A review on Partial replacement of Fly ash, Marble dust & Crushed concrete aggregate in concrete mixture

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Abstract:-

The recycling of waste like fly ash, marble dust, & crushed concrete aggregate from demolished buildings is a growing point of interest in the field of environmental conservation, construction industry & for researchers. The partial addition of such waste will decrease our dependency on virgin products used in construction. Recycling of such waste will take us one step forward in the field of sustainable development. A review of physical & chemical properties from available data of different researchers based on individual research of fly ash, marble dust, and CCA/RCA (Crushed Concrete Aggregate/Recycled Concrete Aggregate).

The partial replacement of these waste combined will positively influence our concrete mix, enhance the properties of concrete & not only this, but it will also decrease the construction cost and make construction more economical.

Keywords:-

Recycling, Partial waste, sustainable development, properties, enhances, economic, environment, Fly ash, Marble dust, CCA/RCA, etc.

1. Introduction

Globalization and progress are accelerating daily. And as the world's population grows, so does the need for housing and infrastructure, particularly in developing nations like India. As the need for building grows, so does the demand for resources. Concrete is perhaps the most widely used building material globally, with an annual usage of about six billion tonnes. It is also the second most requested item, just behind water usage per capita.
Cement, sand, aggregate, and water are the materials used in the production of concrete. All of these materials are derived from natural resources. As the demand for concrete rises, so does the need for these materials. Natural resource depletion grows as demand rises. And this rise in demand poses a significant danger to both the environment and society
In today's world, it has become a guiding concept for the building sector all over the globe. In the area of the building, recycling and reuse of concrete debris may be an efficient method to promote sustainability in construction by requiring less trash to be disposed of and reducing negative environmental impact via waste recovery.
The detrimental effect on the environment put pressure on researchers to discover a substitute for the naturally occurring materials used in concrete and develop an alternative. Because trash recycling without appropriate scientific study and development may have the opposite effect as intended and become a more significant environmental issue than the garbage itself.
As a result, here is an analytical mix of some previous studies, by substituting a portion of natural resources. Demolished buildings partly replace coarse aggregate, cement is partially replaced by fly ash and marble dust. After successfully testing in the lab, the concrete mixture made from the materials mentioned above and designed using the concrete mix design can be utilized to construct structural and non-structural elements of the building.

2. Background:-

2.1 Fly ash

Fly ash is one of the residual left during the combustion of coal in coal-fired power plants. As a supplementary pozzolanic ingredient, fly ash lowers the negative environmental impact of concrete by reducing CO_2 emissions during the cement production process. Fly ash, a waste product, may improve the mechanical properties and durability of concrete, and therefore has the potential to play a significant role in sustainable design [1]. Since fly ash is generated through the burning of coal, so it has various chemical compound also & composition of such component are expressed as a percentage by weight in table 1.

Table 1:- Coal components percentage by weight [2-3]

S No	Chemical	Wt%
1	Fe_2O_3	30.13
2	SiO_2	26.40
3	CaO	21.60
4	Al_2O_3	9.25
5	TiO_2	3.07
6	K_2O	2.58
7	SrO	1.57
8	P_2O_5	0.67

According to ASTM C618 there are two classes of fly ash.

Table 2:- Classes of fly ash [3]

CLASS TYPE	PRODUCED FROM	LIME PERCENTAGE
Class F	Anthracite & bituminous coal.	<20%
Class C	Lignite , & sub-bituminous coal.	>20%

In India, about 63% of electricity is generated through thermal power plants, which runs on coal, and about 75% of extracted coal is utilized by thermal power plants. The amount of generation of coal in India is shown in below graph 1.

Table 3:- Summary of Fly Ash Generation and Utilization during the Year 2019-20 [4]

Description	Year 2019-2020
• **No of thermal Power Stations from which data was received**	197
• **Installed capacity (MW)**	200691.50
• **Coal consumed (Million tones)**	678.68
• **Fly Ash Generation (Million tones)**	226.13
• **Fly Ash Utilization (Million tones)**	187.81
• **Percentage Utilization (%)**	83.05
• **Percentage Average Ash Content (%)**	33.32

Since, generation of fly ash in such a considerable amount creates a problem in fly ash disposal.

Figure 1:- Fly ash

The following points will further clarify why fly ash was chosen as a substitute material:

1.Fly ash is also known as "pulverized fuel ash" and is a standard coal combustion product.

