CONCRETE WITH RECYCLED AGGREGATE AND POZZOLANIC AND NON-POZZOLANIC FILLERS CONTAINS MECHANICAL AND LASTING PROPERTIES

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Abstract— The goal of this study to enhance the characteristics of repurposed aggregate concrete, various pozzolanic and non-pozzolanic filler kinds were used in place of the recommended quantity of cement. Additionally, depending on % retention value, mechanical handling of recycled aggregate is optimized. As a starting point, the blend proportion with treated recycled aggregate was created using 100% substitution of natural aggregate and was given the designation tRAC. Then, when preparing the mixture, the fillers silica fume, GGBS, marble dust, and recycled concrete fines are used at optimal amounts of 11%, 14%, 14%, and 15% by weight of cement and are referred to as tRAC-SF, tRAC-GGBS, MD, and RCF, respectively. Concrete made with repurposed aggregate and fillings is more similar to all the qualities enhanced by fillers. This demonstrates the efficacy of the filler refining method. When compared to tRAC, the compressive strength of tRAC-SF and tRAC-GGBS rose by 8.01% and 2.26%, respectively, while tRAC-MD and tRAC-RCF saw decreases of 16.72% and 4.82%, respectively. All blend amounts had chloride ion penetrability that was in the very low penetrability range. The mechanical and longevity characteristics of every blend are also equivalent. Therefore, using any of the substitutes for additional exercise is advised.

1. INTRODUCTION

Construction and demolition debris (C&D garbage) is produced quickly in India and contributes to landfill problems. Natural aggregate will also be in limited supply in the foreseeable future. because of the extremely high demand for natural material brought on by widespread urban migration. There is a need for new concrete, such as reclaimed rock concrete, to solve these problems.

Construction and demolition waste
Construction and demolition refuse (C&D waste) is the detritus produced during the building, remodeling, repairing, or dismantling of any civil structure, including a building, road, bridge, railway, dam, water tank, pipeline, waterway, drainage work, or tower. The majority of C&D trash is composed of big, hefty, inactive, and non- degradable materials. Major components of C&D debris include pipelines, electrical fittings, panels, and other minor components. Minor components include cement, concrete, bricks, steel, stone, cement plaster, and cement cement. (glazed tiles, glass panes). C&D waste has harmed public health & social life, the ecosystem, and the economy (loss of essential resources, diminished international renown, decreased tourists, and increased use of transportation fuel). (health hazards, impact on working safety, pest proliferation, & use of public space) (Spies, 2009).
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The main reasons for the increase in removal concrete debris are as follows:

- Many old buildings and other constructions need to be destroyed because they are no longer functional.
- Buildings that are still useful are being torn down because of imperative requirements.
- Natural catastrophes contribute to the production of building waste.

Since the conclusion of World War II, the majority of law in developed countries has promoted C&D waste management. Many of these regulations were implemented to protect the ecosystem. Heavy fees and penalties have been used to deter the disposal of C&D refuse in landfills and incinerators and to promote the use of recycled materials. (Poon, 2007).

India's constructed environment has been quickly increasing in recent years, and this trend is likely to continue in the future to handle the nation's expanding metropolitan population and rising living standards. (Ramachandra et al. 2016; Seto et al. 2012).

Construction & Demolition waste generations
Recycling C&D trash enables cities to minimize the use of virgin materials, decrease landfill area usage, and lessen their environmental effect. Given that there are few projections of the volume of C&D garbage produced in India, it is difficult to build C&D waste recycling plants.

India is the second-largest supplier of C&D garbage after China. (Akhtar & Sarmah, 2018). According to Jain et al. (2018), India produces 100–400 MT of C&D garbage annually, mainly from urban areas. As more than 300–400 million people move to cities in the future decades, this amount will only continue to rise. (UN DESA, 2018). A significant quantity of urban land and construction materials will be required for this rise. India would require roughly 600-700 MT of natural sediments and the equivalent amount of sand each year (BMTPC, 2018). (Ministry of Mines, 2018). According to reports, India has a restricted quantity of both minerals. (BMTPC, 2018; Ministry of Mines, 2018). Due to the growing shortages in various areas, India has started purchasing sand from other nations. (Kukreti, 2018). In order for India to keep moving into cities and improve resource economy, C&D garbage recycling is crucial. Indian C&D garbage recycling facilities are presently scarce. (BMTPC, 2016, 2018).

