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DIFFERENT MINERAL ADMIXTURES IN ROLLER COMPACTED CONCRETE

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ABSTRACT

In today's world, all kind of materials are used to improve the materials used in project. Our research is about different mineral admixture on a type of concrete called roller compacted concrete (RCC), which has various uses in paving and dam construction. In this article, the effect of some mineral admixture on the mechanical properties and durability of roller compacted concrete has been investigated. Several mineral admixtures, such as metakaolin, fly ash, silica fume, ground granulated blast furnace slag, rice husk ash, palm oil fuel ash, and, either completely or partially replace cement. In this work, an attempts has been made to find out how adding these mineral admixtures can improve the performance of roller compacted concrete. The strength obtained varies based on the mineral admixtures produced by adding them to roller compacted concrete. The reviewed results of the work done have shown that 5-10% of silica fume, 15-20% of metakaolin, 10-15% of fly Ash, 10% of limestone, 5% of RHA and Coal waste powder, 15% of steel filing, 10% of (Bagasse Ash , natural pozzolan and Basalt rock flour), 15% of GGBS, 10% of POFA and Sugarcane ash, 2% of nano silica cement substitute has the best results on mechanical properties and durability of RCC.

KEYWORDS: GGBS · Fly ash · Metakaolin · Palm oil fuel ash · Silica fume · Rice husk ash, roller compacted concrete (RCC), natural pozzolan (NP).

1. INTRODUCTION

The amount of concrete produced for every human being on Earth is approximately equivalent to one ton of concrete produced worldwide, making concrete the second most used material after water. Environmental issues come from the production of the individual parts of concrete. Since each ton of Portland cement produced results in the emission of one ton of carbon dioxide into the atmosphere, and since cement production makes up about 7% of the total emission of greenhouse gases worldwide, [1].production of cement around 1.6 billion tons of worldwide [2].also Portland cement consumption is increasing significantly in countries that are developing. [3].Roller Compacted Concrete (RCC) was a type of concrete that was invented around 1980[4].Nowadays RCC pavement structures are becoming more common, and there are many places using RCC instead of flexible pavement (asphalt pavement) [5].For many pavement applications, roller-compacted concrete (RCC) provides a practical, quick-to-build option [6].RCC is made up of the same basic components as conventional concrete, including well-graded aggregates, cementitious materials, and water, but it has a different mixing composition. [7, 8]. RCC has grown in popularity in recent years, especially in the urban areas. Because RCC pavement can be constructed more quickly than conventional concrete pavements and has sufficient structure for truck traffic, it was chosen as a viable solution for developing pavements in this area [9].However, RCC is now being used more often to build pavement because it is more economical. [10].The properties of concrete is increased by the addition of additional components, such as mineral admixtures. [11].Adding more cementitious substances during the concrete manufacturing process can result in significant energy, economic, and environmental pollution advantages. [12].Different mineral admixtures, such as metakaolin, GGBS, fly ash, rice husk ash, palm oil fuel ash, and silica fume, can improve the properties of concrete [13].By adding these

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admixtures, the amount of cement decreases, thereby minimizing the impact on the environment. [14].Due to the nature that these admixtures are industrial by-products, disposal problems could also be minimized [15]. According to the mentioned information, the study of the effect of mineral admixture on the properties of RCC is considered valuable

2. PROPERTIES OF MINERAL ADMIXTURE

Physical and chemical properties have been collected from previous studies and are provided in the tables below. Table 1 shows the physical properties of various mineral admixtures, and Table 2 shows the physical properties of different mineral admixtures. Figure 1 depicts the mineral admixtures.

