Rubber Powder As a Partial Replacement To Fine Aggregate in Geopolymer Ferrocement

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Abstract— Tyre manufacturing over the world has increased as the automobile industry has rapidly grown. The waste tyre disposal is very time-consuming and environmentally damaging process. Even though it is frequently disposed of in landfills, issues with supply and demand mean that the shortage and lack of available landfill space is very big concern. The fundamentals ferrocrete is used in the construction of structures. Mix of sand and cement the manufacture of aggregates from stone Quarries are also a major source of environmental degradation. Thus, the goal of the project; the purpose of this research is to investigate the effects of varying the quantities of crumb rubber replacing sand content in ferrocrete mixes. In order to enhance different percentages of glass fibre have a compressive strength included into the mix of cement. In this study, the primary objective is to discover replacing the old rubber with a new type of rubber Cement ferrocrete aggregates are mixed with glass fibres. Finally, the product will have excellent engineering qualities.

Ferrocement is a flexible building material with unique structural features. It's a composite made of tightly wound wire mesh around skeletal steel and rich cement mortar.

It is made of welded mesh, mild steel angles or bars, and reinforced by chicken mesh, square mesh or expanded metal. 1:1.5 to 1:4 mortar mix by volume Ferrocement can be used to build foundations, wallpanels, floors, roofpanel, ornamental structures,shells, etc. They are thin-walled, durable,ductile, light-weight, strong, and impermeable. It combines the strength of steel with the mouldability of ferrocrete, is lightweight and easy to work with, and has high tensile strength of pre-stressed ferrocrete and crack control. Ferrocement requires no formwork or shuttering. Ferrocement has transformed RCC into a homogenous, ductile composite. This is because continuous meshes of fine steel wires replace steel bars. It has strengthened the link between wires and mortar such that wires break but are not pulled out of the matrix. Steel and mortar are bound together until steel yields, providing ductility to the composite. The structure may flex or deflect but will not fail.

Keywords— Waste tyre crumb rubber in Geopolymer ferrocrete, , replacement

I. INTRODUCTION

The number of unusable waste tires from different kinds of vehicles is rapidly growing and is in fact turning out as one of the major ecological and environmental problems of the present day. Nearly one-billion waste tires are discarded each year and are predicted to be almost 1.3 billion per year by 2025. Large amount of waste tyre rubber accumulate in the world every year ,and the easy process to decompose the rubber is by burning but because of burning of rubber alarge amount of smoke and pollution is generated. Another method to dispose waste rubber is by landfill, but now days availability and capacity of land fill places decrease**s**

A expanding global automobile industry and a growing preference for automobiles as a mode of transportation have resulted in a dramatic increase in tyre manufacturing over the last several decades. As a result, massive stockpiles of old tyres have been created. In the early 2010s, extensive research was conducted on the numerous applications of recycled tyres. At room temperature, scrap tyre is composed of non-biodegradable components. They almost always have a negative impact on the environment. One way to put these resources to use is to incorporate them into ferrocrete and other building materials.

The following macroeconomic aspects should be contrasted and considered when evaluating the use of these materials in ferrocrete. The cost of collecting, processing, and transporting scrap tyres reduced environmental expenses and increased landfill voids result in an increase in landfill voids. By substituting tyre rubber for original materials in the manufacture of ferrocrete; rubber waste is extremely durable and resistant to most natural environments. As a result, proper tyre recycling is critical, as improper disposal can have serious environmental and aesthetic consequences.

Fine wire mesh reinforcement is the most basic element of ferrocrete, because it controls the specific surface, which is an important factor in design. The no. of steel mesh layer if meshes, decided the thickness of composite structure. Various types of meshes are in use:

- Expanded wire mesh

- Fine wire mesh in form of woven square mesh and interlocked diamond type or hexagonal mesh
- Weld mesh
- Crimped wire mesh

In Indigent countries, where this is especially true, used tyre management is primarily governed by environmental regulations. Following the implementation of numerous EU directives, reuse and material recovery are now regarded as the most environmentally sound waste management methods. The amount of waste glass has increased in recent years as a result of increased industrialization and a rapid rise in the standard of living. As a result, a significant amount of waste glass is discarded rather than recycled, resulting in environmental and natural resource loss and pollution. Ferrocrete's brittle nature can be softened by adding fibres with short lengths and small diameters.