Construction & Demolition waste recycling

Since the adoption of sustainable practices in the building industry, C&D waste generation and handling issues have received attention in an effort to meet sustainability goals for our better future. The 3Rs idea (Reduce, Reuse, Recycle) is very useful when handling with C&D waste.

Unlawful landfilling and negligent deposition of trash in urban areas contribute to material loss and unsuitable land-use practices. Environmental issues and land-use disputes will worsen as the population, size, and economy of these towns expand in the coming decades (UN DESA, 2018), especially in the absence of appropriate C&D waste management practices. (Duan et al. 2019; Zheng et al. 2017).

The use of non-traditional construction materials can improve current mineral supplies while easing the burden on the environment and valuable property. (Akhtar and Sarmah, 2018; Hansen, 1992). On the other hand, the environmental benefits of recycling C&D garbage are hotly debated and significantly influenced by regional factors. life cycle thinking has been used to assess the benefits and drawbacks of recycling C&D waste in many countries, such as China (Ding et al., 2016), Brazil (Rosado et al., 2019), Hong Kong (Hossain et al., 2016), Spain (Mercante et al., 2012), Italy (Simion et al., 2013),

Difference between RCA and Natural aggregate

The difference between adhesive mortar and the interface transition zone (ITZ) between natural aggregate (NA) and RCA is that the latter has two additional components. RCA has higher porosity than NA due to the masonry on NA. RCA has greater porosity and water uptake than NA, but less tensile strength. The range of water uptake for RCA is 3–12%.NA has a 1–5% water uptake rate. (Gomez-Soberon, 2002; Katz, 2003). The water-cement ratio and connected mortar volume of the initial concrete have an impact on the density and water absorption of RCA. (Etxeberria et al., 2007). The size of the RCA and the breaking procedure have an impact on how much mortar is affixed. (Ajdukiewicz and Kliszczewicz, 2002; de Juan and Gutierrez, 2009).

Aggregate, ITZ, and solidified cement are the three components that make up concrete. ITZ is typically the poorest zone in concrete due to its greater porosity and cracks in either completed cement paste or gravel. (Zhang et al., 2015a). More original ITZs between the material and the old mortar as well as new ITZs between the adhesive mortar and the new mortar matrix were created in concrete by RCA than NA. The connected mortar was found to be the poorest component in recycled concrete. (Etxeberria et al., 2006). ITZs are shown in RCA in Figure 1.1.

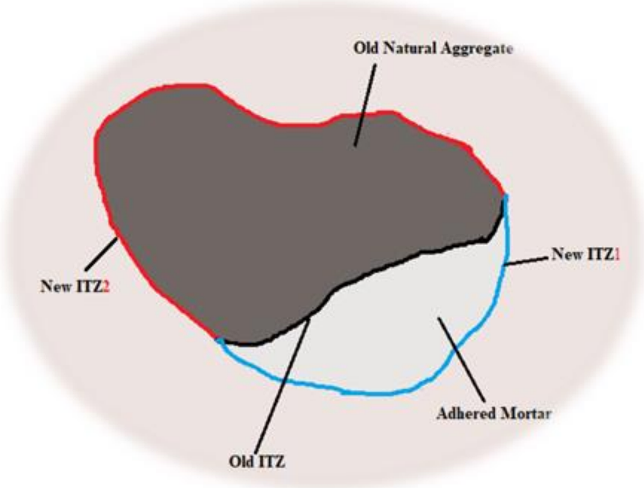


Figure 1.1. Interfacial transition zone (ITZ) of RAC

Classification of RCA

Crushed concrete, crushed brick, and mixed concrete & brick are the three main types of material derived from most C&D refuse. After being crushed and processed in approved recycling facilities, the resulting aggregates can be divided into three groups. (De Brito and colleagues, 2018).

Recycled concrete aggregates (RCA)

The majority of RA contain concrete because it is the most prevalent building substance. Given that they are made from a material whose characteristics are similar to those of their intended application, RCA are among all types of RA the most appropriate for the recovered concrete product. The methods used in C&D refuse recycling facilities, the mix composition of the source concrete, and construction and demolition activities all have a significant impact on RCA. (Figure 1.2).

