber is produced by further grinding or milling the ground rubber to a smaller particle size, typically to a particle size of 30 mesh or smaller (i.e., less than 0.6 mm in diameter). The crumb rubber may also be further processed to remove any steel or fiber materials that may still be present in the rubber.

In summary, scrap tires can be classified as whole tires, slit tires, shredded or chipped tires, ground rubber, and crumb rubber. The different classifications are based on the processing method used and the resulting size and shape of the tire particles.

Ground Rubber

Ground rubber may be sized to particles as big as 19 mm to as small as 0.15 mm. It depends upon the type of size reduction equipment and intended applications. Ground rubber particles are subjected to a dual cycle of magnetic separation, then screened and recovered in various sizes.

On the other hand, the micro mill process uses a combination of cryogenic freezing and mechanical grinding to produce crumb rubber particles as small as 10 microns in size. This method is commonly used to produce fine crumb rubber for high-performance applications such as asphalt rubber, sports surfaces, and molded products.

Crumb rubber has a wide range of applications in various industries. It is commonly used in the production of asphalt rubber, which is a blend of asphalt cement and crumb rubber used to create durable, long-lasting road surfaces. It is also used in the production of rubberized concrete, which is concrete mixed with crumb rubber to enhance its durability and resilience. Additionally, crumb rubber is used in the production of various molded products such as mats, flooring, and playground surfaces. It is also used in the production of sports surfaces such as running tracks, artificial turf, and tennis courts. Crumb rubber has environmental benefits as it helps in reducing waste from used tires, and it can also reduce the demand for new raw materials. It also helps in reducing the amount of rubber that is disposed of in landfills or incinerated, which can have negative environmental impacts.

III. METHODOLOGY AND EXECUTION

The objectives of the study on self-compacting concrete made with partially replaced crumb rubber are comprehensive and involve investigating various properties and behaviors of the proposed concrete mix.

The first objective aims to investigate the overall properties and behavior of self-compacting concrete when crumb rubber is used as a partial replacement for fine aggregate. This can include studying factors such as workability, density, and setting time of the concrete mix.

The second objective focuses on finding the optimal proportion of crumb rubber to fine aggregate to achieve the desired properties of the self-compacting concrete. This involves determining the appropriate ratio of crumb rubber to fine aggregate that would not compromise the overall properties and behavior of the concrete.

The third objective involves investigating the effect of partial replacement of fine aggregate with crumb rubber on the mechanical properties of the proposed self-compacting concrete. This can include testing the compressive strength, split tensile strength, and flexural strength of the concrete mix at different levels of crumb rubber replacement.

The fourth objective aims to investigate the effect of partial replacement of fine aggregate with crumb rubber on the durability properties of the self-compacting concrete. This can involve testing the resistance of the concrete mix to acid attack using dilute sulfuric acid, which can be an indicator of the durability of the concrete in harsh environments.

The objectives of comparing the proposed self-compacting concrete with conventional cement concrete and finding the optimum combination for partial replacement of fine aggregate with crumb rubber are important to determine the suitability and potential of the proposed concrete mix.

The first objective involves comparing the mechanical properties of the self-compacting concrete made with partially replaced crumb rubber with those of conventional cement concrete. This can include testing the compressive strength, split tensile strength, and flexural strength of both concrete mixes and analyzing the differences between them.

The second objective focuses on comparing the durability properties of the self-compacting concrete made with partially replaced crumb rubber with those of conventional cement concrete. This can involve testing the resistance of both concrete mixes to acid attack using dilute sulfuric acid and comparing the results.

The third objective involves finding the optimal combination of crumb rubber to fine aggregate for partial replacement to achieve maximum compressive strength, split tensile strength, flexural strength, and acid attack resistance. This can involve conducting experiments with different ratios of crumb rubber to fine aggregate and analyzing the results to determine the optimal combination for each of the mechanical and durability properties. Comparison of the proposed self-compacting concrete with conventional cement concrete and the determination of the optimal combination of crumb rubber to fine aggregate for partial replacement are important to establish the viability and effectiveness of the proposed concrete mix. The results of these objectives can provide insights into the potential of using crumb rubber as a sustainable alternative to fine aggregate in concrete production while maintaining or even improving the mechanical and durability properties of the concrete. Combination of crumb rubber and fine aggregate that can be used to obtain the maximum values of compressive strength, split tensile strength, flexural strength, and resistance to acid attack is an important step towards optimizing the use of crumb rubber in self-compacting concrete production.