Sustainability can be defined as the ability to use depleting nonrenewable resources indefinitely while also retaining depleting renewable resources. Sustainability is one of the most studied but least understood concepts on the planet.

For the majority of countries, organizations, and individuals who consider its significance, sustainability entails the preservation of the Earth and critical issues related to development, such as stable economic growth, productive resource utilisation, poverty eradication, and consistent social advancement. In the coming years, sustainable construction expects to meet current prerequisites for a working situation, housing, and infrastructure without sacrificing people's capacity to address their issues. According to researcher's writing, the current state of the construction industry is unsustainable. In the industry, sustainable construction could be accomplished by substituting strong recycled products for normal crushed stone in ferrocrete. However, the use of conventional coarse aggregates undermines sustainability by causing additional environmental issues. According to the India Farmer's Welfare and Horticulture Ministry, over 2390 billion were formed in India in 2016–2017, which will increase farming waste accumulation. Thus, the successful use of agricultural wastes as a substitute for traditional aggregates contributes to the preservation of non-renewable resources, reduces energy consumption, and lowers construction material costs. The authors used a variety of scrap materials in their ferrocrete, including recycled aggregate, fly ash, silica fume waste elastic tyre, and GGBFS and waste and glass plastics. They also used tobacco wastes, coconut shell, rice husk ash, palm shell, pistachio shell, and oil palm shell.

Aside from cement, aggregate is a major component of ferrocrete. Fine aggregates are obtained from river beds or weathering of rocks into dust, whereas coarse aggregates are formed by crushing of stones. Waste tyres are currently a major problem all over the world. Because waste tyres decompose slowly and take over a century to disintegrate at ambient temperature, they can be reused in land filling. These tyres rubber are cut into small and large pieces for the reduction or reuse of waste tyres. Crumb rubber (C.R.) is made by cutting up old tyres. Large pieces are considered coarse crumb rubber, while small pieces are considered fine crumb rubber; in ferrocrete, these are replaced with coarse aggregate and fine aggregate, respectively. Crumb rubber from tyre waste, reduced to a very fine size, was used as a fine aggregate in this research paper. The amount of crumb rubber is calculated as a percentage of the fine aggregate weight as 2.5 percent, 5.0 percent, 7.5 percent, and 10.0 percent replacement. ferrocrete mixes are used to cast cubes, beams, and cylinders & Panels for various laboratory tests. Slump variation, compressive strength, compressive strength tests are performed in the laboratory According to research, increasing the percentage of crumb rubber & glass fiber reduces strength.

One of the most concerning issues in the early stages of GRC development was the durability of the glass fibres, which became fragile over time due to the alkalinity of the cement mortar. Significant progress has been made since then, and the problem is now practically solved thanks to new types of alkali-resistant glass fibres and mortar additives that prevent the processes that cause GRC embrittlement. The lighter weight and higher tensile strength of GRC compared to ferrocrete prompted a recent research programme to investigate its viability as a structural material. The study was conducted in collaboration with ferrocrete precast companies, for whom the improved characteristics are particularly appealing because the precast elements' reduced weight is critical for transportation and installation. Reinforcement systems, such as carbon or glass strands and stainless steel bars, were also investigated in order to obtain a GRC with high durability, resulting in corrosion-free solutions. Although some of the average mechanical properties of GRC are known and are currently used for nonstructural elements, a much more thorough characterization is required when structural design is considered. The mechanical strength, Young's modulus, creep and shrinkage behaviour, and stress–strain diagrams of GRC specimens were then determined through experimental tests. The experimental tests had to consider cementitious matrix with various plain mortar productions, various types of glass fibres, and reinforced with carbon or glass strands or steel elements, as the material characteristics were highly dependent on the production procedures. These tests resulted in a characterization of the manufacturing conditions, allowing for the optimization of material properties.

Dispersion of steel wire:

Ferrocrete is formed by tying together a no. of layers of continuous wire meshes. Volume of steel Per cent is very large, may be upto 8%. Also the mortar cover over the meshes is upto 3-5 mm. Hence throughout the body of the composite, the wire reinforcement is fully dispersed. This leads ferrocrete4 to become more homogeneous. It results in improving the properties of ferrocrete in tension, flexure, impact resistance and crack resistance.