Recycled masonry aggregate (RMA)

A building substance called masonry brick is produced from the C&D waste of civil engineering and building constructions. Masonry refuse frequently contains mortar fragments and burned clay slabs and panels. (Hansen, 1992). The best recycling facilities produce RA with a high recycled brick percentage by making a concerted effort to remove concrete and asphalt from other stocks. Concrete can be prepared using RMA if it has the necessary characteristics. When compared to RCA concrete, the mechanical qualities and longevity of RMA concrete will likely suffer. (Figure 1.3).

Mixed recycled aggregates (MRA)

This substance is composed of different ratios of crushed and sorted concrete and masonry block within the confines of the two previous RA. (Figure 1.4). This kind is most likely to be extracted from C&D refuse recycling processes, resulting in a substance with a very complex makeup, as there is still a general lack of material separation at the source. The two main components obtained from C&D Waste processing make up the finished material. To make concrete with the necessary characteristics, MRA can be used. When compared to RCA concrete, the technical characteristics and longevity of MRA concrete will most likely suffer.

2. LITERATURE REVIEW

As climate change is a worldwide problem, recycled building and demolition refuse must be used to create green concrete. By crushing the original concrete, recycled aggregate is produced, which has the dual advantages of alleviating the strain on dumps and supplying the growing demand for building aggregate by displacing natural aggregate. One of the viable and ecological options is recycled gravel.
C&D waste

Jain, et al. (2019) investigated that in 2012, India generated over 130 million tonnes of C&D trash, which is expected to increase to over 750 million tonnes by 2050. towns produced more waste total than towns with populations over one million. This is due to the bigger commercial floor space and higher people density in cities. Resources and the ecosystem suffer from poor C&D waste handling in a number of ways. For instance, land is a precious resource in Indian cities. A sizable percentage of C&D garbage is unlawfully discarded or landfilled in typical Indian towns. Large C&D waste consumes a lot of disposal space.

Yeheyis, et al. (2012) designed a method for managing construction and demolition (C&D) waste throughout the full life cycle of a project, including the 3Rs (reduce, reuse, and recycle). By reducing material loss during the planning and design stage, reducing waste on the work site, and recycling resources, the complete C&D waste management technique saves money and time. After that, choices regarding the choice of materials, classification, recycling, and remedies for C&D waste may be made using the developed composite C&D waste sustainable development index.

Bovea and Powell (2016) As per him, it was important to include a variety of studies, not just those that compared approaches to C&D waste management in general. For example, studies examining how waste plants treat the environment when classifying and recycling various C&D waste components or contrasting natural materials with those made from recycled C&D waste. The need to specify how the LCA methodology is used to assess the environmental impacts of C&D waste management in order to compare the findings from various case studies is one of the study's key insights. Due to the intricacy of LCA studies, this calls for openness and a straightforward explanation of the assumptions made in order to encourage proper outcome interpretation and comparison.

Central Pollution Control Board (2017) The Swachh Bharat Mission (MoUD)'s primary goal, according to the Central Pollution Control Board, is to handle all solid refuse produced in cities and localities, including C&D trash, by October 2, 2019. In an effort to address issues related to the reduction of adverse environmental effects resulting from C&D waste management events, the Central Pollution Control Board had already issued "Guidelines on Environmental Management of C&D Waste" in accordance with Rule 10 sub-rule 1(a) of the C&D Waste Management Rules, 2016. The suggestions made by the CPWD and BMTPC did not address these issues.
Butera et al. (2015) found that using C&D debris as a substitute for natural stones in road construction was preferable to landfilling for the majority of environmental impact categories. Distances of less than 40 km are recommended to achieve complete savings in the case of usage because, in contrast to most other waste management situations, transit was shown to be essential for the effects of C&D waste management on global warming. As capital products have only minor effects, smaller, decentralised crushing sites with quicker transit times, or alternatives for on-site crushing and potential usage, may be preferable from a life cycle perspective. It was also shown that the source of substitute natural aggregates—gravel pits as opposed to rock crushing—is significant for the use's environmental effect.
Rosado et al. (2019) According to his findings, the importance of avoided impacts from reclaimed materials—particularly those connected to recycling of steel, glass, and plastics—was emphasised. In this respect, cities could participate in programmes that promote construction site sorting, thereby enhancing the grade of recovered materials and increasing recycling rates. Additionally, it is suggested by this result that LCA analyses of C&D waste management avoid concentrating solely on the mineral portion and ignoring the presence of other components. The findings of the various situations show that raising recycling and RA production significantly enhances the impact category of acidification and respiratory inorganic materials. To optimise the advantages of C&D refuse recycling, it is crucial to conduct study on the impacts of natural aggregate scarcity in the construction industry.