2. Fly ash is mixed with concrete to make green concrete. Fly ash, as the name implies, is environmentally beneficial.

3. Fly ash, if not utilized correctly, causes a slew of environmental difficulties, including groundwater pollution, fugitive dust, and health concerns, to name a few.

4. Fly ash provides the strength and durability needed to replace cement in concrete.

5. Fly ash is often used to replace 0 to 100% of the cementitious material by mass.

6. Fly ash is cost-effective, which aids us in keeping a healthy economic balance.

7. It's also believed to lower interior temperatures and boost productivity. The ball-bearing action of spherical fly ash particles occurs as a consequence of this.

8.The exemplary particle distribution system is smoothed out, which enhances the grading of the mixture.

9. It also cuts down on the quantity of water needed.

10.Compressive strength, pumping ability, concrete finishing, flexural strength, corrosion, shrinkage, and alkali-silica reactivity are all increased by fly ash.

11.When compared to conventional PCC, the most appealing feature of fly ash concrete is its resilience.

2.1.1 Fly ash physical characteristics

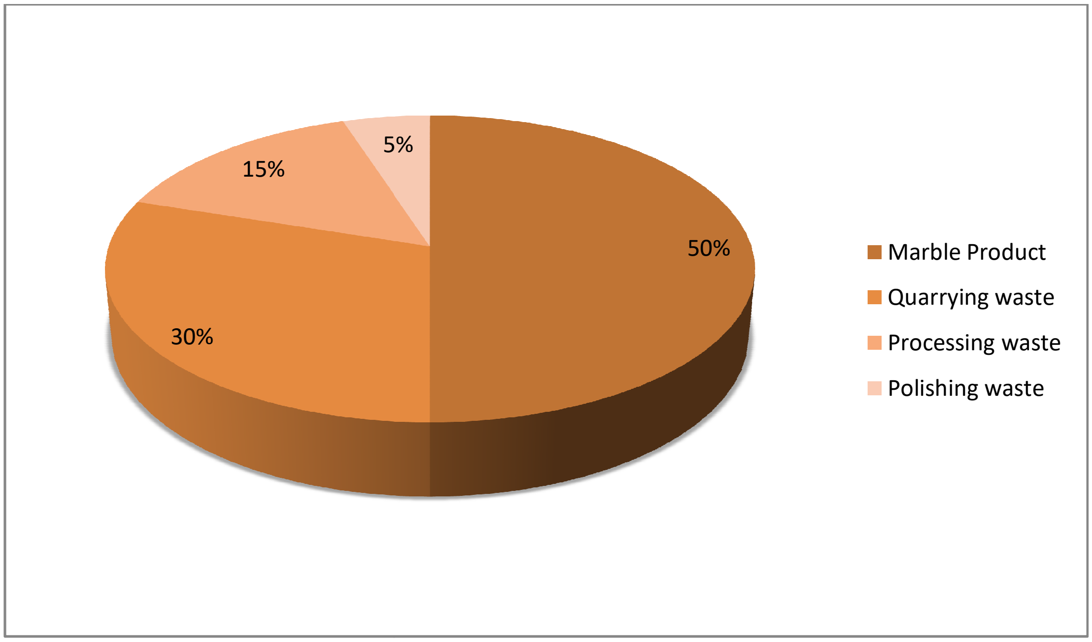
Table 4: Fly ash physical characteristics [5]

S NO	PROPERTIES	VALUES
1	Color	Grey
2	Density	2.0-2.4 g/cc
3	Moisture Content	10^{-9}-10^{-6} m/sec

2.2 Marble dust

Since ancient times, marble has been widely utilized as a construction material. Marble dust is a solid waste product produced during the marble manufacturing process. Figure 2 depicts the dumping of marble trash, whereas Graph 1 illustrates the variation in acquired marble vs. waste kind. During the cutting of marble, waste marble powder is produced as a byproduct. The amount of trash generated is about 20% of the total marble handled. Every year, tonnes of debris are produced and deposited in open areas. As a result, there is significant environmental and dust pollution. Contamination of underground water supplies is also a possibility. The ecological, physical, chemical, and biological components of the environment are threatened by the environmental issues caused by waste marble powder. As a result, it is critical to utilize the leftover marble powder to address most problems. The possibility of using excess marble powder as a partial substitute for cement is discussed in this paper.