Crack control:

Closely spaced fine wires, very near to the surface of ferrocrete, act as crack arrestors. In conventional reinforced ferrocrete the bars are spaced some distance apart and the ferrocrete in between them is prone to temperature expansion and contraction. This tendency is overcome by the tension taking member fully bonded to mortar and spaced very to the surface of ferrocrete.

Equal strength in both directions:

The continuity and placement of equal mesh reinforcement in both directions make ferrocrete to achieve equal strength in two direction and become strong in resisting diagonal tensions due to shear.

Containment off mortar matrix in mesh layers:

In ferrocrete, layers of wire meshes tightly tied together are impregnated with cement mortar. The matrix is held by the meshes in between and is contained by them. In RCC, steel bars are encased in ferrocrete while in ferrocrete layers of wire meshes encase the mortar and hold it bonded strongly. Thus there would not be sudden brittle failure of ferrocrete element. In case of test upto failure or in the case of sudden shock loading like earthquake, the member will undergo large deflection with adequate warning.

Formless construction:

Tightly tied meshes in ferrocrete can hold wet cement mortar when it is press filled in them. The consistency of cement mortar is very thick with very low water cement ratio. It won't out of the meshes. Thus casting of ferrocrete does not need any formwork or shuttering. The other advantage of this aspect is that no honeycombing in press filling as the mortaring is done in front of your eyes.

Self -quality conscious material:

If the steel wire mesh is tied loosely or water to cement ratio is not maintained to thick consistency, or over sanding is, the mortar will flow down and will not be held by the meshes. Thus the ferrocrete may be characterized as a self-quality conscious material and will does not allow less cement, more sand or more water in the mortar mix.

Strength through shape:

Ferrocrete structure is thin walled and may be hardly 25 to 50mm in thickness. Hence to take care of slenderness and buckling, ferrocrete is shaped in different forms to achieve its strength.

II. LITERATURE REVIEW

Camile B. George Saleem 2021

As waste accumulates and landfill capacity diminishes, agencies are expanding application and use of recycled resources such as crumb rubber from tyres in building. Ferrocrete is made up of gravel and cement. Using recycled materials wisely may reduce costs and improve performance; however, not all recycled materials are suitable for ferrocrete construction. The primary reasons for not using reused material are (1) performance loss and high cost. This study investigates the effectiveness of recycled crumb rubber as a 0–80% fine aggregate replacement for crushed sand in ferrocrete mixtures. Using crumb rubber to replace up to 25% of fine aggregates improved compression strength.

Feng shi Guiuan Chen, Liuan Li Yoshugchan Guo 2018

Using chosen rubber particles of 0.175 mm, 1.15 mm, and 2 mm, and steel fibre of upto 25 mm in length and 0.5 percent volume percentage, he studied the impact resistance of rubber reinforced and rubber/steel fibre reinforced ferrocrete. Ferrocrete containing 5%, 10%, 15% and 20% rubber particles was tested dynamically under 0.2 MPa, 0.3 MPa, 0.4 MPa and 0.5 MPa impact loads. These curves were then utilised to depict the strain rate levels connected with the rubber reinforced ferrocrete. Based on the findings, the impact resistance of rubber reinforced ferrocrete was studied. The improved Holmquist–Johnson–Cook dynamic constitutive model was developed by finding the parameters of the improved Holmquist–Johnson–Cook constitutive model. The constitutive model of rubber reinforced ferrocrete was created, with parameters given for various strain rates.

F. Pacheco-Torgal, Yinning Ding 2018

The volume of polymeric wastes like tyre rubber and PET bottles is rapidly growing. Every year, an estimated 1000 million tyres are wasted, with 5000 million more projected by 2030.Currently, only a small percentage gets recycled, while millions are dumped or buried. The yearly PET bottle use is above 300 million units. The majority is dumped. Research on ferrocrete including tyre rubber and PET wastes is reviewed. It also addresses the impact of waste treatments, waste particle size, and waste replacement volume on ferrocrete's fresh and hardened characteristics.