Borghi et al. (2018) studied that recycling C&D garbage has more disadvantages for the ecosystem currently than benefits. Transporting trash has the highest environmental costs, which are not mitigated by the meagre advantages of using recovered aggregates in practical uses. The following improvements have been found for the regional government to put into practise in order to boost the advantages of C&D garbage recycling and, as a result, achieve a more sustainable management system: It is essential to boosting RA demand and advancing their use in the building industry. It may be possible to reclaim "clean aggregates" from recycling facilities by using more stringent standards for selective demolition techniques on the work site. Establishing connections between recyclers and architects as well as strategically placing recycling facilities throughout the local area.

Environmental Protection Agency (EPA) United States (2021) reducing the amount of construction and demolition (C&D) debris disposed of in landfills or incinerators by a) boosting the recycling sector's employment and economic activity as well as local business opportunities, particularly when deconstruction and selective demolition techniques are used. b) Reduce the overall cost of the construction project by forgoing purchase and disposal expenses and giving recovered materials to 501(c)(3) organisations that qualify in exchange for a tax break. Reuse on-site also reduces the cost of shipping. c) Lessen the quantity of dumping locations, perhaps easing environmental worries. d) Minimize the environmental impact of mining for and using raw resources and producing new materials. e) Use less waste area. Learn more about the environmental effects of building single-family homes in the United States from our life cycle research, which also discusses the benefits of salvaging, recycling, and reusing C&D products.

Recycled concrete aggregate (RCA)

De Brito et al. (2019) conducted research on how to incorporate growing quantities of C&D waste-based RA into concrete while maintaining performance that is at least predictable and on par with that of regular concrete. Little adoption has been observed in practise because RA incorporation seems to worsen durability-related characteristics. This is particularly true given that RA produced in C&D waste reprocessing facilities has considerably changed in makeup and features. Given that they are made from a product with characteristics comparable to those of their intended use, RCA are by far the most appropriate RA for concrete production among all types of RA from C&D waste. The methods used by C&D refuse reprocessing companies, the blend design of the source concrete, the quality control procedures used during construction and deconstruction, and other factors all have a significant impact on RCA. Although concrete produced using RMA or MRA can have sufficient mechanical qualities, its longevity will almost certainly be reduced when compared to concrete created using RCA.

Silva et al. (2014) finds a mathematical analysis of the fundamental physical characteristics and constitutions of RA for use in concrete was done. The main conclusions that could be drawn from this research are as follows: a) Selected destruction should be encouraged and enacted whenever possible. b) A RA's physical characteristics and makeup should be assessed before it is approved and used in the production of concrete. This will facilitate better understanding of the material and make categorization simpler. The literature states that this substance has been successfully used in the production of bituminous mixtures despite the fact that it is very bad for materials that are bonded to cement. This only adds to the significance of finding out the components and physical characteristics of treated C&D refuse.

Bhasya and Bharatkumar (2018) The Author used a heating and scraping treatment method to eliminate the attached cement of the RCA. In order to quickly decrease temperature and introduce stresses, RCA was heated to temperatures of 250°C before being immersed in water. The attached mortar with a weak contact on the RCA detached after rubbing. They also found that the main factor contributing to the RCA's bad quality was the existence of linked mortar. By removing 70% to 80% of the sticking cement, the heating and scraping cleaning method improved the RCA's quality. The mass density and specific gravity of RCA both rose after treatment by about 9% and 6%, respectively. The steaming and cleaning treatment method reduced RCA's water uptake by about 66%. The mechanical properties of concrete produced with silica fume and processed recycled concrete aggregate demonstrated a significant increase over traditional concrete. A cost-benefit analysis was done to show that recycling building waste is profitable.