Table (1):- Chemical properties of mineral admixtures

	Metakaolin [16]	Fly Ash [17]	Silica fume [18]	GGBS [19]	RHA [20]	POFA (Palm-oil-fuel-ash) [21]
Sio_2	80.76	34.5	91.6	37	62.96	50.3
Al_2o_3	15.69	12.8	1.69	13	22.73	4.74
fe_2o_3	0.04	23.6	1.68	0.6	0.21	8.08
Cao	1.46	19	0.91	40	0.26	5.19
MgO	0.05	2.27	---	8	0.01	3.22
K_2o	0.04	2.08	1.19	0.6	0.45	11.8
Na_2o	0.01	---	---	0.3	---	0.1
Mno	--	---	---	---	---	--

Table (2):- physical properties of mineral admixtures

Physical properties	Metakaolin [16]	Fly Ash [22]	Silica fume [23]	GGBS [23]	RHA [24]	POFA (Palm-oil-fuel-ash)[25]
specific gravity	2.7	2.645	2.24	2.9	2.23	2.15
Specific surface (cm2/g)	----	6500	19995	4180	5980	1710

Fig.(1):-depicts the mineral admixtures. . [53], [35], [50], [35], [52], [53]

3. The Evaluation of the Effect of Mineral Admixtures on The Compressive Strength of RCC was Done in The Article.

Compressive strength is the most basic qualitative measure of a concrete's mechanical properties, and it is often employed by design standards and regulations to determine whether a concrete mixture is suitable for a certain application. Because RCC has a compressive strength comparable to that of conventional concrete, the use of different types of minerals admixture has an effect on the RCC's compressive strength. In the study we have done, we want to show what percentage of mineral admixture showed the best increase compressive strength. In one of the experiment replacing cement with metakaolin compressive strength increase due to the metakaolin addition, with a maximum value of 53.1% related to 20% cement replacement for RCC tested at 7 days, and a maximum value of 41.8% related with 15% MK. At 90 days of age. [16].

These results show that metakaolin is a good substitute for cement and helps in filling the void in the mixture and increase the life of RCC due to slow hydration. Through specimen testing, RCC mixes with high strengths were developed. It is obvious that the addition of fly ash and pozzolan can provide excellent RCC strength, especially over a long period of time. Approximately 20% replacement is suitable for produce long-term compressive strength and reduced accumulative heat of hydration. [28].

According to this result, the effect of fly ash can be considered close to metakaolin. The compressive strength of RCC was increased by 33.6 MPa and 30.6 MPa, respectively, when 10% of the cement was replaced with Silica Fume and Fly ash at 28 days. And when mixed both together with the dosages (7.5%) the optimal compressive strength of roller compacting concrete is increased by 34.2 MPa. [31].

Silica fume and slag were utilized the compressive strength enhancement was about 13.9% with the optimum dosages (5, 27.5) respectively. [29]. The optimal amount of nano silica is up to 2%, and it has been observed that adding more nano silica than 2% causes a gradual decrease in the compressive strength of RCC. [30].

Silica fumes have been used in combination with other materials and this shows that the combination of different mineral admixture can improve the properties of concrete. GGBS improved the mechanical properties of RCC concrete. GGBS enhanced adhesion and filled in the voids of pores and cracks. Furthermore, it prevented crack propagation. [32].In the research the results was found that the average strengths of all concrete specimens at 28 and 56 days were improved by 38% and 51%, respectively, compared to that of the 7 days, and an important strength development was noticed when the curing age was increased. This can be explained by the fact that the GGBS had a higher hydration rate at later curing ages, which led to the creation of secondary C-S-H gel and a denser microstructure in the cementitious matrix. [19].

Due of the finer and greater specific surface area of RHA particles compared to cement, the optimum w/c ratio rises as the replacement ratio of RHA increases. In comparison to the control samples, compressive strength is improved when RHA is used to replace cement in the range of 5 to 15%.It is because of the amorphous silica in RHA that when it comes into contact with cement, it reacts and creates C-H-S. The main cause of the strength in pozzolanic samples is C-H-S. The compressive strength decreases when the RHA is added outside of the previously specified range, certainly as a result of an increase in the optimum w/c ratio for a constant cementation material content that reduces compaction effort. [26]. RHA enhances the mechanical properties of concrete, reduces permeability properties, and greatly increases its durability because of its high activity and high specific surface area. [27].

According to the results mentioned above, it can be said that due to the fineness of the mineral admixture that replaces cement, the void of mixtures is filled, and it improves their Density and strength. In RCC, due to low water cement ratio (W/C), hydration takes place slowly and this helps the age of RCC.