The study focuses on the strength properties of self-compacting concrete with partially replaced fine aggregate by crumb rubber. The M30 concrete mix with 0% waste material is used as the control mix, and the water-cement ratio is 0.9, which is in accordance with the European Federation of National Associations Representing for Concrete (EFNARC). The fine aggregate is replaced by 50% and 70% by weight with crumb rubber. To achieve the objective, various tests can be conducted on the self-compacting concrete samples with varying combinations of crumb rubber and fine aggregate. The compressive strength, split tensile strength, flexural strength, and resistance to acid attack can be tested and analyzed for each sample.

The results can be used to determine the best combination of crumb rubber and fine aggregate that can be used to obtain the maximum values of compressive strength, split tensile strength, flexural strength, and resistance to acid attack. The findings can also provide insights into the potential of using crumb rubber as a sustainable alternative to fine aggregate in self-compacting concrete production.

The inclusion of both fresh and hardened concrete tests in the study is important to fully evaluate the behavior of the self-compacting concrete made with partially replaced crumb rubber. The slump flow and U-Box test are used to measure the workability of the concrete, which is an important property for its practical use in construction.

The hardened concrete tests, including compressive strength, split tensile strength, and flexural strength tests at different curing periods (7 days and 28 days), provide important insights into the strength properties of the concrete. These tests are commonly used in concrete research and are important indicators of the quality and durability of the concrete.

The flexural strength test is particularly important as it measures the ability of the concrete to withstand bending forces. This is especially important in construction applications where concrete may be subjected to bending or flexural stresses.

In addition to the strength properties, the study also includes durability tests such as acid attack ($\text{dil H}_2\text{SO}_4$) on the optimum mix. This test is important as it measures the ability of the concrete to resist the corrosive effects of acid exposure, which is important in environments where the concrete may be exposed to acid-based chemicals or other corrosive substances.

It is also important to study the physical properties and chemical composition of the crumb rubber used in the study as this can have an impact on the properties of the resulting concrete. Understanding how the crumb rubber interacts with the other components of the concrete can help to optimize its use and ensure that the resulting concrete meets the desired strength and durability requirements.

MATERIAL INVESTIGATION

CONCRETE

Your statement provides a good overview of the composition of concrete and its properties. However, there are a few corrections to be made in your list of materials used for concrete production. First, crumb rubber is not a commonly used material for concrete production. While it is possible to incorporate recycled rubber into concrete mixtures, this is a relatively new and uncommon practice.

Second, while water is certainly a necessary ingredient in the production of concrete, it is not typically considered a "material" in the same way that aggregates, cement, and other additives are. To provide a more accurate and comprehensive list of materials used in concrete production, here is an expanded version:

Aggregates:

- Fine aggregate (such as sand)
- Coarse aggregate (such as gravel, crushed stone, or recycled concrete)

Cement:

- Portland cement is the most commonly used type of cement in concrete production, but other types (such as blended cement or supplementary cementitious materials) may be used as well.

Admixtures:

These are materials added to the concrete mixture to modify its properties or enhance its performance. Examples include:

- Water-reducing admixtures (which can help to reduce the amount of water needed in the mixture while maintaining workability)
- Set accelerators or retarders (which can speed up or slow down the setting and hardening of the concrete)
- Air-entraining admixtures (which create tiny air bubbles in the concrete to increase its freeze-thaw resistance)
- Coloring agents (which can be used to give the concrete a specific color or appearance)

Reinforcement:

- Steel reinforcement (such as rebar) is commonly used to increase the tensile and flexural strength of concrete structures.

A. AGGREGATES

Aggregates play a crucial role in determining the properties of concrete, including its strength, durability, workability, and overall economy. They are typically classified into two categories: fine and coarse aggregates. Fine aggregates, such as sand, are usually used in the production of concrete, while coarse aggregates, such as gravel and crushed stone, provide the bulk and strength of the concrete. The quality of the aggregates used in concrete is important, as it can affect the overall quality and performance of the finished product. Aggregates must be clean, hard, strong, and free from any contaminants, such as clay, organic matter, or other deleterious substances that could compromise the integrity of the concrete. Properly selected aggregates can also reduce the amount of cement needed in the concrete mix, which can help to reduce costs and environmental impact. In addition to natural aggregates, recycled materials, such as crushed concrete,

can also be used as aggregates in concrete production, which can help to reduce waste and environmental impact. However, the quality and suitability of recycled aggregates for use in concrete can vary, and careful testing and quality control are needed to ensure their performance.