Shi et al. (2015) In order to decrease the amount of connected mortar and to enhance the RCA attributes, the author examine these two techniques for improving RCA characteristics. Carbon dioxide pre-treatment of RCA is not only a cost-effective method to enhance its properties, but it is also good for the ecosystem. The carbonation of RCA was enhanced using the chemical reaction between CO2 cement clinker particles and hydration molecules. It can enhance connected mortars and both new and ancient ITZs close to the RCA. Therefore, carbonation treatments were the most effective and feasible method for enhancing the mechanical and longevity of RCA concrete.

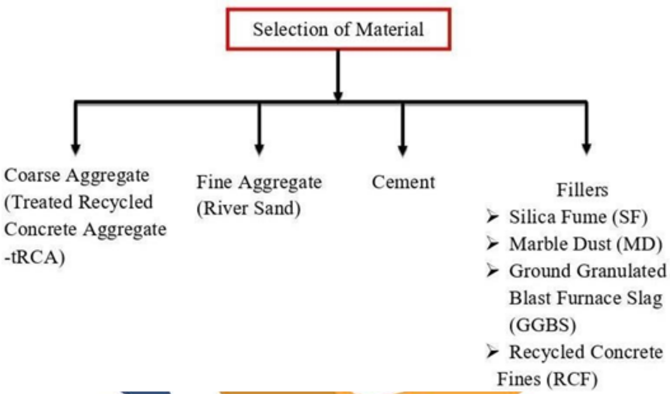
Kho Pin et al. (2018) The contrast in features between RCA and NA is primarily caused by the connected mortars on RCA, according to author. This pestle is the cause of RCA's higher absorption, poorer abrasion resistance, and lower specific gravity when compared to NA. Before using RCA as an aggregate in the blend to make concrete, it is essential to check its grade. The grade of the concrete is influenced by how RCA is managed prior to mixing. In comparison to concrete batched using dry RCA, the use of partly saturated and completely saturated RCA, along with an appropriate blend formulation and batching method, has been shown to improve concrete performance. Utilizing saturated RCA, adding sufficient amounts of SCMs to the mix, and making other mix design changes, coating the RCA, utilizing new concrete mixing techniques, surface-modification methods, and RCA's self-healing property before using it in the concrete mix, reducing the amount of old mortar and other pollutants in the RCA, and incorporating fiber.

Katrina and Thomas (2013) finds that, the aggregate characteristics on RCA are most affected by the leftover attached mortar. Because of this, RCA is less thick, extremely porous, and absorbs more water than NA. While RCA and NA particles have similar gradations, RCA is more rounded and exhibits a higher proportion of small fractures during abrasion and crushing experiments. The compressive strength of concrete decreases when NA is substituted with RCA, but the breaking tensile strength remains the same or increases. The modulus of fracturing of RCA concrete was lower than that of ordinary concrete because the weakened ITZ was brought on by leftover mortar. The aggregate's higher ductility also causes the modulus of elasticity to be lower than anticipated. The mid-span deflections of beams with RCA increased under a service load, but they remained significantly below the designated maximums. Overall, RCA is a lower-quality aggregate that has a negative effect on the properties of concrete. However, research has shown that, when used as a complete structural component, RCA can still be used to produce structural concrete. RCA concrete pillars are structurally viable because their performance still meets predetermined standards. After all, RCA quality differs so greatly between sources.

Juan and Gutiérrez (2008) The amount of attached mortar in RCA and its connection to other aggregate characteristics

examined in an experiment were given. RCA is of lower grade than NA because of the mortar that is permanently attached to NA. The amount of mortar attached to the fine fraction is greater than that attached to the coarse fraction: 15 examples produced broad ranges of 23–44% for the 8/16 mm fractions and 33–55% for the 4/8 mm fraction, highlighting the huge diversity of recycled aggregates. The main characteristics that masonry composition negatively affects are absorption, density, Los Angeles roughness, and sulphate content.
Silva et al. (2019) examine new exploratory study on the use of RAC in practical situations is constantly being produced as a result of the rarity of RAC output. According to several transportation organizations, including the US Federal Highway Administration, the majority of road networks constructed using RAC survived well despite sporadic problems with shrinking, cracking, and susceptibility to freezing and thawing. Many of the most recent cases took place in Germany, where strict standards and current law both call for increased use of RA. These instances demonstrate how correctly utilising recycled materials can conserve resources and the ecosystem by reducing the amount of waste that would otherwise end up in dumps, especially if the RA is purchased locally

3. MATERIALS AND METHODOLOGY



Coarse aggregate

The coarse aggregate used was treated recycled concrete aggregate (tRCA) of size 4.75mm to 20mm. The recycled concrete aggregate (RCA) is prepared from a laboratory tested cube and treated by Los Angeles abrasion machine to remove attached mortar.