However, due to their slow hydration of mineral admixture during the mix, the long-term strength and age of RCC increases. It may be seen in future experiments that by using mineral admixture and increased W/C a smoother surface can be reached, which is a big challenge in the RCC pavements. We tried to summarize the optimum of each mineral admixture and its effect. According to the Data in table 3 and mentioned above, the type of optimal mineral admixture in roller concrete can be written as (FA, MK, GGBS, SF, RHA, N.P, steel filling,

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POFA, sugarcane ash, basalt flour, CWP).

4. The evaluation of the effect of mineral admixtures on the durability of RCC was done in the article.

The durability of concrete materials is critical when analyzing the life cycle of constructions. In general, concrete durability is primarily concerned with resistance to characteristics such as sulphate, chloride, and acid corrosion solution. However, just a few investigations on ammonium nitrate solution have been done. As mentioned above that RHA improved compressive strength, also enhancing durability of the RCC concrete with a better result. The reasons are that RHA reduces Ca (OH) 2 and clearly improves the pore structure, providing a denser micro-structure, decreased penetrability, and hence improved durability. Several studies have shown that RHA significantly improves the durability of concrete. RHA with different replacement amounts ranging from 5% and 20% have improved the durability of RCC. [44, 45, 46, 47]. When GGBS is replaced in cement, the load carrying capacity and compressive potency of concrete are increased to their maximum. However compressive strength decreases in acid attack as GGBS content increases. But the Corrosion resistance of fiber content increases with high amount of replacement of GGBS. [23, 32, 49, 50, 51, 52].

In terms of durability, Metkaolin had been shown to lower water permeability, absorption, and chloride permeability as the replacement percentage increased. This may be due to the filler effect of Metkaolin particles significantly reducing the concrete's permeability or porosity. [16, 36, 37]. As the amount of silica fume in RCC concrete increased it also increased the resistance to chloride ion penetration. Also by using it there was a reduction in water-binder ratio this makes Concrete's ability to absorb water was significantly lowered. The ratio of (5-25) % may also enhanced the mechanical and durability properties of RCC. [31, 33, 34, 35, 36].

The permeability of RCC with fly ash was low after 28 days of curing, but as the age developed, it became more impermeable and achieved significant imperviousness. This is because the pozzolanic reaction is low at the beginning. The ratio of replacement of fly ash ranges (5-15) % to improve both mechanical and durability properties of RCC concrete. [22, 31, 35, 39, 40].

Oil Fuel Ash (POFA), is a byproduct of biomass energy waste used to substitute cement. POFA enhances the pozzolanic reaction by generating more calcium silicate hydrates. Under ammonium nitrate solution, POFA improves the deterioration of RCC concrete and this improve the durability with arranges around (10%) of cement replacement.

According to results above, with increasing density and decreasing voids in RCC, water permeability of RCC reduced and RCC can have longer life. Penetration of water and any liquid into the concrete in different season leads to concrete failure and reduced durability of concrete. Therefore, as in the previous section, we mention the order of optimal mineral admixture that have a better role in improve the durability of RCC. The reviewed results of the work done have shown that optimum type respectively RHA, fly Ash, GGBS, metakaolin, silica fume, Coal waste powder, 10% of (Bagasse Ash, natural pozzolan and Basalt rock flour),, 10% of limestone, 15% of steel filing, , 10% of POFA and Sugarcane ash, 2% of nano silica cement substitute has the best results on durability of RCC.

4. Summary of the all mineral admixtures

All of the mineral admixtures of the optimal amount of cement replacement with desired conclusions/remarks and the type of concrete used for the research are given in Table3.

