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Assessing Roller Compacted Concrete using GGBS as Partial Cement Replacing Material for Application in Low Traffic Volume Road

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Abstract: This paper reports most optimized mix derived from the roller compacted concrete (RCC) using ground granulated blast furnace slag (GGBS) as the partial cement replacing materials in the context of possible utilization of RCC in the construction of rigid pavements in the rural part of the country, especially subjected to low vehicular traffic volume. In the current study, various RCC mix compositions were developed by substituting ground granulated blast furnace slag (GGBS) for ordinary Portland cement (OPC) in varied percentages (0%, 20%, 40%, and 50%) and assessed for mechanical (strength) properties. All the three GGBS blended mix compositions are found to give early age compressive strength more than 20 MPa and 28 days compressive strength more than 30 MPa. Further, they are found to have split tensile strength in the range of 2.8-4.1 MPa. Moreover, they are found to yield the flexural strength more than 3.8 MPa. All the three mixes are found to comply with the requirements of compressive strength, splitting tensile strength and the flexural strengths as prescribed by Indian Roads Congress Specification and American Concrete Institute Standards for possible utilization in the construction of rigid pavements in the rural parts of the developing country like India. Further, the strength values of the GGBS blended mixes increases from 20% to 40% and decreases thereafter, at the higher GGBS contents such as 50%. In view of this, the RCC mix composition with 40% GGBS contents can be regarded as the most optimal mix to be used in the construction of rigid pavements in rural part of the country.

Keywords: Roller Compacted Concrete, Low Traffic Volume Road, Rigid Pavement, Ordinary Portland Cement (OPC), Ground Granulated Blast Furnace Slag (GGBS), Compressive Strength, Split Tensile Strength, Flexural Strength.

1. Introduction

Roller compacted concrete (RCC) stands out as a zero-slump concrete renowned for its cost-effectiveness, robustness, and swift installation [1]. Similar to conventional concrete, RCC comprises constituents and follows a construction process similar to that of the asphalt pavement [2]. Cementitious materials, dense-graded aggregates, and water make up the basic components of RCC. Owing to its low water content, the RCC appears as an extremely dry material that cannot be placed using traditional (slump) concrete techniques. Vibratory rollers are used in the compaction process. The maximum size of coarse aggregates used in RCC varies according on whether the aggregates are used in pavements or dams, with smaller aggregates being preferred for later uses. Its keen adoption over recent years owes much to its economic viability and ease of handling during transportation and placement, which avoids the need for formwork, reinforcing steel, and dowel bars in the RCC pavement construction, thereby reducing the overall construction cost. Moreover, the RCC limits transverse cracking through a denser particle structure, fostering superior aggregate interlock and interface adherence with the sub-base [3].

Remarkably, achieving comparable compressive strength to conventional concrete demands 20-28% less cementitious material in the RCC [4-5]. In addition to traditional building materials, the addition of various mineral admixtures such as fly ash, ground granulated blast furnace slag (GGBS), and micro-silica fume lowers the cost of RCC while improving the qualities of the final mix ([2, 6-8].

By-products, such as fly ash, bottom ash, and the GGBS, pose significant disposal challenges due to their substantial volumes of production. However, redirecting these waste materials toward the construction industry presents an effective solution to these management issues. In addition to cutting capital, adding industrial by-products to the mix increases the concrete's total compressive strength and micro-silica simultaneously decreases the permeability of the concrete. The amount of iron and slag generated is reflected in the GGBS, a by-product of blast furnace iron production [9]. It includes alumina, silica, magnesium oxide, and lime to those present in Portland cement but in different proportions.

Various investigations explored utilisation of these industrial waste materials in Roller Compacted Concrete (RCC) production. The study by Cao *et al* [6]. examined impact of large volume of FA on RCC's strength, noting superior long-term strength despite initial lower strength at early ages. Atis *et al.* [7] investigated fly ash in RCC, discovering enhanced compressive strength with 15% FA replacement, reaching levels akin to normal Portland cement at 30% replacement. Atis [10] delved further into RCC compositions having various low lime class F FAs, revealing varied strengths for different types of FAs used. Vahedifard *et al.* [5] assessed silica fume and pumice in low cement RCCP mixtures, observing increased compressive strength with 10% silica fume but reduced workability. Conversely, pumice improved workability but decreased compressive strength. Srivastava *et al.* [11] recommended 5% silica fume replacement, augmenting both workability and strength. Aghabaglou and Ramyar [8] investigated FA as a substitution for cement as well as fine aggregates, observing reduced strength with increased cement replacement but higher strength when replacing fine aggregates. Hesami *et al.* [4] explored coal waste powder, coal waste ash, and limestone in RCC pavement, finding that a 5% replacement level matched control mix performance. Rao *et al.* [2] investigated FA and prepared sand in RCC, noting improved performance with combined M-sand and fly ash. Various studies indicate RCC's potential to enhance workability, later-age strength, and durability despite the initial reduction in early-age strength [12-14].

In the recent past, some of the studies that are carried out on the roller compacted concrete pavements include those by Hasaninasab *et al.* [15], Ramkumar and Ramkrishna [16] ,Kilic and Gok [17], Amin Ahmadi *et al.* [18], Krishna Bhavani *et al.* [19], Sarsam *et al.* [20], Yildizel [21] , Ozturk *et al.* [22], Huang *et al.* [23], Rambabu *et al*. [24], Yaseen *et al.* [25] and Hosseinian *et al.* [26].