i). FINE AGGREGATE

Fine aggregate is a term used to refer to the aggregate material that passes through a 4.75mm sieve. It is an essential component in concrete mixtures, typically accounting for 35% - 45% of the total aggregate by mass or volume. Fine aggregates serve to fill the voids between coarser particles, creating a more workable concrete mix. Natural sand, silt, and clay are among the materials commonly used as fine aggregate. Silica sand is one such material that has been tested in accordance with the IS: 383-1970 standard. Overall, the quality of fine aggregate plays an important role in determining the properties and performance of the resulting concrete mixture.



Fig 3.1 Fine aggregate

Table 3.1 Properties of Fine Aggregate

TEST STANDARD	IS: 383-1970
Fine Aggregate	M Sand
Grading	4.76mm - 2.38mm : 38% 2.38mm - 1.19mm : 45% < 1.19mm : 27%
Specific gravity	2.48
Region of gradient	III
Water absorption	1.51%
Bulk density	1450 kg/m ³

ii). COARSE AGGREGATE

Coarse aggregate is an essential component of concrete and is the strongest and least porous material used. It is chemically stable and typically consists of particles greater than 4.75mm in size. In this study, machine-crushed coarse aggregates measuring 20mm in size and having an angular shape were used. The types of coarse aggregate used included crushed stone, gravel, sand, and fill. Using coarse aggregate in concrete can help to reduce drying shrinkage and other dimensional changes caused by moisture movement. The maximum size of the aggregate can impact the

strength and workability of the resulting concrete mixture and influence the water demand required to achieve a certain level of workability. Testing of coarse aggregate properties, such as specific gravity and fineness modulus, are conducted in accordance with IS: 2386-1963 recommendations. Other tests, including impact value, crushing value, elongation, and flakiness index, are performed to determine the suitability of the coarse aggregate for use in concrete.



Fig 3.2 Coarse aggregate

Table 3.2 Properties of Coarse Aggregate

TEST STANDARD	IS: 2386 - 1963
CA	Gravel, Sand, Crushed stone
Maximum dimension	12.5mm - 19mm
Grading	4.75mm – 10mm (60%) 40mm – 20mm (60%)
Specific gravity	2.74
Absorption value	0.45%

iii) CEMENT

Cement is a crucial ingredient in concrete, serving as a binder that sets and hardens to bind other materials together. Portland cement is the predominant type of cement employed in construction. Cement types can be categorized as hydraulic or non-hydraulic, depending on their capacity to set in the presence of water. Cement is a powder that can be mixed with water to form a paste, which can then be molded or poured into a solid mass. For this study, IS: 12269-1987 compliant OPC 53 grade cement was utilized and subjected to physical property testing in line with Indian Standard specifications. The cement underwent IS: 4031-1988 tests, which verified its adherence to the different specifications stipulated in IS: 12269-1987.



Fig 3.3 Cement

iv) CRUMB RUBBER

Crumb rubber refers to recycled rubber obtained from scrap tires of automobiles and trucks. The recycling process involves removing steel and fluff from the tires, leaving behind tire rubber with a granular consistency. The particles are then further processed with the help of a granulator or cracker mill, using techniques such as cryogenic or mechanical means, to reduce the size of the particles. The most common method used for mechanical grinding involves the use of cracker mills and granulators to break down the rubber shred into small particle sizes, ranging from several centimeters to fractions of a centimeter. In the process of granulation, the steel bead and wire mesh present in the tires are separated through magnetic means, while the tire fiber is segregated using sieve shakers. The most superior and scarce type of rubber granule, known as cryogenic rubber, can only be produced from approximately 4% of a ground-up tire, while the remaining 96% is reserved for ambient processing. For this research, Crumb Rubber was sourced from a Sundrapuram-based industry in Coimbatore and subjected to several tests to assess its characteristics. The physical and chemical properties of the Crumb Rubber are outlined below.