Preparation of recycled concrete aggregate (RCA)

Following are the steps to get desired recycled aggregate-

1. Collection of tested cubes from the stacks of laboratory tested cubes (2 to 3- years old).
2. Breaking of these cubes into small pieces of size less than 75 mm (feeder opening size of jaw crusher) using hammer or other, such that which are feedable to jaw crusher.
3. Set the jaw crusher to crush them into RCA of desirable size.
4. Sieve these RCA collected from jaw crusher with 20mm and 4.75 mm IS sieve.
   - RCA retained on 20mm IS sieve returned for refeeding to jaw crusher.
   - RCA passing through 20mm IS sieve & retained on 4.75 mm IS sieve accepted as RCA.
   - RCA passing through a 4.75 mm IS sieve was rejected (Need further research to reuse it).
5. Accepted RCA was sent for treatment.

Treatment of recycled concrete aggregate (RCA)
Attached mortar is the major cause for the inferior quality of RCA compared to that of natural aggregate. So, there is a need to either removed or strengthen the attached mortar from RCA. Figure 3.1 shows different method to improve the quality of RCA

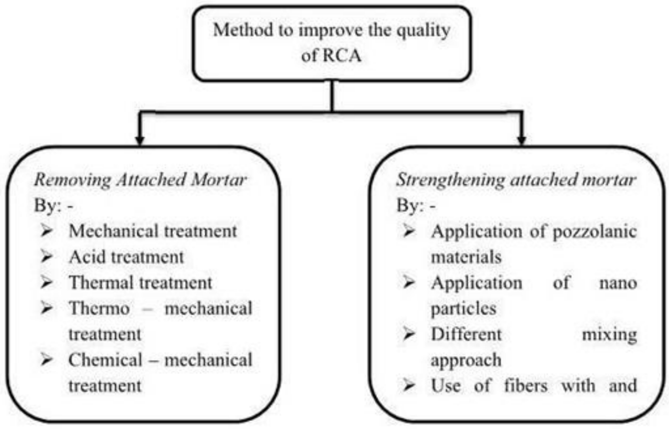


Figure 3.1. Method to improve the quality of RCA

4. RESULTS AND DISCUSSIONS

The mechanical properties like compressive strength, ultrasonic pulse velocity, split tensile strength & flexural strength and durability properties like RCPT & sorptivity of the tRAC, tRAC-SF, tRAC-GGBS, tRAC-MD & tRAC-RCF were determined as per relevant IS code and ASTM.

Compressive strength (IS: 516-1991)
After the components of concrete were combined using a two-stage mixing technique, test samples were formed into 150mm blocks to evaluate compressive strength. Three cubes per blend were tested at the designated curing days using a 2000kN capacity testing equipment (AIMIL) to determine the compressive strength of the cubes after 7 and 28 days of curing. (Figure 4.1 & 4.2). Using the sum of the values from three cubes, the final compressive strength was determined.

Figure 4.1. Compressive strength test setup

Figure 4.2. Brittle failure of cubes under compression

5. CONCLUSION

In this study, the connected mortar of the RCA was removed using a mechanical treatment technique. In this technique, the RCA received abrasion with 9 pellets and 400 revolutions. After erosion, the fragile interfacial cement that was adhered was removed. To make tRCA and RCF, a normal sieve was used to separate the combination of RCA and eliminated mortar. Additionally, this research optimises the mechanical handling of recycled aggregate using retention percentage values. The strength of RAC was increased in the current research by substituting fillers for an optimal quantity of cement and using various pozzolanic and non-pozzolanic filler types. The tRCA's technical and physical characteristics are described. There is also discussion of the engineering and longevity characteristics of tRAC, tRAC-SF, tRAC-GGBS, tRAC-MD, and tRAC-RCF.

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