Hasaninasab *et al.* [15] investigated roller compacted concrete pavements with varied nano CaCO3 contents and found enhancement in mechanical properties, water absorption and porosity. Ramkumar and Ramkrishna [16] examined the effects on the mechanical, durability, and fresh properties of RCC of a variety of materials, including reclaimed asphalt pavement wastes, recycled concrete aggregates, slag from electric arc furnaces, cross-linked polythylene waste, silica fume, bagasse ash, GGBS, jarosite, crumb rubber, rice husk ash, fly ash, sugarcane ash, coal waste ash, etc. The review offered insights into enhancing RCC sustainability benefitting both environmental conservation and cost effectiveness. Kilic and Goak [17] reported reduction in compressive strength with polypropylene based fibers. These fibers were further found to increase water absorption, show resilience to freeze-thaw damage and decrease in specific weight. Mohammad *et al.* [18] investigated mechanical properties of roller compacted concrete containing reclaimed asphalt pavements. The results showed decrease in unconfined compressive strength, modulus of elasticity and indirect tensile strength of RCC. Krishna Bhavani *et al.* [19] outlined the methodology and construction of RCC pavements along with its pros and cons. Sarsam *et al.* [20] optimized fresh RCC mixes using various aggregates (crushed and rounded), fine aggregates (silica and river sand) and cement types (OPC and sulphate resistant cement). The results indicated that RCC mixes with rounded aggregates achieved higher maximum dry densities as compared to crushed aggregates, irrespective of cement and sand type. Yildizel [21] investigated the effect of ground calcium carbonate (GCC) with basalt fiber (BF) on the properties of RCC to find reduction in workability with BF and enhancement with GCC. The GCC further reduced water absorption. The GCC was found to increase the compressive strength while BF, flexural strength. The study by Ozturk *et al.* [22] reported increase in compressive and flexural strength when steel fibers were used while polypropylene fibers decreased both. The impact of fly ash and limestone powder on the freezing and thawing resistance of roller-compacted concrete was documented by Huang *et al.* [23]. Rambabu *et al.* [24] presented a review on the sustainability of roller compacted concrete for constructing the pavements meant for heavy traffic volume. They reviewed RCC mixes constituents regarding strength, durability, and curing effects; and also analyzed the impact the impact of fiber on fatigue life highlighting RCC case studies. Yaseen et al. [25] studied mechanical and micro-structural properties of RCC incorporating brick powder, glass powder and steel slag with a view to developing the eco-friendly RCC using locally available materials as the cement replacing materials. Hosseinian *et al* [26]. examined the influence of aggregate gradation, cement contents and water - cement ratio on the compressive and flexural strength of RCC pavement for 7, 28 and 72 days. The study found increasing curing age and decreasing water- cement ratio improved both the strength parameters. The study provided significant insights into optimizing RCC pavement mix design for enhanced performance. From literature survey, it can be known that GGBS's efficacy in conventional concrete is well-studied, but its impact on RCC remains underexplored. Rao *et al.* [2] investigated

GGBS in RCC, reporting optimal strength at 40% replacement. This study aims to achieve zero-slump concrete by replacing cement with GGBS in varied percentage by resorting to a compaction similar to that in respect of soil, thereby reducing voids and cement-water requirements for RCC pavement field applications. The research explored the long-term strength properties of RCC blended with varying GGBS contents up to 28 days post-casting.

2. Materials, Methodology and Experimentation

2.1 Materials Used

The materials used in the study include cement, sand, aggregates (fine and coarse), water, admixtures and cement replacing materials (mineral admixtures) such as ground granulated blast furnace slag (GGBFS). The cement (Figure.1*a*) used in the said investigation comprised of Ordinary Portland Cement (OPC- 53 Grade) (Ultratech) conforming to IS 8112 [27]. The GGBFS (Durocem), conforming to IS: 12089 [28] and BS 6699 [29] was procured from JSW Cement Ltd., Pen (India) (Figure.1*b*). The fine aggregates (river sand), sourced from local supplier was used in the study. Further, the crushed angular graded coarse aggregates (Metal I and II) of varying sizes such as 6- 20 mm, procured from the local quarry at Turbhe in Navi Mumbai were also used. Figure 2 shows the different aggregates used in the study. The potable water was added for obtaining concrete. The properties of the cement and GGBS provided by the supplier based on the information supplied by manufacturer are indicated in Table 1 and 2. The particle size distribution (PSD) analysis of the cement and other cementitious material is indicated in Figure. 3. The properties of the fine aggregates and the coarse aggregates are reported in Table 3.

a. OPC

b. GGBS

Figure 1. Cement and supplementary cementitious material (GGBS)

Figure 2. Aggregates used in the present study

Table 1. Properties of the cement

Physical Properties		**Chemical Composition**	
Property	*Value*	*Chemical Constituent*	*Percentage by weight*
Blaine fineness (m^2/kg)	305	SiO_2	20.68
Standard consistency (%)	28	Al_2O_3	4.87
Specific gravity	3.14	Fe_2O_3	3.35
Autoclave expansion (%)	0.059	CaO	62.13
Loss on ignition (%)	2.81	MgO	1.73
		SO_3	2.43
		Na_2O	0.21
		K_2O	0.69