Waung Her Yung a, Lin Chhin Yung 2020

The mixing of regular sand with waste tyre rubber powder of varying fineness is described. The results revealed that adding 5% waste tyre rubber powder sieved #50 increased the 91-day compressive strength by 10% over the control group. The shrinkage increased with the amount of discarded rubber and peaked at 20%. The ultrasonic pulse velocity dropped as additional powder was added, and the 56-day electrical resistance rose from 20 kX-cm to over 30 kX-cm. Meanwhile, the ultrasonic pulse velocity and electrical resistance correlated well with compressive strength. The addition of 5% waste tyre rubber powder improved anti-sulfate corrosion. Leaky self-compacting rubber ferrocrete can benefit from waste tyre rubber powder.

P Paramasivam (et.al, 2018):

Ferrocement is ideally suited for thin wall structures as the uniform distribution and dispersion of reinforcement provide better cracking resistance, higher tensile strength to weight ratio, ductility and impact resistance. By adapting available mechanized production methods and proper choice of reinforcements it can be cost competitive in industrialized countries. Research and development works of ferrocement, at the National University of Singapore, since early 1970's, has resulted in several applications such as sunscreens, secondary roofing slabs, water tanks, and repair material in the building industries.

Aim

“This study's goal is to substitute sand in ferrocrete with crumb rubber in varying quantities. The Geopolymer in the cement is to be tried to increase flexural and impact strength”.

Objectives

- Study on its use in cement ferrocrete is limited. Rubberized Portland cement ferrocrete strength and hardness tests
- To study goal is to substitute sand in ferrocrete with crumb rubber in varying quantities. The proportion of geopolymer in the ferrocrete is to be tried to increase flexure and impact strength.
- To check flexure strength Up to 5%, 10%, 15%, 20% replacement of rubber aggregate to fine aggregate and

Problem Statement

“Study on Flexural strength Up to 5%,10%, 15%, 20% replacement rubber aggregate to fine aggregate in Geopolymer Ferrocement

Scope of the Study

Rubberized ferrocrete has many applications in construction, further research is needed to determine its elastic constants and mechanical properties by varying the rubber volume proportions, water-cement ratios, aspect ratios, and rubber forms such as fibre chips, powder, etc. The study uses varied percentages of rubber waste in ferrocrete.

III. RESEARCH METHODOLOGY

Research Work

- Study for literature review survey
- To study the construction techniques of ferrocrete, we have gone through various research papers, books, and some field works
- To cast Panel for configuration size Length - 1000mm, Width-.300mm, Thickness. 30mm and to study after 28 days curing
- To check flexure strength Up to 5%, 10%, 15%, 20% replacement of sand to tire rubber aggregate
- Impact test
- Compression Test
- Analysis result
- Result and discussion
- Conclusion

IV. EXPERIMENTAL CONSIDERATION

Material Collection

Cement

Ordinary IS: 269 – 1976 Portland cement, 40 grade. All of the specimens were cast with ordinary Portland cement, grade 53. To produce pastes of uniform consistency, different types of cement require different amounts of water. Different types of cement will result in different rates of strength development in ferrocrete. The most important factor in producing high-quality ferrocrete is choosing the right brand and type of cement. Because the type of cement used affects the rate of hydration, the strength of the ferrocrete at an early age can be significantly influenced. It's also crucial to make sure that the chemical and mineral admixtures are compatible with cement.

Aggregate

Local river sand conforming to IS: 383 –1970 Grading zone II. Local river sand will be used. All the specimens will be cast in IS 4.75mm sand.

Rubber

The crumb rubber particles ranging from 75µ to 2.36mm with different different shape.

Fly ash

Fly ash used in this study is low calcium class F unprocessed fly ash from thermal power plant. Quantity and fineness of fly ash plays an important role in the activation process of geo- polymer. It was already pointed out that the strength of geo-polymer ferrocement increases with increase in quantity and fineness of fly ash

GGBS

Ground granulated blast furnace slag is a hydraulic binder, acquire by quenching molten iron slag from a blast furnace in water or steam to create a glazey, granular product that is then dried and ground into a fine powder.

Alkaline Solution

Sodium Hydroxide Solution (NaOH)

Sodium silicate solution (Na_2SiO_3)

Steel Mesh

Wire diameter of across 0.5mm to 5 mm should adopted. Size of mesh opening is between 7mm to 35 mm. Maximum utilization of upto 3 layers of work for various thickness. There should maximum 10% volume portion in both bearings Steel cover 1.5 to 5 millimeters.