Figure 2:- Marble dust [6]



Graph 1:- Marble Products vs Waste obtained [6]

2.2.1 Marble's physical characteristics

Table 5 : Marble physical characteristics[6,7]

S No	Characteristic	Requirement	Method of Test
1	**Moisture absorption after 24 hours immersion in cold water**	0.4 % max by weight	IS : 1124 - 1974
2	**Specific Gravity**	2.5 min	IS : 1122 - 1974
3	**Hardness**	3 min	Mohs Scale

2.2.2 Marble's chemical characteristics

Table 6 : Marble chemical characteristics[6]

Oxide compounds	Marble Dust (Mass %)
SiO_2	28.35
Al_2O_3	0.42
Fe_20_3	9.70
CaO	40.45
MgO	16.25
Density (g/cm^3)	2.80

2.3 Crushed Concrete Aggregate (CCA) from demolished buildings

This article focuses on coarse RCA, which is the coarse aggregate left over after the mortar has been removed from the rock that will be reused. The use of RCA in the new building is still a relatively recent technology. One of the primary motivations for using RCA in structural concrete is to make it more ecologically friendly and "green." Construction "takes 50 percent of raw materials from nature, uses 40 percent of total energy, and produces 50 percent of total trash," according to several major environmental concerns. By recycling waste materials and preventing additional NA from being collected, the use of RCA on a wide scale may assist in minimizing the impacts of building on these variables.

Table 7 : Tests result in comparison on Recycled Aggregate and Natural Coarse Aggregate [8]

S NO	PROPERTIES	RECYCLED AGGREGATE	NATURAL COARSE AGGREGATE
1	**Aggregate Impact test**	34.26 %	28.21 %
2	**Aggregate Abrasion values**	26.35 %	15.58 %
3	**Specific Gravity**	2.26	2.67
4	**Water Absorption**	2.13	1

3 Literature Review

1. **P.Kumar Mehta, 2004** [9] investigated HVFA, replacing 50% cement concrete with fly ash by mass. He explained how using a large amount of fly ash enhanced workability, durability, decreased water consumption, reduced sulphate attack, and reduced cracking. He said that this technology would undoubtedly benefit emerging nations such as China and India.

2. **Chao-Shun Chang, Chung-ho-Huang, How-Ji Chen, and Shu-ken Lin, 2013** [10] developed a design mix technique that substituted 20 to 80 per cent fly ash for cement. They utilised two kinds of class F fly ash, one with a loss on ignition of 4.6 per cent and the other with a loss on ignition of 7.8 per cent. They next carried out experiments to determine the characteristics of the concrete. The addition of fly ash increases the setting time of concrete, and therefore the development of strength takes between 91 and 365 days, according to tests. For all grades of HVFA, he developed a relationship between flexural and compressive strength. The fly ash with no igniting suggested that it had better mechanical characteristics. He eventually discovered that by adopting a reasonable mixing proportion, 80 per cent of class F-fly ash might be utilised as a substitute in concrete.

3**. L.K.Crouch, Ryan Hewitt, and Ben Byard, 2007** [11] investigated two HVFA mixes, one containing class C fly ash and the other containing class F fly ash, and compared the findings to TDOTA mixtures containing fly ash of the same class in smaller amounts. In comparison to TDOTA mixes, he discovered that using HVFA improves durability, reduces void content, and decreases absorption. At an average temperature, 22 degrees Celsius, the setup time increased by 2 hours. They claimed that HVFA would be suitable for hot-weather situations and have similar prices and improved compressive strength.

4. **Yash Srivastava and Ketan Bajaj, 2012** [12] investigated the effectiveness of fly ash in soil stabilisation by substituting 10 to 60% of it with other soil. His study also looks at all of HVFAC's toughened characteristics, including compressive and flexural strength, using prisms and cubes with fly ash replacements of 35, 50, and 75 per cent. Their findings showed that up to 50% replacement might be done for just a 12% increase in total cost.

5. **Muhammad Shahzada, Tufail, Khan, Bora Genturk, and Jianqiang Wei, 2016** [13] investigated the mechanical characteristics of limestone, concrete, and quartzite when exposed to high temperatures.
For two hours, the samples were heated to a temperature of 25 to 650 degrees. The modulus of elasticity, compressive strength, and tensile strength were all tested. They concluded that temperature has a significant impact on the mechanical characteristics of concrete. The compressive strength, tensile strength, and modulus of elasticity all dropped as the temperature rose, but the ultimate train increased.