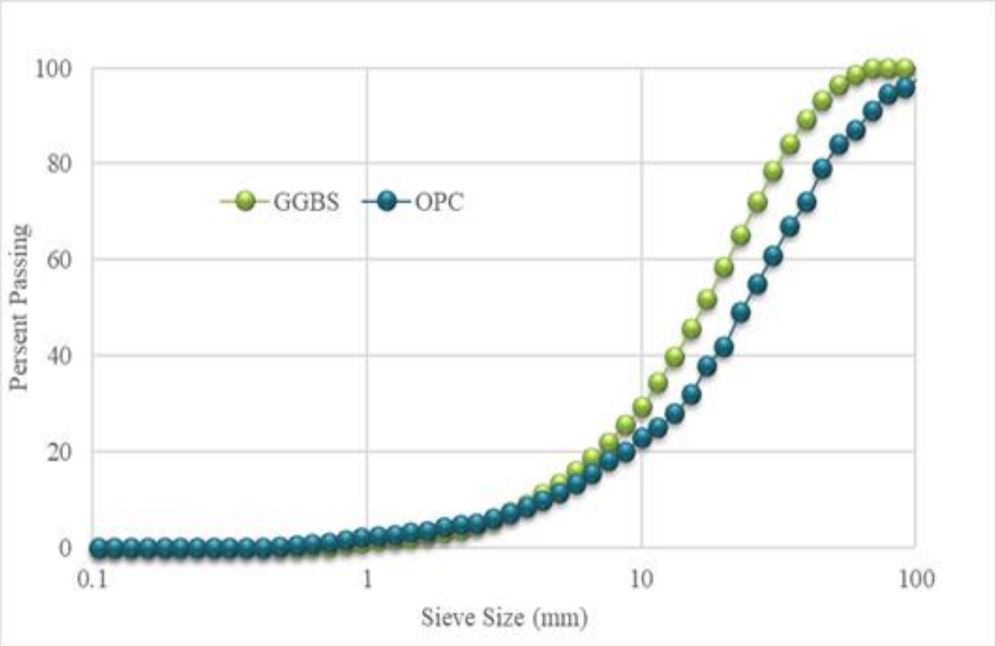

Figure 3. Particle size distribution (PSD) curve of OPC and GGBS used in the study

Table 2. Properties of the GGBS

Physical Properties		**Chemical Composition**	
Property	*Value*	*Chemical Constituent*	*Percentage by weight*
Blaine fineness ((m^2/kg)	390	SiO_2	31.6
Specific gravity	2.85	Al_2O_3	21.7
Loss on ignition (%)	0.37	Fe_2O_3	2.5
		CaO	33.2
		MgO	8
		SO_3	0.18
		Na_2O	0.85

Table 3. Properties of Aggregates

Property	**Fine aggregates**	**Coarse aggregates (5-12 mm)**	**Coarse aggregates (12-19 mm)**
Max. size (mm)	5	10	19
Sp. Gravity (SSD)	2.67	2.69	2.71
Sp. Gravity	2.70	2.79	2.81
Bulk density[1] (gm/cc) (Compacted)	1791	1540	1582
Bulk density[2] (gm/cc) (loose)	1697	1459	1458
Water absorption (%)	1.8	1.58	1.51
Fineness modulus	3.14	-	-
Value of Crushing (%)	-	12.12	
Value of Impact (%)	-	13.78	
Los Angeles abrasion value	-	16.3	

The chemical admixture (superplasticizer) used in the investigation included Sika Plast with density 1.16-1.19 kg/lit and pH (5-8 (approximate) complying with ASTM C494 [30] Type D and G.

2.2 RCC Mixture Compositions

Similar to traditional concrete mix design techniques, there are different methods available for RCC mix designs. In this particular study, a soil compaction approach was employed to ascertain the mixture proportions for RCC. This method operates on the principle of achieving optimal moisture content for a laboratory compaction effort, mirroring the compaction exerted by field rollers. As outlined in ACI 211.3R-02 [31], the process begins by establishing the proportion of aggregate to be utilized. Subsequently, the determination of cementitious material content and water is executed through the application of the optimum moisture content method, defined in ASTM D 1557 [32].

2.3 Proportioning

The composition of aggregates in the RCC mixture was accurately chosen to craft a dense-graded combined aggregates curve in accordance with the guidelines outlined in ACI 211.3R-02 [31]. To determine the ideal combined aggregate curve, a variety of combinations of fine aggregates and 10 mm and 20 mm coarse aggregates were tested. Following extensive testing, the mixture including 55% fine aggregates, 30% coarse aggregate with a size of 10 mm, and 15% coarse aggregate with a size of 20 mm produced a densely graded aggregate curve that complied with the requirements outlined in ACI 211.3R-02 [31].

2.4 Sample preparation

The RCC mixture preparation involved a rotating mixer with a standardized mixing time of 5 minutes. Achieving comprehensive compaction relied on a vibrating table set at a frequency of 60 Hz, complying with ASTM C 1170 specifications [33]. Following a 24-hour casting period, all specimens were taken out from the mound and placed in the curing tank with a constant temperature of 25 ± 2°C and relative humidity of 100%. Table 4 gives the particulars of the RCC mix proportions.