Constituent Materials Used Materials that are used for making ferrocrete for this study will be tested before casting the specimens. The preliminary tests will be conducted for the following materials.

- Cement
- Aggregate
- Water

Methodology and preparation

Cement

Cement used in construction is categorized as hydraulic or non-hydraulic. Hydraulic cement (e.g., Portland cement) harden because of heat of hydration, chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (e.g., lime and gypsum plaster) must be kept dry in order to retain their strength. The most important use of cement is the production of mortar and ferrocrete. The bonding of natural or artificial aggregates to form a strong building material that is durable in the face of normal environmental effects.

Aggregates

"Fine aggregate" is defined as material that will pass through 4.75mm sieve and will, for the most part, be retained on a 1.18mm sieve. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape.

Mix Proportion

Ordinary portland cement and river sand passing through No. 8 (2.38 mm) sieve and having a fineness modulus of 2.72 were used for casting. In design mix proportion 40% cement replace with combination of fly ash and GGBS with different proportion. The geopolymer mortar used in this study is composed of low-calcium fly ash and alkaline solution composed of NaOH and sodium silicate combinations. NaOH is mixed with deionized water at a required concentration(12M) and kept for at least 24 h prior to casting. All geopolymer mortar specimens were made with sand-to-geopolymer ratio in equal proportion.

The cement, fly ash and fine aggregate were dry mixed together in a mixer machine for 5 min. W/c ratio is taken as 0.46 followed by the addition of activator solution containing hydroxide and silicate to the mixture, and mixed for another 10 min. The mixing was carried out at a room temperature of approximately 27–30°C

The crumb rubber is immersed in 1N NaOH solution for 30 minutes. After that the rubbers are water washed to remove the presence of NaOH residue. The moist rubber is free dried under sun light with ambient condition. 1lit of NaOH solution may require for treating up to 1kg of crumb rubber.

The Ferro cement panel is made by using expanded chicken mesh and geopolymer mortar. The panel mold is made of wooden base with the size of 1000mmX300mmX30mm with open top and bottom is rest on base plate & cubes of 150x150mm are prepared to check compressive strength of mixture.

Compressive Strength

This test is execute to check the required compressive strength is gained by Rubberised Geopolymer Ferrocement mortar when compared to regular specimen. The rubberized geoplymer ferromix mortar cube and conventional specimen are water cured for 28 days at room temperature. After completion of curing, the cubes are tested on 1000KN capacity universal testing machine.

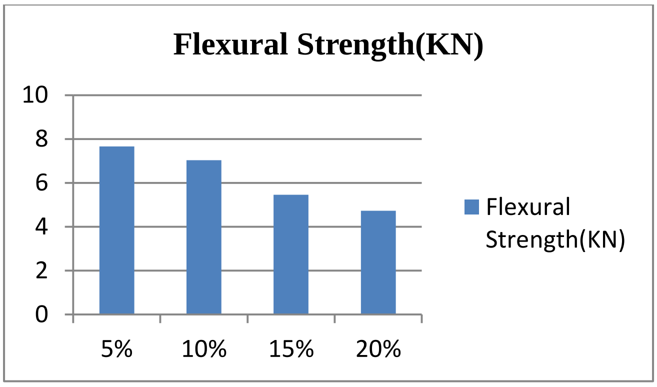
Sample Type	Compressive strength (Mpa)	Compressive Strength (Mpa)
	7 Days	28 Days
Conventioal Ferrocement	17	30
GRF (5%)	17	29
GRF (10%)	15	27
GRF (15%)	16	27
GRF (20%)	16	24

GRF : Geopolymer Rubberised Ferrocement

Flexure Test on Ferrocement

Ferrocement specimens size (1000mmx300mmx30mm) were tested in accordance with the applicable provision standard testing methods for flexural strength of ferrocement, using a fixed supported slab with uniformly distributed load. An experimental load-deflection curve of ferrocement with clearly defined transition point.