6. **Steel fibres were used by H.W. Hwang and P.S. Song, 2004** [14] to eliminate the inadequate strain capacity and tensile strength of high strength concrete. Steel fibres were added in volume fractions of 0.15 per cent, 1 per cent, 1.5 per cent, and 2 per cent. The hardness index increased as the proportion increased, peaking at 0.15 per cent. Because expanded polystyrene is low weight and excellent energy absorption material, it may even segregate during the casting process;

7. **Bing Chen and Juanyu Liu, 2004** [15] produced EPS concrete using a technique similar to sand wrapping. According to the findings, EPS beads may be utilised instead of coarse and fine aggregate, with a density of 800-1800 kg/m3 and a compressive strength of 10-20 MPa.

8. The impact of polypropylene and steel fibres on high strength lightweight concrete was investigated by **KayaliO., M.N. Haque, and B. Zhu, 2003** [16]. The use of fly ash to substitute fines and 0.56 per cent polypropylene by volume resulted in a 90 per cent increase in indirect tensile strength and a 20 per cent increase in indirect rupture. A Review of Fly ash as a Cement Alternative and the Impact of Steel Fibers www.iosrjournals.org | DOI: 10.9790/1684-140301104107

9. The research by **Neelesh Kumar Singh, Rohit Kumar Shakya, Prerit Saxena, and Rishabh Sharma, 2016** [17] highlighted the use of fly ash to substitute cement at 5 per cent, 10%, 15%, and 20% ratios. Their investigation showed that a 10% fly ash concentration provides greater strength than other ratios without applying any admixtures. When the amount of fly ash in a product increases, the strength decreases and the amount of water required increases.

10. **P. Nath and P. Sarker, 2011** [18] comprised a 30-40% substitution of cement with fly ash, resulting in compressive strength of 60 MPa after 28 days and 85 MPa after 56 days of curing. The strength required for 30% replacement was more significant than that required for 40% replacement. The chloride ion permeability was also examined, and it was shown to be decreased by 35 to 45 percent or more after 28 days. The concrete's drying shrinkage and sorptivity were both reduced by using fly ash.

11. **Snehal Afiniwala, Nirav Patel, and Dr Indrajit Patel, 2013** [19] examined the effects of fly ash on self-compacting concrete (SCC). M20 and M25 mixes were created by replacing 50 per cent, 55 per cent, and 60 per cent cement with class F fly ash. Concrete's rheological characteristics were determined via tests. It was discovered that all of the properties met the 50 per cent and 55 per cent replacement requirements. The flow of concrete was reduced as the amount of fly ash in the mix increased. As a result, it may be concluded that fly ash can create a low-cost SCC.

12. **Indrajit Patel and C D Modhera, 2011** [20] investigated the impact of polyester fibres in high-volume fly ash concrete (HVFA). Fly ash was used to replace 50, 55, and 60% of the trail mix for M25, M30, M35, and M40 HVFA concrete. 0.25 per cent of fibre was evaluated for compressive strength. After including fibre into HVFA concrete, the 28-day compressive strength of M25 50 per cent fly ash mix improved by 13%. The strength of M30 has risen by 20%. The strength of M35 and M40 rose by 15%. The intensity of all trail mixes was reduced by 3-5 per cent when the fly ash concentration was raised from 50 per cent to 60 per cent. All of the mix's strength and slump values were within the required standard limits. The best compressive and flexural strength for plain and polyester fibre concrete was 55 per cent fly ash substitution.

13.**P. Vipul Naidu and Pawan Kumar Pandey, 2014** [21] researched the required strength for M40 grade by substituting up to 75% of cement with fly ash and lime to decrease manufacturing costs. Superplasticizer was used in both the trail mixes, one without lime and the other with lime. The trail mix without lime demonstrated that for 65 per cent fly ash and a 46 per cent cost reduction, 28-day similar strength up to 45 MPa could be achieved with a 46 per cent cost reduction; however, increasing the amount of fly ash resulted in a significant decrease in strength. The second trial mix, which included 10% lime, demonstrated that 28-day compressive strength of up to 39 MPa could be produced with 75 per cent cement substitution at a cost savings of 41 per cent.