Test specimens with dimensions of (a) 150 × 150 × 150 mm were cast to assess compressive strength; samples with a diameter of 150 mm were cast to assess split tensile strength; and beams with dimensions of 150 × 150 × 700 mm were cast to assess flexural strength respectively. Following days 7 and 28, the compressive strength evaluations were carried out in compliance with BIS: 516 recommendations [34]. Furthermore, in accordance with BIS: 516 [34] standards, split tensile strength and flexural strength tests were carried out at 7, and 28 days after curing.

Figure 4 illustrates some of the stages involved from mix preparation up to curing of the specimen.

3. Discussion of Results

3.1 Compressive Strength (CS)

Figure 5 shows graphically the variation of the CS of the mixes tested after 7 days and 28 days. The results represent average CS values of 03 samples obtained for each mix.

After curing for 07 days, the CS in control mix is found to be quite higher as compared to that of the RCC mixes containing GGBS in various percentages considered in the present investigation. The CS in all the mixes with GGBS contents is found to be above 20 MPa. The CS in remaining three mixes comprising GGBS 20%, 40% and 50% GGBS seems to be almost equal, the difference in the strength values being too marginal. When the variation in strength in the context of all RCC mixes with 20%, 40% and 50% GGBS with respect to the strength in the control mix (R0) is compared, the decrease of 6%, 6.6% and 6.8% is found in all the mixes, i.e., R-G20, R-G40 and R-G50, respectively.

Table 4. RCC mix proportion

Mix Notation	Cementitious materials (kg/m^3)		Water (kg/m^3)	Aggregates		w/c
	Cement (kg)	GBS (kg)		6-12.5 mm	12.5-20 mm	
R0	370	0	130	542.88	588.12	0.35
R-G20	296	74	137.7	542.88	588.12	0.35
R-G40	222	148	211.00	495.00	525.22	0.44
R-G50	185	185	130.00	502.00	680.00	0.36

a. Mixing of materials

b. Placement of mix in rotating drum

c. Casting of mould

d. Vibration of mould

e. Curing of samples

Figure 4. Various stages involved in study from of mix preparation to curing

When the strength at higher curing period of 28 days' is observed, strength in the control mix (R0) is found to be higher when compared with the strength obtained in all three RCC mix compositions with GGBS contents. Further, the CS in two GGBS blended mixes, i.e., R-G20 and R-G40) is found to be above 30 MPa while that in mix R-G50, below 30 MPa. When the variation in strength in the context of all RCC mixes with 20%, 40% and 50% GGBS with respect to the strength in the control mix (R0) is compared in the context of 28 days curing, the decrease of around 4.6%, 3.2% and 22% is found in all the mixes, i.e., R-G20, R-G40 and R-G50, respectively. Further, when the variation of strength in GGBS blended mixes are considered, the strength is found to increase from R-G20 mix to R-G40 mix and then, the strength is found to decrease for last mix with 50% GGBS contents, i.e., R-G50.

Further, the strength is found to increase with curing period. The percentage increase in the CS corresponding to 28 days curing with respect to 7 days curing is found to be 19.3, 21, 23.6, 12 in the control mix and those in three GGBS blended mixes (R-G20, R-G40 and R-G50), respectively.

The control mix R0 is found to show the highest compressive strength at the testing age of 7 days and 28 days. This could be due to the smaller contribution of GGBS to the development of strength as compared to OPC. Further, the strength is found to increase with curing period.