Table (3):-Mineral admixture used in past

Mineral admixture	author	year	% replacement	Conclusion
Silica fume	(A. Ashteyat et all) [32].	2022	5%	increase compressive strength, increase tensile strength, decreasing the water absorption
	(Ch.Chennakesava)[33].	2014	5%	increase in flexural strength of about 5.6%
	(M. Adamu et all)[34]	2017	5%	Reduction in compressive strength was higher for fly ash mineral filler than silica fume which was mainly due to the slower pozzolanic reaction of fly ash. Replacing fly ash with silica as a mineral filler was successful in mitigating loss in compressive strength for up to 20%CR.
	(C. Xupeng et all)[35]	2021	25%	increase 30% of compressive strength and 15% of tensile strength
	(A. Kumar et all)[30]	2021	10%	The compressive strength of mixtures increases by 15% and The tensile strength of mixtures increases by 9%, The water absorption of roller compacted concrete was recorded as 1%.
Metakaolin	(A. A. Hamzah et all)[36]	2008	20%	metakaolin increase in compressive strength of about 5% , increase flexural strength, increase tensile strength
	(C.Xupeng et all)[35]	2021	50%	Increase 30% of compressive strength and 15% of tensile strength.
	(M. Abu-Bakr at al.)[15]	2022	20%	Increase in compressive strength of about 53%, increase in tensile strength of about 20%, increase freezing and thawing resistance and permeability decreases.
FLY Ash	(S. I. Sarsam) [21]	2021	20-30-40%	The flexural strength of dense graded mixtures increases by 63% at 20 % replacement by fly ash while it declines by at (30 and 40) %replacement.
	(M. Adamu et all)[34]	2017	5%	Reduction in compressive strength was higher for fly ash mineral filler than silica fume which was mainly due to the slower pozzolanic reaction of fly ash. Replacing fly ash with silica as a mineral filler was successful in mitigating loss in compressive strength for up to 20%CR.
	(P. N. Ojha et al.)[37]	2022	60%	Fly ash increase compressive strength, tensile strength, modulus of elasticity, porosity and water Absorption.
	(S.S.Rahman et all)[38]	2021	15%	Fly ash increase compressive strength35%, fly ash increase flexural strength43%.
	(S.K. Rao et all)[39]	2016	10%	The compressive strength, the UPV and the Dynamic modulus of elasticity were decreased with increase in fly ash content.
	(A. Kumar et all)[30]	2021	10%	The compressive strength of mixtures increases by 7% and The tensile strength of mixtures increases by 9%. The water absorption of RCC was calculated by 1.4%.
limestone	(S. I. Sarsam)[21]	2021	10%	The flexural strength increases by (96.2, 84, and 17.2) % and (109, 86, and 9.3) % for replacement of (10, 12, and 15) % of cement
	(S. I. Sarsam et all)[40]	2013	5%	The rate of increase in compressive strength is 109% for dense mixes and 115.8% for gap mixes. Increase 62% at mixes with 5% lime, increase in splitting tensile strength 150%.
	(S. N. SAOUDI et all)[41]	2022	0-10-15%	reduction in compressive strength of about 20%, tensile strength slightly decreases about 7%
	(Z. Huanga et al.)[42]	2021	10%	increase compressive strength by 16% and decrease water absorption 18% , increase freezing and thawing resistance
M-sand	(S.K. Raoet all)[39]	2016	50%	The compressive strength, the UPV and the Dynamic modulus of elasticity were decreased with increase in fly ash content.
rice husk ash (RHA)	(E. K. Vahidi et all)[43]	2017	5%	Increase in compressive strength of about 15%, permeability decreases.
	(A.Dhanalakshmi et all) [44]	2023	20%	Increase in compressive strength of about 5%, increase in flexural strength of about 4.8%, increase in tensile strength of about 60%.
	(J. A. Del Carpio et al.)[45]	2011	5%	increase in compressive strength of about 50%
	(P. Chindaprasirt a et all) [46]	2007	20%	increase in compressive strength of about 7%