Fig 3.4 Crumb Rubber

Table 3.4 Physical Properties of Crumb Rubber

Size	9.5 mm to 0.5 mm
Specific gravity	1.10
Water absorption	0.1%

Composition	Percentage
Recoverable	71%
Steel	14%
Fiber	3%
Extraneous material	12%

v) WATER

Water plays a crucial role in the production of concrete, as it is a key ingredient in the chemical reaction of cement with water to form the hydrated product C-S-H gel. The strength of concrete is primarily dependent on the binding action of this hydrated cement paste gel. However, a higher water-binder (w/b) ratio can decrease the strength, durability, and water-tightness of concrete, as it leads to the formation of voids (capillary pores) in the hardened cement paste.

Therefore, it is essential to add only the minimum amount of water required for the chemical reaction of un-hydrated cement to occur. Ordinary water is used in concrete, as it is free from salts, acids, alkalis, and other harmful products. If the exact volume of

water is used in concrete production, higher strength can be achieved in the final product.

vi) SUPER PLASTICIZER

Ceroplast 200 is a chloride free super plasticizing admixture based on selected sulphonated naphthalene polymers. It is supplied as brown solution which instantly dispersed in water. Ceraplast SP430 is used where the high degree of workability is required. It facilitates the production of high quality concrete. Ceraplast 430 has been specially formulated to give high water reductions up to 25% without the loss of workability produce high quality concrete of reduced permeability.

Table 3.5 Chemical composition of super plasticizer

Appearance	Brown Liquid
Specific Gravity	1.18
Air Entrainment	Less than 2%

III.METHODOLOGY FOR EXPERIMENTATION

A. Materials and its testing

Cement paste: The standard consistency of cement paste is 33. This is the amount of water required to produce a paste of standard consistency, which is defined as the consistency that allows the Vicat plunger to penetrate to a depth of 5-7 mm from the top of the mould.

Cement: The initial and final setting time of cement is 70 minutes and 300 minutes, respectively. This indicates the time taken by the cement to set and harden after mixing with water. The fineness of cement is 7%, which refers to the percentage of the total cement particles that pass through a 90-micron sieve.

Fine aggregate: The bulk density of fine aggregate is 1.74 kg/lit, which is the weight of the fine aggregate per unit volume, including the air and water present in the pores. The specific gravity of fine aggregate is 2.706, which is the ratio of the weight of the fine aggregate to the weight of an equal volume of water. The sieve analysis of fine aggregate gives a fineness modulus of 2.83. This is a measure of the fineness of the aggregate and is calculated by adding the cumulative percentages of the aggregate retained on each of the standard sieves and dividing the sum by 100.

Coarse aggregate: The bulk density of coarse aggregate is 1.29 kg/lit, which is the weight of the coarse aggregate per unit volume, including the air and water present in the pores. The specific gravity of coarse aggregate is 2.72, which is the ratio of the weight of the coarse aggregate to the weight of an equal volume of water.

Super plasticizer: Ceraplast200 is a super plasticizer used to improve the workability of the concrete mix. Its effectiveness can be tested by measuring the slump, which is the consistency of the fresh concrete, before and after adding the super plasticizer.

TABLE I TEST RESULTS OF MATERIALS

Sl.no	Title Of The Experiment	Result
1	Standard consistency of cement paste	33
2	Initial and final setting time	70min&300min
3	Fineness of cement	7%
4	Bulk density of fine aggregate	1.74 kg/lit
5	Specific gravity of fine aggregate	2.706

6	Sieve analysis	Fineness modulus =2.83
7	Bulk density of coarse aggregate	1.29 kg/lit
8	Specific gravity of coarse aggregate	Specific gravity = 2.72

Conventional SCC was used to cast one cube measuring 150x150mmx150mm and one cylinder with a height of 300mm and a diameter of 150mm. On the other hand, SCC with recycled rubber was used to cast three cubes measuring 150mmx150mmx150mm and two cylinders with a height of 300mm and a diameter of 150mm. The recycled rubber was used to replace 50% and 70% of the fine aggregates, and the mix proportion was determined through trial and error, resulting in a fixed ratio of 1:1.44:2.34 for cement, fine aggregate, and coarse aggregate. After a curing period of 7 days, the specimens were tested in a compression testing machine to obtain their compressive strength as part of an experimental study.