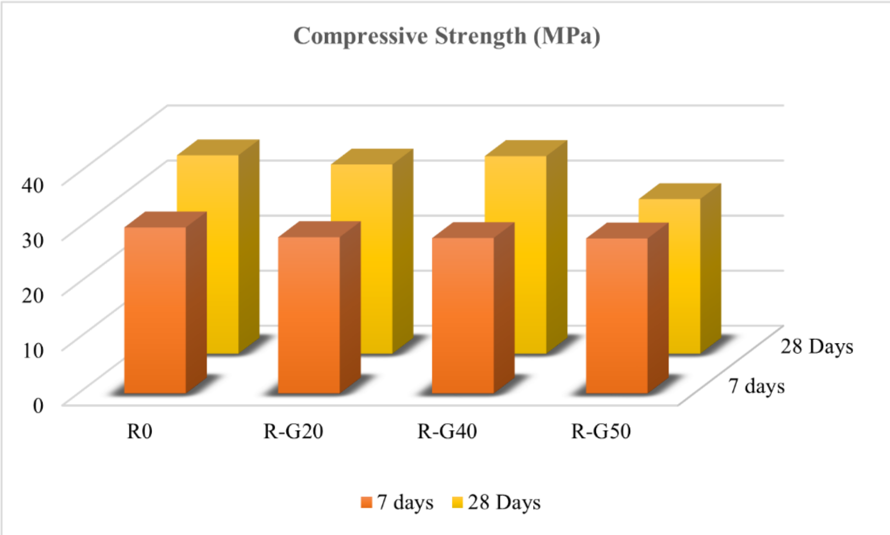

Figure 5. Various stages involved in study from of mix preparation to curing

The results show that the GGBS contents and the curing age have a considerable effect on the development of compressive strength. When the CS of mixes considered in this investigation for 28 days curing is compared, the mix composition R-G40 having 40% GGBS as the supplementary cementitious material is found to show highest value of CS than the mixes R-G20 and R-G50. Because the glossy components of GGBS react with water gradually, there is a sluggish secondary Pozzolanic reaction between GGBS and the (OH) ions generated during cement hydration. Furthermore, because there is less $Ca(OH)_2$ available from the initial hydration process, at significant replacement levels of GGBS, none of the GGBS is consumed in the Pozzolanic reaction. It shows that GGBS functions as filler in the concrete rather than an effective binder at 50% replacement level. From this, it is obvious that 40% replacement of OPC by GGBS replacement is the most optimum. The investigation reported by Liu *et al.* [13] and Li and Zhao [35] also shows the similar trend.

The early age CS, i.e., 7 days' strength, in all the 03 GGBS blended compositions is observed to be more than 20 MPa. This demonstrates the suitability of all the mixes for utilization in rigid pavement in accordance with the criterion of early age strength. Further, as per standards of Indian Road Congress [36]. The minimum value of CS for 28 days' curing should be 30 MPa for application in the construction of rigid pavements for rural roads. Based on aforementioned criteria, all the three GGBS blended mixes, i.e., R-G20, R-G40 and R-G50 considered in the present study are found suitable for application in the roads to be constructed in rural areas where the traffic is less. However, considering the effective GGBS contents, the mix R-G40 is found to be the most optimal mix for pavement. Moreover, at the 28-day mark, all the three RCC mixes considered in the present investigation exhibit compressive strengths surpassing the minimum CS (27.6 MPa), crucial for utilisation in the waring course [1].

3.2 Split tensile strength (STS)

The STS of various RCC mix compositions considered in the study for 7 and 28 days' curing is indicated in Figure. 6. The results represent average STS values of 03 samples obtained for each mix. The strength of the control mixes (R0) in case of either curing period (7 and 28 days) considered in the study is found to be higher when compared with the GGBS blended mixes. Further, splitting tensile strength is found to increase with age. When the strength of all the mixes considered in the investigation, i.e., R0, R-G20, R-G40 and R-G50 at the testing age of 28 days is compared with respect to that obtained after 7 days curing, the former is found to increase by 10.4%, 30.5%, 26.4% and 9.9%, respectively. At an early age following the 7 days' curing, all mix compositions having GGBS contents, i.e., R-G20, R-G40, and R-G50, show an enhancement in STS value with increase in GGBS contents. Nevertheless, when STS in the context of curing of 7 days is compared with what is seen in the case of the control mix (R0), the strength is found to be less in all three mixes. The percentage decrease in strength is found to be 22.7, 16.26 and 13.5 %, respectively when compared with the control (R0) mix. At the higher curing period considered in the study, i.e., of 28 days curing, it is seen that the strength of the GGBS blended mixes increases with increase in GGBS contents up to 40% and thereafter decreases at higher GGBS contents of 50%. When compared with the splitting tensile strength observed in case of the controlled mix (R0) with only cement, decrease in the strength in mix R-G20 is found to be 8.61%; in mix R-G40, 4.17%; and in mix R-G50, around 13.9%.

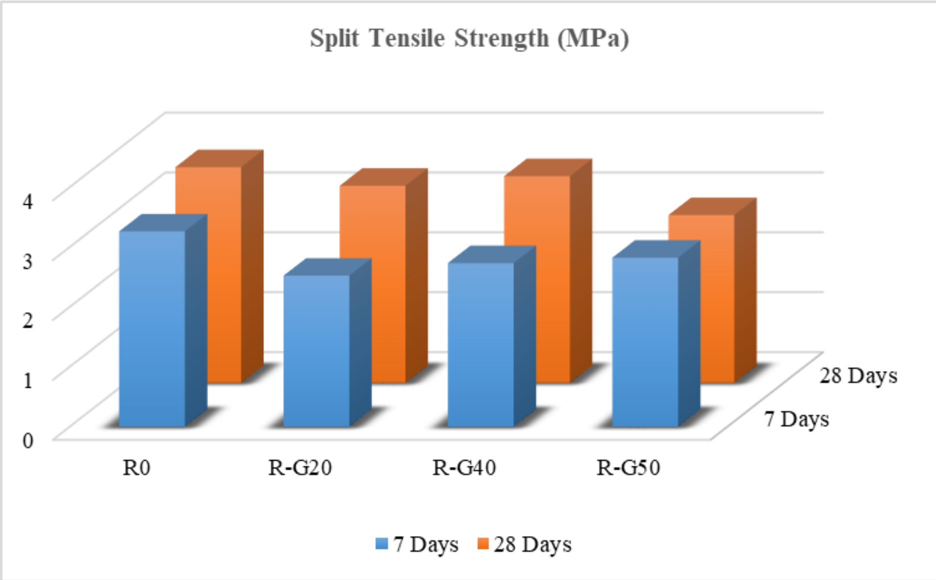

Figure 6. Split tensile strength of various mixes for 7 and 28 days curing

The addition of GGBS contents is found to improve the splitting tensile strength of RCC mixes at higher curing period. The split tensile strength depends on the paste quality and the interfacial transition region in the concrete. The improvement in the quality of the paste is attributed to the fineness and pozzolanic properties of GGBS which further results in improvement in the tensile strength of the RCC mixes.