14. **Aalok D et al., 2014** [22] conducted an “Experimental research on the utilization of marble dust in concrete” and found that when 50 percent marble powder is added to M 25 grade concrete, the compressive strength of cubes increases, and when waste marble powder is added, the strength progressively falls. With the addition of leftover marble powder, the split tensile strength of cylinders increases up to 25%, then decreases as more is added. At 50% marble powder mix, flexural strength is achieved.

15. **Rakesh Gupta et al., 2014** [23] investigated “Partial replacement of cement with marble powder” and found that adding waste marble powder up to 10% by weight of cement increased the compressive strength of cubes for M 20 grade concrete any additional waste marble powder decreased the compressive strength. With the addition of waste marble powder up to 10% by weight of cement, the split tensile strength of cylinders is enhanced. With any further accumulation of waste marble powder, the split tensile strength diminishes.

16. **Jashandeepsingh et al., 2015** [24] investigated “Partial replacement of cement with waste marble powder of M 25 grade” and found an enhancement in all mechanical characteristics up to 12% replacement of cement with waste marble. When 12 percent of the cement is replaced with waste marble powder, the compressive and tensile strength is maximized. For both cubes and cylinders, the optimal proportion for replacing marble powder with cement is almost 12 percent cement. To reduce building expenses by using marble powder that is freely or inexpensively accessible. Our primary goal is to reduce pollution in the environment via the manufacture of cement.

17. **Sudhir P. Patil, Ganesh S. Ingle, and Prashant D. Sathe (2013)** [25] researched recycled coarse aggregate to determine the physical characteristics of concrete made using recycled coarse aggregate. The research

concrete debris was gathered from a destroyed building (near Kamla Nehru Park, Bhandarkar Rd, Pune), and a coarse aggregate of various percentages was utilized to make new concrete. Recycled aggregate is only appropriate for non-structural concrete, according to several experts. On the other hand, this study demonstrates that recycled aggregate derived from concrete specimens produces high-quality concrete. Concrete with 50 percent RCA has a compressive strength that is comparable to that of regular concrete. When concrete is replaced up to 25-50 percent, a tensile splitting test reveals excellent tensile strength. Concrete strength is vital in the beginning but progressively decreases as it progresses. RCA has a greater water absorption rate than natural aggregate. Finally, it can be said that the RCA may be utilized to obtain high-quality concrete up to 50%.

18. **Monalisa Behera (2014)** [26] review article provides a thorough discussion of the manufacture and usage of RA in concrete and an analysis of its impact on several RAC characteristics. It also tries to clarify the methods for improved performance, identifies knowledge gaps, and highlights why this promising technology has not yet gained widespread acceptance in the construction sector. The practical issues associated with using recycled aggregate in concrete are also addressed.

4 . Conclusion

- The use of fly ash minimizes the development of cavities, fractures, and corrosion.
- Fly ash improves workability, durability and reduces water use.
- When 50 percent of the cement is replaced with fly ash, the overall cost of the concrete is reduced by 10-30%, and when 65 percent of the cement is replaced, the total cost is reduced by 46%.
- Using a super-plasticizer in combination with marble powder as a partial substitute for cement in higher grades will benefit high-rise structures in terms of cost savings.
- The characteristics of RCA, the impacts of RCA usage on concrete material properties, and the large-scale impact of RCA on structural elements have all been addressed in this article.
- The residual adhering mortar on RCA has the most significant impact on aggregate characteristics. As a result, RCA is less dense, more porous, and has a more significant potential for water absorption than NA.
- RCA particles are more rounded and have more fines broken off in L.A. abrasion and crushing tests, while N.A. particles have a comparable gradation.
- Replacing NA with RCA in concrete reduces compressive strength while providing equal or better splitting tensile strength.
- The modulus of rupture of RCA concrete was lower than that of conventional concrete, owing to the weak interfacial transition zone caused by residual mortar.
- Because of the more ductile aggregate, the modulus of elasticity is also lower than anticipated.
- This type of partial replacement may give us enhanced results.
- Since fly ash, marble dust & CCA can be bought at significantly cheaper rates, i.e., as low as 0.5-1 rupees, so use of such material will decrease our construction cost, and it will also become economical.
- The use of 20-30% of such waste in construction will reduce cost, enhance the properties of concrete, and positively impact the environment. The use of such waste will lead to a lower percentage of trash to be disposed of.
- If we take all three, i.e., fly ash, marble dust, & crushed concrete aggregate together and partially replace them with cement & natural aggregate, respectively, then we can get some fruitful results.

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