steel filing	(A. A. Al-Shadeedi)[36]	2008	15%	steel filing increase in compressive strength of about 24%, increase flexural strength, increase tensile strength
Bagasse Ash	(A.Dhanalakshmi et all)[44]	2023	10%	Increase in compressive strength of about 5%, increase in flexural strength of about 4.8%, increase in tensile strength of about 60%.
Coal waste powder	(A.Modarres)[47]	2016	5%	increase in compressive strength of about 7%
Saudi Natural pozzolan (N.P)	(A. I. H. Malkawi) [27].	2017	10%	Natural pozzolan increase in compressive strength of about 15%.
Jordanian Natural pozzolan (N.P.)	(A. I. H. Malkawi) [27].	2017	10%	Natural pozzolan increase in compressive strength of about 7%.
Basalt rock flour.	(A.I. H. Malkawi)[27]	2017	10%	Increase in compressive strength of about 25%.
ground-granulated blast-furnace slag (GGBS)	(S. Moradi ,S. Shahnoori) [31]	2021	15%	The rate of increase in compressive strength is 3%, permeability decreases, decreasing the water absorption
	(M.ÖZTÜRK)[48]	2022	15%	Increase compressive strength, flexural strength, tensile strength (43%, 3%, 9%) respectively.
	(S. Saluja et al.)[49]	2019	40%	increase in compressive strength is 8.5%, increase in flexural strength is 5.4%, increase in split tensile strength is 26.6%, Optimum water content of RCC mixture decreases
	(Z. M. Abeda)[22]	2023	25%	increase in compressive strength is 10%, increase bulk density
	(S. K. RAO)[50]	2015	40%	increase in flexural strength of about 14%
	(V. Afroughsabet et al.)[51]	2023	80%	Achieved a compressive strength.
POFA (Palm-oil-fuel-ash)	(A. M. Ashteyat)[32]	2022	10%	decrease Compression Strength , Splitting strength , Flexural strength and Modulus of elasticity
	(J.N. Panchal)[52]	2021	10%	increase in compressive strength of about 2%, increase in flexural strength of about 2%, increase in tensile strength of about 1%,
Sugarcane ash	(S. Debbarmaa0[53]	2020	10%	reduce compressive, flexural and tensile strength
	(A.Choubdar)[54]	2021	10%	Reduce compressive, flexural and tensile strength.
nano silica	(M. Hemalatha et al.)[55]	2022	2.25%	The rate of increase in compressive strength is 11%
	(M.Adamu et al.)[56]	2018	1%	Increase fatigue and flexural strength.
	(v. Gokulanadh et al.)[57]	2022	2%	The rate of increase in compressive strength is 9% in room temperature, The rate of increase in compressive strength is 9% in 50c temperature, The rate of increase in compressive strength is 7% in 100c temperature,

5. CONCLUSIONS

The present information is an attempt has been made to enhance the properties of RCC mixes containing supplementary cementitious material (SCMs) based on a number of laboratory tests to obtain the optimum dosages of each mineral admixtures, according to the literature reviews mentioned above, the various admixtures utilized in concrete are as follows:

❖ Regarding the mechanical properties of RCC, attention has been paid to the compressive, and with the increase of the compressive strength, the flexural and splitting tensile strength has also improved. For better review, two mechanical properties are mentioned in table 3. Therefore, we can use the strengths mentioned in the table to improve the mechanical properties.

❖ Each mineral additive is partially replaced with cement in varying amounts. If the percentage limit is exceeded, it has an influence on the strength properties of concrete, such as compressive, split, and flexural strength, as well as the durability properties.

❖ According to the above literature evaluations, the optimum amount of silica fume and RHA ranges from 5 to 15%.

❖ Typically, silica fume and metakaolin are used, increases hydration heat, and while others reduce it.RCC with metakaolin efficiently improves the strength properties. As the percentage of metakaolin increases, it also improves workability. Also RCC with fly ash improves the properties of the concrete and makes it more resistant to chemical attack.

❖ The addition of GGBS to cement increases the tensile and flexural strength of the RCC concrete. When GGBS is partially replaced in cement, fine aggregate is also partially replaced by other materials, which improves the mechanical properties of the concrete. By using the mineral admixture in an acceptable percentage, all mineral admixtures reduce the bleeding in roller compacted concrete.

❖ Most of the time, it is preferable to use mineral admixtures that have more specific areas and smaller sizes to create highly dense and impermeable concrete.

❖ Also using different mineral admixtures in RCC have advantages and most of minerals could be using which are environment issue, as a results of the data analysis many parameters influence the improvement of the properties of RCC concrete by minerals, such as fineness, specific area ,sources of mineral admixture as well as percentage of used in the manufactured.

❖ The findings of the current study should also help with the application of SCMs for more durable RCC construction. Especially in road construction, also improve aesthetics of the road.

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