In accordance with ACI 325.10R-95 [1] criteria, the splitting tensile strength for RCC pavement for 28 days' curing should range between 2.8 and 4.1 MPa. It is evident that all RCC mixtures considered in this study complies with this requirement.

3.3 Flexural strength (FS)

The FS of all the RCC mix compositions as well as that of the control mix in respect of 7 and 28 days curing is indicated in Figure 7. The results represent average FS values of 03 samples obtained for each mix. The strength of the control mixes (R0) in case of either curing period (7 and 28 days) considered in the investigation is found to be higher when compared with the mixes blended with GGBS.

Further, the FS is found to increase with age in respect of the control mix and the GGBS blended mixes. When the strength of all the mixes considered in the investigation, i.e., R0, R-G20, R-G40 and R-G50 at the testing age of 28 days is compared with respect to that obtained after 7 days curing, the former is found to increase by 26%, 15.8%, 57.6% and 35.7% in the control mix (R0) and the mixes R-G20, R-G40 and R-G50, respectively.

Following the curing of seven days', the FS for all three RCC mixes (R-G20, R-G40 and R-G50) is found less when compared with control mix (R0). Furthermore, when trend of strength variation is compared in all three mixes with GGBS contents vis-à-vis, it is observed that the FS reduces with enhancement in GGBS contents. When the decrease in the strength is compared in the context of the strength in respect of control mix (R0), the decrease of 15.4 %, 35.85% and 37.63 % is observed in the mixes R-G20, R-G40 and R-G50, respectively.

At higher curing period (28 days), the FS values for the control mix composition (R0) is observed 4.75 MPa and that in respect of the compositions having GGBS contents (20%, 40% and 50% as the supplementary cementitious materials) is found to be above 3.8 MPa. The strength of the mix with 40% GGBS (R-G40) is comparatively higher when compared with the strength of the mix with 20% GGBS (R-G20) and that of the mix with 50% GGBS (R-G50) is on quite lower side. The flexural strength of mix R-G 20 is 7.4% less than the control mix composition (R0). Further, when the FS for mix R-G40 is compared with that of control mix R0, the decrease of 4.42% is observed in the mix with 40% GGBS. Lastly, the flexural strength in the mix with 50% GGBS (R-G50) is compared with that of the control mix R0, the corresponding decrease is seen to be 20%. This indicates that the 40% replacement of cement with GGBS is found to yield optimum strength.

According to IRC specifications [34], the minimum value of the flexural strength corresponding to 28 days curing is 3.8 MPa for the application in pavements for rural roads catering to the low vehicular traffic. When the FS values of all the mix compositions with varying percentage of GGBS as partial replacement to OPC considered in the study are seen, all the mixes (R-G20, R-G40 and R-G50) are found to have the flexural strengths more than 3.8 MPa; and hence, are found suitable to be used as the concrete for low vehicular traffic road on the basis of flexural strength criterion only.

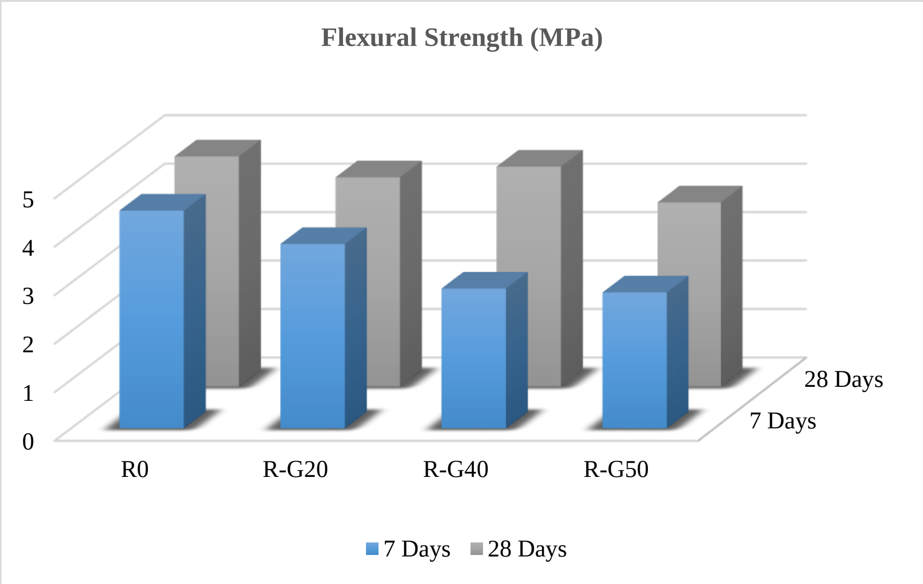

Figure 7. Flexural strength of various mixes for 7 and 28 days curing

4. Summary and conclusions

The strength properties of the roller compacted concrete using GGBS are evaluated in the present investigation for possible application in the pavement subjected to the low vehicular traffic in the rural area. Three contents of GGBS (20%, 40% and 50%) are considered as the substitution to OPC (as the supplementary cementitious materials). The mechanical properties, i.e., strength parameters such as CS, STS and FS are evaluated. On the basis of the results, inferences as mentioned below are deduced.