Sr. No	Sample	Temperature (Celcius)	%Rubber Replaced	%GGBS	Flexural Strength (KN)
1	**A**	**28°**	**5%**	**20%**	**7.66**
2	**B**	**28°**	**10%**	**20%**	**7.03**
3	**C**	**28°**	**15%**	**20%**	**5.46**
4	**D**	**28°**	**20%**	**20%**	**4.73**

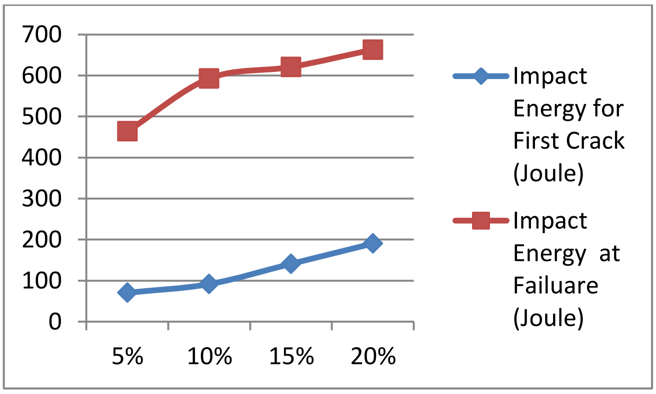


Flexural Strength of Rubberised Geopolymer Ferrocement

Impact Testing

After the 28 days of curing, slabs are taken out from the curing tank and white wash was applied to the slabs surface in order to get clear indication of cracks on repetitive drops. Impact test was conducted on the geopolymer ferrocement panel slabs after 28 days of curing by using a drop weight method and the test setup is consisted of a rigid welded steel frame square in plan and supported by short columns. The specimen was laid flat resting on four 75 mm diameter bars to provide line support along the four edges. The test setup consists of a cylindrical ball of 60mm diameter; 150mm height (the plunger) with hemispherical blunt tip to a height of 50mm.The plunger which loads the panel has a spherical tip enabling a point contact to be made. A rope and pulley arrangement with a pipe guide, which enables a central impact in the vertical direction, was used to manually raise the hammer to the required height for repeatedly dropping it on the specimen surface. Grease was applied on the rollers to reduce friction and to ensure smooth fall. The weight of the ball is 3.22kg and it is dropped from a height of 670mm. The mass was then dropped repeatedly and the number of blows required to cause first crack was recorded. Then the number of blows required for the failure is also recorded

Specimen with (%)rubber replacement	No. of Drops for First Crack	No. of Drops Failuare	Impact Energy for 1st crack (N-m)	Impact Energy at failure (N-m)
5%	3	23	70.53	463.7
10%	4	28	91.6	592.5
15%	6	29	141.03	620.7
20%	8	30	190.43	663.0



Impact Energy of Rubberised Geopolymer Ferrocement

Failure pattern on surface of geopolymer ferrocement panel

As per above test in the result ,it was observed that

• All the slabs failed by punching shear.

• Initially as we start impacting first crack was developed at initial impact drops and then further cracks are increased and propagated to a length of 28- 50mm.

• Then on further impact loadings, cracks propagate and reached the boundaries of the slab.

• The panel with 20% rubber aggregate has more impact resistance capacity against crack development as it take more blows before appearance of first crack

V. CONCLUSION

1. A 12% to 15% sand replacement level in ferrocrete mixes was found to be optimal for increasing strength and durability after 28 days.

A low coefficient of permeability was found in all samples of ferrocrete containing Rubber Powder.

2. The regular controlled specimen has flex. Strength is between 4.75-5.5KN,which means we can get better result up to 10% to 15% replacement of fine aggregate by rubber powder.

3. Increase in the thickness and molarity concentration in the GF panels increased the load-carrying capacity,ductility, energy absorption, and stiffness of the element and decreased the crack width and crack spacing.

4. The cracking behavior of the various specimen shows that the cracking region and the cracking space are less in the geopolymer specimens and large number of cracks compared with the control specimens.

5. The rubber addition in mix increases the flexural strength of geopolymer base panel by 1.41times with lesser crack pronouncement.

6. The impact resistant property of the rubberised geopolymer ferrocement is slightly more than conventional ferrocrete

7. The increased rubber powder ratio decreased the compressive strength and the modulus of rupture of the panel but delays the appearance of first crack and final failure.

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