IV.RESULTS

TABLE II SLUMP TEST RESULT OF COVENTIONAL SCC AND SCC WITH RECYCLED RUBBER

% Of CR in The Mix	0%	50%	70%
Slump (cm)	63	74	82

TABLE III COMPRESSIVE STRENGTH TEST RESULTS OF CONVENTIONAL SCC AND SCC WITH RECYCLED RUBBER

% of Recycled rubber	0%	50%	70%
Average compressive strength after 7 days in MPa	18	16	14
Average compressive strength after 28 days in MPa	24	20	18

TABLE IV : FLEXURAL STRENGTH TEST RESULTS OF

CONVENTIONAL SCC AND SCC WITH RECYCLED RUBBER.

% of crumb rubber	0%	50%	70%
Average compressive strength after 28 days in MPa	3.5	3.8	4.1

Fig. . Schematic Representation of Stages of the Project

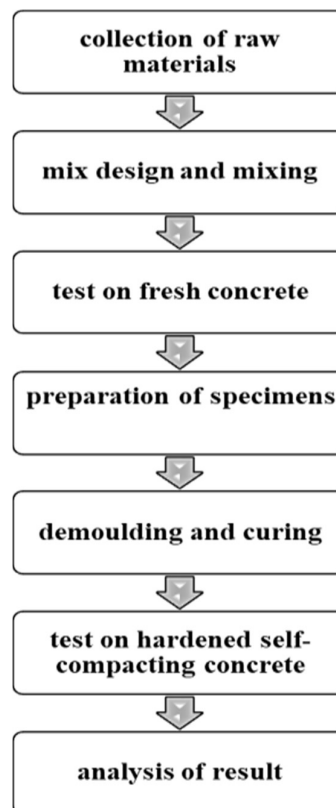




Fig. 5. Moulded cubes



Fig. 6. Cured Specimens



Fig. 7. Compressive Strength Test of Concrete Cube

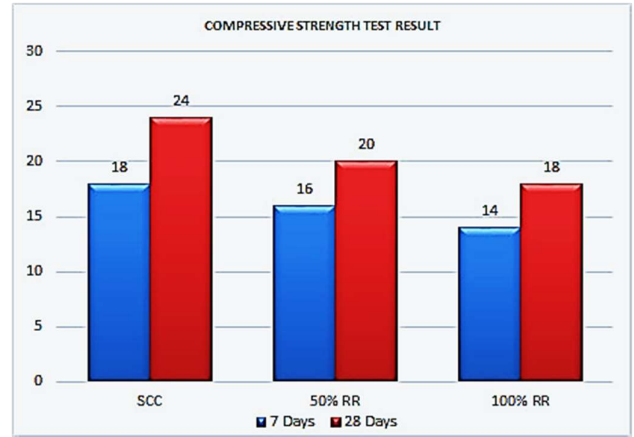


Fig.8. Variation of Compressive Strength with % Replacement of recycled rubber



Fig. 9. Flexural Strength Test for Concrete Cylinder

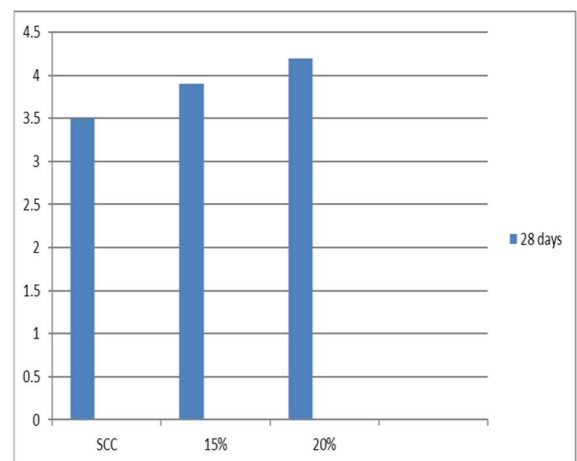


Fig. 10. Variation of Flexural Strength with % Replacement of recycled rubber

IV. CONCLUSION

The flexural strength of SCC increases as the percentage of recycled rubber in the mix increases. This suggests that incorporating recycled rubber into SCC can lead to stronger beams. Based on your findings, you recommend using rubber mixed SCC for casting beams.

However, you also found that the compressive strength of SCC decreases as the percentage of recycled rubber increases. This means that SCC with high amounts of recycled rubber may not be suitable for load-bearing components.

You suggest that rubber mixed SCC can be used for non-load bearing components instead.

Your study highlights the potential benefits of using waste rubber in SCC. Not only can this help reduce the cost of storing rubber waste, but it can also make use of a material that would otherwise be considered a hazard.

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