- All the 03 GGBS blended mix compositions are suitable for application in pavements to be constructed in the rural area subjected to low vehicular traffic volume on the basis of early age (7 days) compressive strength criterion.
- Based on 28 days' compressive strength criteria as per Indian Roads Congress standards and ACI standards, all the three GGBS blended mixes are found suitable for construction of concrete pavement in the rural area catering to low traffic volume.
- All mixes can be used for application in rigid pavements based on the splitting tensile strength as per ACI standards.
- Based on 28 days' FS values, all the three GGBS blended mix compositions (R-G20, R-G40 and R-G50) are suitable for use in the pavements meant for rural area subjected to low vehicular traffic volume.
- The RCC mix R-G40 with 40% replacement of cement by GGBS is found to obtain the most optimised mix when evaluated in the context of CS, STS and FS values, for application in the construction of rigid pavements in the rural part of the country subjected to low vehicular traffic volume.

The present study underscores the effective use of the industrial by-products in the road infrastructure development in the rural area. The use of GGBS as the supplementary cementitious materials for construction of roller compacted concrete pavement will reduce the environmental concern as the disposal of such waste being produced in abundance poses a big problem. Moreover, it will reduce the carbon footprint involved in the manufacturing of cement. The part utilization of GGBS in lieu of ordinary Portland cement would render the economical and sustainable road construction in the rural part of the developing country like India

References

[1] ACI 325.10R-95, (2001). Report on roller-compacted concrete pavements. American Concrete Institute (2001).

[2] S.K. Rao, P. Sravana, T.C. Rao, Investigating the effect of M-sand on abrasion resistance of fly ash roller compacted concrete. Construction and Building Materials, 118, (2016) 352–363. https://doi.org/10.1016/j.conbuildmat.2016.05.017

[3] D. Zolilinger, Roller compacted concrete pavement. Tech Brief, U.S.Department of Transportation, Federal Highway Administration, FHWA-HIF-16-003 (2016).

[4] S. Hesami, A. Modarres, M. Soltaninejad, H. Madani, Mechanical properties of roller compacted concrete pavement containing coal waste and limestone powder as partial replacement of cement. Construction and Building Materials, 111(15), (2016) 625–636. https://doi.org/10.1016/j.conbuildmat.2016.02.116

[5] F. Vahedifard, M. Nili, C.L. Meehan, Assessing the effect of supplementary cementitious

materials on the performance of low-cement roller compacted concrete pavement. Construction and Building Materials, 24 (12), (2010) 2528–2535. https://doi.org/10.1016/j.conbuildmat.2010.06.003

[6] C. Cao, W. Sun, H. Qin, The analysis on strength and fly ash effect of roller-compacted concrete with high volume fly ash. Cement and Concrete Research, 30(1), (2000) 71–75. https://doi.org/10.1016/S0008-8846(99)00203-3

[7] C.D. Atis, U.K. Sevim, F. Ozcan, C. Bilim, O. Karahan, A.H. Tanrikulu, A. Eksi, Strength properties of roller compacted concrete containing a non-standard high calcium fly ash. Materials Letters, 58(1), (2004) 1446–1450. https://doi.org/10.1016/j.matlet.2003.10.007

[8] A.M. Aghabaglou, K. Ramyar, Mechanical properties of high-volume fly ash roller compacted concrete designed by maximum density method. Construction and Building Materials, 38, (2013) 356–364. https://doi.org/10.1016/j.conbuildmat.2012.07.109

[9] A. Oner, S. Akyuz, An experimental study on optimum usage of GGBS for the compressive strength of concrete. Cement and Concrete Composites, 29(6), (2007) 505–514. https://doi.org/10.1016/j.cemconcomp.2007.01.001

[10] C.D. Atis, Strength properties of high-volume fly ash roller compacted and workable concrete, and influence of curing condition. Cement and Concrete research, 35(6), (2005) 1112–1121. https://doi.org/10.1016/j.cemconres.2004.07.037

[11] V. Srivastava, R. Kumar, V.C. Agarwal, P.K. Mehta, Effect of silica fume on workability and compressive strength of OPC concrete. Journal of Environmental Nanotechnology, 3(2), (2014) 32–35. https://doi.org/10.13074/jent.2014.09.143086

[12] R.N. Swamy, A. Bouikni, Engineering properties of slag concrete as influenced by mix proportioning and curing. ACI Materials Journal, 87, (1990) 210–220. https://doi.org/10.14359/2148

[13] S. Liu, Z. Wang, X. Li, Long-term properties of concrete containing ground granulated blast furnace slag and steel slag. Magazine of Concrete Research, 66(21), (2014) 1095–1103. https://doi.org/10.1680/macr.14.00074

[14] S.E. Chidiac, D.K. Panesar, Evolution of mechanical properties of concrete containing ground granulated blast furnace slag and effects on the scaling resistance test at 28 days. Cement and Concrete Composites, 30(1), (2008) 63–71. https://doi.org/10.1016/j.cemconcomp.2007.09.003

[15] S. Hasaninasab, Effects of nano-particles on cold recycled asphalt properties, SN Applied Sciences 3(6), (2018) 632. https://doi.org/10.1007/s42452-021-04463-1

[16] B.A.V. Ram Kumar, G. Ramakrishna. Use of Red Mud and Reclaimed Asphalt Pavement Wastes in Roller Compacted Concrete, International Journal of Pavement Research and Technology, 17, (2022) 291-305. https://doi.org/10.1007/s42947-022-00236-0

[17] I. Kilic, S. Gokce Gok, Strength and durability of roller compacted concrete with different types and addition rates of polypropylene fibers. Revista de la construcción, 20(2), (2021) 205-214.

[18] A. Ahmadi, M.K. Gogheri, M. Adresi, E. Amoosoltani, Laboratory evaluation of roller compacted concrete containing RAP. Advances in concrete construction, 10(6), (2020) 489-498.

[19] K Krishna Bhavani Siram, Operation of Roller Compacted Concrete in Pavements, International Journal of Current Engineering and Scientific Research (Ijcesr), 8(6), (2021) 82-85.

[20] S.I. Sarsam, Assessing the Influence of Aggregates and Cement Types on Fresh Roller Compacted Concrete Mixture. International Research Journal of Multidisciplinary Technovation, 3(3), (2021) 23-31.

[21] Sadik Alper Yildizel, Bassam A. Tayeh, Mehmet Uzun, The evaluation of calcium carbonate added and basalt fiber reinforced roller compacted high performance concrete for pavement, Case Studies in Construction Materials, 17, (2022) e01293. https://doi.org/10.1016/j.cscm.2022.e01293

[22] O. Ozturk, N. Ozyurt, Sustainability and cost-effectiveness of steel and polypropylene fiber reinforced concrete pavement mixtures. Journal of Cleaner Production, 363, (2022) 132582. https://doi.org/10.1016/j.jclepro.2022.132582

[23] Z. Huang, E.W. Sookree, H.M. Abdulkadir, Z. Wang. Influence of Limestone Powder and Fly Ash on the Freezing and Thawing Resistance of Roller-Compacted Concrete, KSCE Journal of Civil Engineering, Structural Engineering, 25, (2021) 2501–2507. https://doi.org/10.1007/s12205-021-1457-z

[24] D. Rambabu, S.K. Sharma, M.A. Akbar. A Review on Sustainability of Roller Compacted Concrete for Constructing High Traffic Resisting Pavements, Innovation Infrastructure Solutions, 8(20), (2022).

[25] M.H. Yaseen, S.F.S. Hashim, E.T. Dawood, & M.A.M. Johari, Mechanical properties and

microstructure of roller compacted concrete incorporating brick powder, glass powder, and steel slag. Journal of the Mechanical Behavior of Materials, 33(1), (2024) 20220307. https://doi.org/10.1515/jmbm-2022-0307

[26] S.M. Mohsen Hosseinian, A.A. Kordani, A. Attari, Optimizing the Mix Design of Roller Compacted Concrete Pavement (RCCP) to Improve Compressive and Flexural Strength, Innovative Infrastructure Solutions, 9(1), (2024) 19. https://doi.org/10.1007/s41062-023-01330-3

[27] I. BIS (1989) Specification for 43 Grade Ordinary Portland cement. Bureau of Indian Standards, New Delhi.

[28] BIS (1987) Specification for Granulated Slag for the manufacture of Portland Slag cement. Bureau of Indian Standards, New Delhi.

[29] BS 6699, Specification for ground granulated blast furnace slag for use with Portland Cement. British Standards Institution (1992).

[30] A.S.T.M. Standard, (2017). C494/C494M-17 Standard specification for chemical admixtures for concrete. ASTM International, West Conshohocken.

[31] ACI 211.3R-02, Guide for selecting proportions for No-slump concrete. American Concrete Institute (2002).

[32] A.S.T.M. Standard, (2009). Standard test methods for Laboratory compaction characteristics of soil using modified efforts. American Society of Testing and Materials (ASTM), Philadelphia.

[33] A.S.T.M. Standard, (2008) Standard test method for determining consistency and density of roller compacted concrete using a vibrating table. American Society of Testing and Materials (ASTM), Philadelphia.

[34] I. BIS, (1959). 516 Indian Standard methods of tests for strength of concrete. Bur Indian Stand New Delhi, India.

[35] G. Li, X. Zhao, Properties of concrete incorporating fly ash and ground granulated blast-furnace slag. Cement and Concrete Composites, 25(3), (2003) 293–299. https://doi.org/10.1016/S0958-9465(02)00058-6

[36] I.R. Congress, (2014) Guidelines for design and construction of cement concrete pavements for low volume roads. Indian Roads Congress, New Delhi.

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Raksha J. Khare - Visualization, Methodology, Experimental investigation, Data curation, Formal analysis, Writing- Original draft. **Rajendra Magar** - Conceptualization, Supervision, Coordination of research, Methodology, Validation, Writing -Review of original draft and editing. **Hemant S. Chore**: Conceptualization, Supervision, Coordination of research, Methodology, Validation, Writing -Review of original draft and editing. All the authors read and approved the draft.

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Competing Interests

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Data Availability

The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

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